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Whitepaper

"Making cost-effective batteries without compromising safety and performance expectations."

Prepared by

Xtrawrkx

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Who we are?

INTRODUCTION

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Our diverse team of full-time professionals and independent consultants excels in offering flexible, scalable support tailored to the unique needs of each client. We address a broad spectrum of challenges including EV expertise, testing and validation, program management, and strategic growth. By harnessing our extensive network of over 4,000 companies, we facilitate connections with key partners, suppliers, and clients, enabling innovative collaborations and co-investment opportunities.

Our approach integrates deep industry knowledge with cutting-edge strategies, delivering detailed project plans, cost analyses, and efficient solutions that drive operational success and sustainable growth. At Xtrawrkx, we are committed to transforming challenges into opportunities, helping our clients navigate the complexities of the automotive and manufacturing sectors with confidence and agility.

Acknowledgment

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Executive Summary

The cost of electric vehicle (EV) battery packs continues to pose a barrier to widespread EV adoption, particularly in India's price-sensitive two-wheeler market. Despite technological improvements and decreasing raw material costs, retail prices remain high, and fleet operators struggle to scale efficiently.

This white paper captures insights from a high-level discussion involving battery manufacturers, fleet operators, EV consultants, and infrastructure providers. It evaluates how cost-effective battery solutions can be implemented without compromising safety and performance—particularly by tailoring strategies to B2B (fleet/gig worker) and B2C (retail/commuter) segments.

Key Findings:

- One-size-fits-all battery packs are economically inefficient. Differentiated products based on usage intensity—such as high-cycle packs for fleets and low-cycle, low-cost packs for light-use consumers—should be developed.

- Business models like Battery-as-a-Service (BaaS), pay-per-kilometer billing, and franchise-based fleet deployment can radically improve affordability and scalability.

By combining technical insights with business innovation, this paper proposes flexible strategies for battery deployment, including IoT integration, tiered product offerings, and lifecycle management frameworks to enable sustainable growth of India's two-wheeler EV market.

Introduction

Purpose of the White Paper:

The aim of this white paper is to explore how India's two-wheeler EV segment can address the challenge of high battery costs while maintaining safety, performance, and regulatory compliance. Drawing from the experiences of fleet operators, consultants, and battery technologists, the paper outlines adaptable business and engineering models suitable for diverse market segments.

Industry Context and Stakeholder Motivation:

Despite policy support, EV adoption is lagging in India due to high upfront costs, largely driven by battery prices. Batteries can constitute up to 50% of a vehicle's total cost, creating affordability barriers for both fleet operators and individual buyers.

Key stakeholders include:

- **Fleet Operators:** Seeking affordable, durable battery packs for gig workers and delivery fleets.
- **Battery OEMs:** Balancing cost-efficiency with compliance (e.g., AIS-156), safety, and performance.
- **Investors & Financiers:** Exploring models with quicker ROI and scalable deployment (e.g., franchise-led growth).
- **Retail Customers:** Demanding affordable ownership or subscription-based access.

This paper addresses the central question:

Can India build a battery strategy that supports both affordable access and long-term sustainability—across different user segments and charging infrastructure models?

Key Challenges in EV Battery Cost Optimization

Despite progress in battery technology and favorable policy incentives, EV battery packs remain prohibitively expensive for both fleet operators and retail customers in India. Stakeholders highlighted several challenges preventing the industry from unlocking truly low-cost solutions:

1. High Battery Costs Despite Falling Cell Prices:

While the price of lithium-ion cells has steadily decreased on the global market, the corresponding reduction in retail battery pack prices has not kept pace.

Currently:

- LFP cells rated for 0.5C–1C charging cost ~$70/kWh.
- 3C-rated cells required for fast-charging applications cost upwards of $100–$140/kWh.
- For a typical 2.2 kWh battery, the cost of cells alone can range from ₹12,000 to ₹25,000 depending on chemistry and cycle life.

When accounting for the battery casing, BMS, potting material, connectors, bus bars, and assembly, total pack costs can increase by 40–50%. This makes it difficult to bring down prices for high-volume deployment, especially in the B2C segment.

2. Disparity Between Manufacturing Cost and Market Pricing:

Fleet operators report cases where OEMs quote ~₹35,000–₹50,000 for battery packs that may only cost ₹15,000–₹20,000 to manufacture.

Dealers and OEMs often claim up to 25–35% gross margins. While justified by marketing, logistics, and warranty obligations, this pricing leaves little room for operators or retail buyers to scale adoption.

For example:

- A high-speed electric scooter might be sold for ₹1.05 lakh.
- The same vehicle (excluding the battery) costs around ₹38,000–₹45,000.
- The battery pack and associated components often exceed ₹50,000–₹60,000.

3. Technical Trade-Offs Between Cycle Life, C-Rate, and Safety:

Reducing battery cost usually involves cutting back on either:

- **Cycle life:** Using 200–300 cycle cells instead of 1000+.
- **Charge rate:** Using 0.5C cells instead of 3C fast-charging types.
- **Material quality:** Lower-grade electrolytes, less thermal management, or non-automotive-rated cells.

However, each compromise has consequences:

- Low-cycle cells degrade within 6–9 months under high B2B usage.
- Fast charging a low C-rate battery reduces lifespan and may cause thermal runaway.
- Inadequate BMS or thermal design can lead to non-compliance with AIS-156 standards, increasing risk of fire or failure.
- Fleet operators stress that warranty of even 12 months is hard to honor on low-cost packs without optimized pack design and charging discipline.

4. Undefined Target Specifications for Low-Cost Packs:

Participants stressed the need to define "what exactly" the low-cost battery should deliver:

- Is it acceptable to offer 200–300 cycles with a 12-month shelf life?
- Should it target 100–150 km of real-world range per charge?
- Is fast charging a requirement or can slower charging suffice if batteries are swapped?

Without fixed specs, cost engineering cannot proceed meaningfully. OEMs and battery pack manufacturers require clarity to reconfigure chemistries, capacities, and thermal envelopes accordingly.

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Market Segmentation & Use-Case Scenarios

A critical insight from the stakeholder dialogue is that battery performance and pricing must be tailored to user segment needs. The Indian EV two-wheeler market is not monolithic—users vary widely in terms of daily usage, charging access, price sensitivity, and tolerance for risk.

1. High-Utilization Users (B2B / Fleet Operators):

User Profile:

- Delivery executives (Zomato, Blinkit, Dunzo, etc.).
- Medical representatives, field sales staff.
- Ride-share gig workers.

Usage Pattern:

- 80–120 km per day
- Multiple charge cycles per day or swapping.
- Battery charged aggressively or swapped daily.
- Usage in both urban and semi-urban environments.

Battery Requirements:

- High cycle life (≥1000 cycles), robust thermal and BMS control.
- Fast charging compatibility (≥1.5C, ideally 3C).
- Battery-as-a-Service (BaaS) or swapping compatibility.
- Compliance with AIS-156 and strong field reliability.

Preferred Models:

- Long-life fixed batteries with centralized fast-charging.
- Battery subscription models at ₹50–₹60 per day.
- Swapping-based models with fleet-level service guarantees.

2. Low-Utilization Users (Retail / B2C):

User Profile:

- Daily commuters in Tier 2/3 cities.
- Students, office-goers with 5–10 km one-way trips.
- Elderly or part-time riders.

Usage Pattern:

- 10–30 km per day, often with access to home charging.
- Charging only once every 2–3 days.
- No urgent need for fast charging or battery swapping.

Battery Requirements:

- Lower cycle life acceptable (~200–300 cycles).
- 1.5–2.5 kWh packs with standard charging (0.5C–1C).
- AIS-156 compliance with conservative BMS tuning.
- Emphasis on cost savings over long-term performance.

Preferred Models:

- Purchase of full vehicle with low-cost fixed battery.
- Optional replacement pack model every 12–18 months.
- Static home charging preferred over public infra.

3. Urban vs Rural Deployment Models:

Urban Settings:

- Suitable for centralized infrastructure (swapping/fast-charging hubs).
- High vehicle density supports shared infrastructure ROI.
- Multiple vehicle OEMs can partner with shared battery providers.

Tier 2/3 Towns and Villages:

- Require portable battery packs (due to limited public charging).
- Home or workplace charging dominates.
- Opportunity for low-cost packs with replacement/recycling tie-ups.

Conclusion:

A single battery configuration cannot serve both high-mileage B2B fleets and cost-conscious B2C riders. A tiered segmentation approach must be adopted to optimize for safety, affordability, and scale.

Flexible Battery Design Philosophies

One of the most significant takeaways from the round table was the need to move beyond one-size-fits-all battery engineering. Instead, battery packs must be designed based on targeted usage profiles, which can dramatically improve both cost-efficiency and user satisfaction.

The white paper identifies two primary battery design philosophies, each with its own technical configuration and commercial logic:

1. High Cycle Life Battery Packs (≥1000 Cycles):

Ideal For:

- High-utilization B2B fleet operators.
- Battery-as-a-Service (BaaS) and swapping models.
- Gig economy use-cases with predictable payback periods.

Technical Configuration:

- Premium LFP or NMC cells with ≥1.5C–3C charge rates.
- Advanced BMS with real-time telemetry, thermal control.
- Ruggedized pack casing and potting for extended field life.
- Optimized for 4–5 years of daily use.

Pros:

- Lower total cost of ownership over 3–5 years.
- Fewer battery replacements → less waste, less downtime.
- Strong residual value for leasing and reuse markets.

Cons:

- High upfront cost due to cell and component selection.
- Requires patient capital or subscription model to reduce capex burden.
- Infrastructure-dependent (fast chargers, hubs, etc.).

2. Low Cycle Life Battery Packs (200–300 Cycles):

Ideal For:

- Price-sensitive B2C retail customers.
- Rural and semi-urban riders with home charging.
- Vehicles with low daily utilization (<30 km/day).
-

Technical Configuration:

- Mid- or low-grade cells (often 18650s or low C-rate pouch cells).
- Standard BMS with conservative current limits.
- Packs designed for planned obsolescence (~12–18 months).
- May use repurposed or surplus cells (e.g., from laptops or consumer electronics).

Pros:

- Very low upfront cost (₹10,000–₹15,000 per pack).
- Quick market penetration for rural or cost-sensitive users.
- Faster manufacturing cycles and local sourcing opportunities.

Cons:

- Not suitable for high-usage applications.
- Increases scrapping and recycling burden if not managed properly.
- May lead to customer dissatisfaction if not transparently marketed.

Engineering Levers to Enable Flexibility:

Design Lever	High Cycle PackLow	Cycle Pack
Cell Chemistry	LFP / High-C NMC	Standard LFP / Used NMC
Charge Rate	1.5C–3C	0.3C–0.5C
BMS Intelligence	Full telemetry + safety override	Basic protection + cutoff logic
Casing & Potting	Impact-resistant, IP-rated	Lightweight, semi-protected
Warranty Support	3–5 years	6–12 months
Ideal User Profile	Delivery fleets, gig riders	Budget commuters, low km/day

Conclusion:

Cost optimization is not about universally reducing price. It's about designing purpose-fit battery systems based on real-world operating needs—and enabling corresponding business models to deliver them.

Safety & Performance Considerations

While cost reduction is a major focus, safety and performance remain non-negotiable priorities—especially in a market that is rapidly evolving and highly scrutinized. The adoption of AIS-156 safety standards in India has further emphasized the importance of stringent battery design, testing, and quality assurance practices.

1. Risks of High C-Rate Charging on Low-Cycle Batteries:
Many fleet operators and OEMs are tempted to charge low-cost, low-cycle battery packs at high rates to reduce vehicle downtime.

However, this introduces critical safety and degradation issues:

- Overcharging or fast-charging low C-rate cells leads to rapid thermal buildup.
- Internal lithium plating can occur, increasing fire risk.
- Reduced life expectancy: A 0.5C-rated cell may degrade in less than 150 cycles when charged at 2C–3C.
- Pack-level imbalances exacerbate risk if BMS is not equipped for rapid current shifts.

Conclusion: Charging rates must match cell specifications. Misalignment results in unsafe field performance and higher warranty claims.

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Safety & Performance Considerations

2. Safety-Centric Standards (AIS-156 Compliance):

India's AIS-156 regulation governs safety standards for traction battery packs, particularly for electric two-wheelers.

Key requirements include:

- Thermal propagation resistance to prevent cell-to-cell fire spread.
- Mechanical shock, vibration, and thermal cycling resistance.
- Over-voltage, over-current, and short-circuit protection.
- BMS diagnostics, cell balancing, and fault alert capabilities.
- Mandatory testing by ARAI, ICAT, or other certified labs.

As a result:

- Cell choice must be AIS-156 compliant or tested as part of a certified pack.
- Battery manufacturers must standardize design practices and test protocols to prevent post-sale liability.

3. Role of Electrolyte Chemistry and BMS Tuning:

Cost-effective safety can also be achieved by optimizing chemistry and electronics:

- Electrolyte tuning (e.g., additives, solvent ratios) can slow degradation while lowering costs.
- BMS tuning (charge limits, active balancing, and thermal cutoffs) plays a critical role in maximizing safety within budget constraints.
- The use of real-time telemetry can help identify unsafe behavior, preemptively alerting users or disabling the pack.

4. Real-World Incidents and Implications:

The discussion referenced multiple field incidents:

- Battery fires in home charging setups due to subpar chargers or battery overuse.
- Lack of control over charging behavior once the battery is sold to a consumer.
- Fleet operators banning home charging after such incidents and mandating centralized charging or swapping.

These examples highlight the importance of safety not just in hardware design, but in deployment and usage monitoring.

Conclusion:

Safety cannot be compromised to cut costs. Instead, safety must be engineered as a default—even in low-cost packs—through thoughtful chemistry selection, robust BMS design, and adherence to AIS-156 compliance frameworks.

Diverse Business Models for Market Fit

As battery costs remain high, business model innovation becomes critical to unlock affordability and access. Participants discussed several successful deployment strategies across different market conditions:

Battery-as-a-Service (BaaS)

- Riders pay a daily or monthly fee (₹50–₹60/day or ₹1,600/month) for access to battery power.
- Vehicle cost drops significantly (e.g., from ₹1.2 lakh to ₹40,000–₹50,000).
- Ideal for high-mileage users who benefit from predictable energy costs.
- Manufacturer retains ownership of the battery, ensuring better maintenance and recycling.

Battery Swapping Models

- Riders swap discharged batteries for charged ones at hubs (typically <5 mins).
- Used heavily in B2B and urban deployment, where downtime must be minimized.
- Fleet operators can deploy thousands of batteries across hubs without waiting for long charging cycles.
- Swapping reduces dependence on fast-charging hardware and enables centralized safety compliance.

Pay-Per-Kilometer Pricing

- Through IoT and BMS integration, billing can be tied directly to usage.
- Offers greater fairness: riders only pay for what they consume.
- Useful for low-utilization B2C customers who may not ride daily.

Hybrid Subscription Models

- Combines minimum fixed fees with variable per-km pricing.
- Ensures manufacturer ROI while supporting flexible usage.

Role of IoT and Data Monitoring

Data is central to sustainable battery operations—especially in shared or pay-as-you-go models. Key use cases of IoT in battery packs include:

Battery Usage Monitoring:

- Real-time tracking of SOC (State of Charge), DOD (Depth of Discharge), voltage, and temperature.
- Enables prediction of degradation and preemptive servicing.

Billing and Dynamic Pricing:

- Enables per-kilometer or per-use billing models.
- Can offer customer discounts or credits for optimal usage patterns.

Safety & Compliance

- Live alerts for thermal anomalies, overcharging, or unsafe riding conditions.
- Tamper detection and remote shutdown reduce misuse risks.

Warranty and Lifecycle Planning

- Manufacturers retain visibility over actual usage.
- Batteries can be proactively recalled, retired, or reassigned based on condition.

Procurement Strategies and Cell Sourcing

Battery cost begins with the cell. Effective sourcing strategies must balance price, cycle life, safety, and compliance:

Domestic vs Imported Cells:

- Most Indian pack makers still rely on cells from China, Korea, or Japan.
- While Indian manufacturing is rising, it still lags on high-quality automotive-grade cell production.

High-Cycle vs Low-Cycle Sourcing:

- Tiered sourcing allows you to buy lower-cycle cells (200–300) for light use cases.
- Premium cells reserved for swapping/BaaS applications.

Using Surplus or Secondary Cells:

- Cells used in laptops or consumer electronics (18650s, pouch cells) can be adapted for EVs under strict control.
- Requires repackaging and cycle life estimation.

Negotiation Levers:

- Bulk volume commitments can bring down pack prices by 15–25%.
- Shared supply contracts between OEMs and operators offer additional pricing power.

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Battery Lifecycle Management & Recycling

With millions of EV batteries entering the market, end-of-life planning is no longer optional.

Environmental Risk of Disposable Packs:

- Low-cycle batteries may require annual replacement.
- Without a retrieval or repurposing system, these become e-waste hazards.

Second-Life Strategies:

- **Lower-usage or partially degraded batteries can be reassigned for:**
  - Stationary energy storage.
  - Light electric vehicles.
  - Rural backup power.

Scrap Management & Recycling Infrastructure

- AIS-156 encourages safe disposal protocols, but enforcement remains weak.
- Participants stressed the need for:
  - Manufacturer take-back programs.
  - Localized recycling partners.
  - Policy support for battery reuse businesses.

Financing and Asset-Light Models

Cost-effective financing is a pillar for scale—especially for fleet operators and EV entrepreneurs.

Hire-to-Purchase from OEMs:

- Bypasses high-interest NBFC loans.
- OEMs offer vehicles with one-year credit terms.
- Enables predictable deployment without upfront burden.

Leasing Only the Battery:

- Reduces asset depreciation and ensures better maintenance.
- Operators grow faster by deploying more vehicles at a lower capex.

Franchise-Based Deployment

- Entrepreneurs invest capital (e.g., ₹40 lakh) for vehicle deployment.
- Central operator manages battery subscription and maintenance.
- Profits shared through structured ROI models.

Tiered Product Strategy for OEMs

OEMs must create product segmentation based on user needs—not just vehicle pricing.

Tier-1: High-Performance Fleet Batteries

- ≥1000 cycles.
- Fast-charging (≥1.5C).
- Rugged casing, 3–5 year life.

Tier-2: Standard Commuter Packs

- 500–800 cycles.
- Moderate charging speeds.
- 2–3 year life.

Tier-3: Entry-Level, Low-Cycle Packs

- 200–300 cycles.
- For city commuters with limited budgets.
- Replaced every 12–18 months.

Communicating Value

- OEMs must transparently explain battery tier and lifecycle expectations.
- Empower dealers and end-users to choose based on actual use.

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Summary of Findings & Strategic Recommendations

Key Takeaways:

- Different users need different batteries: B2B ≠ B2C.
- Low-cost ≠ low-safety. Design smart, not cheap.
- Subscription models ease adoption and reduce scrap.
- IoT enables transparent billing and usage control.
- Recycling needs urgent focus alongside growth.

Strategic Recommendations:

- OEMs must standardize tiered packs with disclosed cycle life.
- Swapping and BaaS should be pushed in metros.
- Encourage franchise models for fleet rollout.
- Build partnerships with cell suppliers and recyclers.
- Support policy for second-life reuse.

Appendix

Cell Cost Benchmarks (as per 2025 Q2)

Cell Type	C-Rate	Price per kWh	Typical Use Case
LFP - Standard	0.5C	$65–$75	B2C, city usage
LFP - Fast Charge	1.5–3C	$100–$140	B2B, swapping, delivery
Reused 18650s	0.3C	₹35–₹45 per cell	Experimental, low-cycle EVs

Glossary:

- SOC – State of Charge.
- DOD – Depth of Discharge.
- C-Rate – Charge/Discharge Rate relative to battery capacity.
- BaaS – Battery-as-a-Service.
- AIS-156 – Indian safety standard for EV battery systems.

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