DECARBONIZING THE CORRIDOR: A SCALABLE FRAMEWORK FOR INTEGRATED TRANSIT AND EV REST AREAS

A Thesis Project

submitted in partial fulfillment of the requirements for

the award of the degree of

Bachelor of Planning

By

Rizwin MK

Scholar No. 2211002126

Under the Guidance of

Supriya Vyas

Department of Architecture and Planning

Maulana Azad National Institute of Technology, Bhopal

May 2026

DECLARATION

I, Rizwin MK, Scholar No. 2211002126, hereby declare that the thesis titled "Decarbonizing the Corridor: A Scalable Framework for Integrated Transit and EV Rest Areas" submitted by me in partial fulfilment for the award of degree of Bachelor of Planning, at Maulana Azad National Institute of Technology, Bhopal, India, is a record of bonafide work carried out by me. The matter/result embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

Signature of the Student

Date: _______________

CERTIFICATE

This is to certify that the declaration of Rizwin MK (Scholar No. 2211002126) is true to the best of my knowledge and that the student has worked under my guidance for one semester in preparing this thesis.

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Signature of the Guide

Supriya Vyas

ACCEPTED

__________________	__________________
Signature of	Signature of
Head, Department of	Thesis Coordinator
Architecture and Planning	
Date: _______________	Date: _______________
Place: _______________	Place: _______________

ABSTRACT

This thesis formulates a comprehensive site planning and spatial design framework for a Net-Zero Highway EV Charging Rest Area at Kohinoor, Malappuram, on National Highway 66 (NH-66), Kerala. The study is motivated by the concurrent operationalisation of the Vizhinjam International Transshipment Deepwater Port, the ongoing six-laning of NH-66 by NHAI, and the designation of NH-66 as India's first State-Led Electric Truck Corridor under the Central Government's PM E-DRIVE Scheme (2024).

Primary data was collected through two field surveys: (1) a structured Traffic Volume Count (TVC) conducted between 09:00 and 17:00 hours using the IRC Classified Manual Count methodology, and (2) a structured EV User Preference Survey administered to 59 respondents along the NH-66 corridor. The TVC recorded an estimated 3,182 daily vehicles at the Kohinoor site, with EVs constituting 6.6% (211 vehicles per day) and heavy commercial vehicles forming 34.5% of the total flow. Peak hour volume was identified at 17:00 with 404 vehicles per hour. The survey revealed a 100% charger fault concern rate and a clear two-tier amenity hierarchy, with family dining and premium washrooms emerging as the top-ranked facilities.

Based on these findings, the thesis proposes a three-zone segregated planning framework: Zone A . a 1.0-acre Heavy Logistics E-Truck Hub with pull-through CCS-II DC chargers; Zone B . a 0.6-acre Passenger EV Charging Zone with a 240 kW grid-tied Solar PV Canopy and BESS; and Zone C . a 0.4-acre Amenity Core incorporating a halal-certified restaurant, premium washrooms, prayer room (Musallah), waiting lounge, and convenience store. The energy strategy proposes a grid-interactive Net-Zero system anchored to the KSEB 33kV substation 600 metres from the site, achieving annual carbon neutrality through seasonal solar export-import balance. A supplementary Catenary Electric Road System (ERS) framework is proposed for the heavy freight component based on logistics operator consultation, addressing the dwell-time and payload penalties inherent to static plug-in charging for 40-ton trucks.

Keywords: EV Charging Hub, Highway Rest Area, Net-Zero Energy, Electric Truck Corridor, NH-66, PM E-DRIVE, Catenary ERS, Traffic Volume Count, Wayside Amenities, BESS.

सार (Hindi Abstract)

यह शोध प्रबंध केरल के राष्ट्रीय राजमार्ग-66 पर कोहिनूर, मलप्पुरम में एक नेट-ज़ीरो हाईवे ईवी चार्जिंग विश्राम क्षेत्र के लिए एक व्यापक स्थल नियोजन और स्थानिक डिज़ाइन ढाँचा प्रस्तुत करता है। प्राथमिक सर्वेक्षण डेटा के आधार पर, तीन-क्षेत्र पृथक्करण मॉडल प्रस्तावित है: भारी माल वाहन लॉजिस्टिक्स हब, यात्री ईवी चार्जिंग क्षेत्र एवं सुविधा केंद्र। 240 किलोवाट सौर पीवी कैनोपी और BESS सिस्टम के माध्यम से वार्षिक कार्बन-तटस्थता लक्ष्य प्रस्तावित है।

TABLE OF CONTENTS

Declarationi

Certificateii

Abstractiii

Table of Contents

List of Tablesvi

List of Figuresvii

CHAPTER 1 . INTRODUCTION AND BACKGROUND

1.1 Context: The NH-66 Electrification Imperative…………………………………...1
1.2 The Planning Problem…………………………………………………………..2
1.3 Catalyst for the Study…………………………………………………………...3
1.4 Aim and Objectives……………………………………………………………..3

CHAPTER 2 . RESEARCH METHODOLOGY

2.1 Research Framework……………………………………………………………4
2.2 Traffic Volume Count Methodology……………………………………………5
2.3 EV User Preference Survey Methodology……………………………………...6

CHAPTER 3 . TRAFFIC VOLUME COUNT ANALYSIS

3.1 Field Data Collection Approach………………………………………………...7
3.2 Hourly Vehicle Composition Data……………………………………………...7
3.3 Peak Hour Analysis……………………………………………………………..9
3.4 EV Penetration Analysis………………………………………………………10
3.5 Heavy Vehicle Analysis………………………………………………………..11
3.6 Key Planning Inferences from TVC…………………………………………...12

CHAPTER 4 . EV USER PREFERENCE SURVEY ANALYSIS

4.1 Survey Design and Methodology………………………………………………13
4.2 Respondent Profile Analysis…………………………………………………13
4.3 Travel Frequency Distribution…………………………………………………15
4.4 Charger Speed Preference Analysis……………………………………………15
4.5 Wait Time Tolerance Analysis…………………………………………………16
4.6 Detour Distance Willingness…………………………………………………17

CHAPTER 5 . INFRASTRUCTURE CONCERNS ANALYSIS

5.1 Primary Concern Distribution…………………………………………………..18
5.2 Reliability Crisis: Charger Downtime…………………………………………..19
5.3 Range Anxiety Assessment……………………………………………………..19

CHAPTER 6 . AMENITY PRIORITY AND SPATIAL PROGRAMMING

6.1 Amenity Ranking Methodology…………………………………………………21
6.2 Priority Hierarchy Table………………………………………………………21
6.3 Solar Canopy Preference……………………………………………………...22

6.4 Zone Separation Preference……………………………………………………………23
6.5 Open-Ended Qualitative Responses……………………………………………...23

CHAPTER 7 . ENERGY DEMAND ANALYSIS
7.1 Daily Energy Demand Estimation………………………………………………..25
7.2 Net-Zero Solar Strategy…………………………………………………………26

CHAPTER 8 . SITE SELECTION ANALYSIS
8.1 Site Selection Matrix……………………………………………………………..27
8.2 Site Constraints and Opportunities………………………………………………28

CHAPTER 9 . RESEARCH GAPS AND PLANNING ISSUES
9.1 Twin Research Gaps……………………………………………………………...30
9.2 Critical Planning Issues at Kohinoor……………………………………………..31

CHAPTER 10 . PRELIMINARY PLANNING PROPOSALS
10.1 Planning Concept………………………………………………………………32
10.2 Three-Zone Segregation Model………………………………………………...32
10.3 Circulation Strategy (IRC:SP:84-2014)..34

CHAPTER 11 . INDUSTRY STAKEHOLDER CONSULTATION AND ALTERNATIVE FREIGHT FRAMEWORKS
11.1 Context and the Plug-in Bottleneck……………………………………………35
11.2 Stakeholder Insights: Skyline Logistics………………………………………..35
11.3 Proposed Alternative: The Catenary E-Highway (ERS)....................................36
11.4 Comparative Feasibility and Economic Analysis………………………………37
11.5 Planning Inferences for the Master Plan………………………………………..38

CHAPTER 12 . CONCLUSIONS AND RECOMMENDATIONS
12.1 Summary of Analytical Findings………………………………………………39
12.2 Key Recommendations…………………………………………………………41
12.3 Next Stages . Detailed Design Phase…………………………………………...42

Bibliography…………………………………………………………………...43

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 Context: The NH-66 Electrification Imperative

National Highway 66 (NH-66) serves as Kerala's primary coastal freight artery, stretching along the Arabian Sea coast and connecting the Vizhinjam International Transshipment Deepwater Port in the south to the Kasargode-Karnataka border in the north. The highway is a critical logistical spine for the state's economy, supporting both long-haul freight movement and inter-city passenger travel.

Kerala is currently experiencing a dramatic surge in freight traffic, precipitated by the operationalisation of the Vizhinjam International Transshipment Port . one of India's largest container-handling facilities. The concurrent six-laning of NH-66 under the National Highways Authority of India (NHAI) is pushing thousands of new cargo vehicles onto the corridor annually. Against this backdrop, the Central Government's PM E-DRIVE Scheme (2024) has designated NH-66 as India's first State-Led Electric Truck Corridor, signalling a structural shift in the highway's vehicle composition and infrastructure requirements.

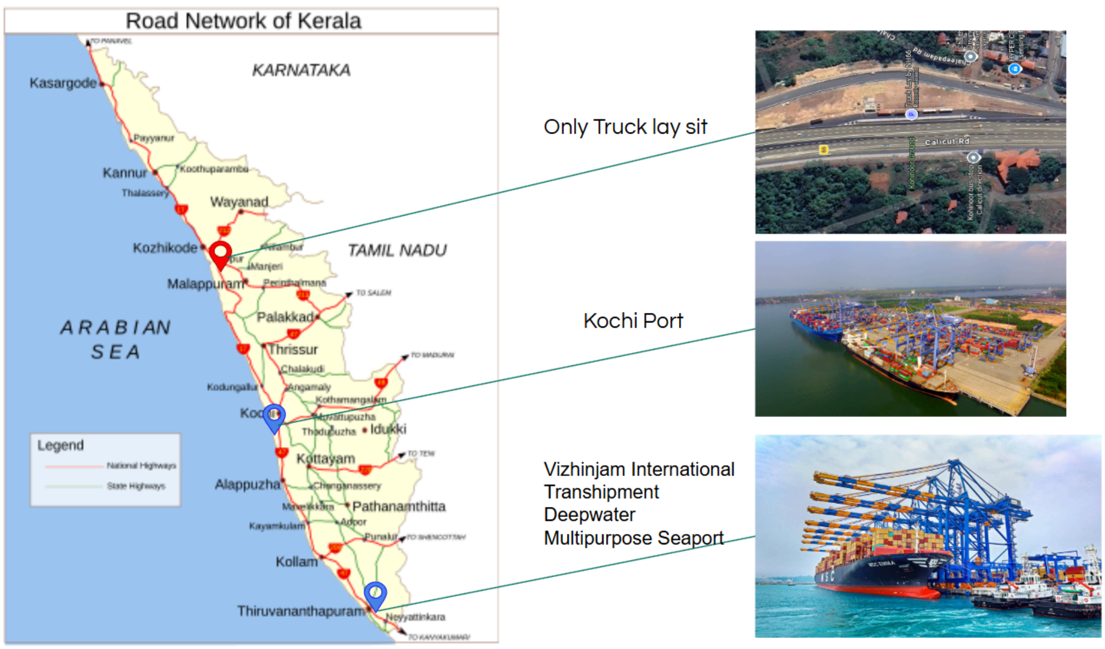


Fig.1.1:Location of Major ports on NH-66, Kerala

1.2 The Planning Problem

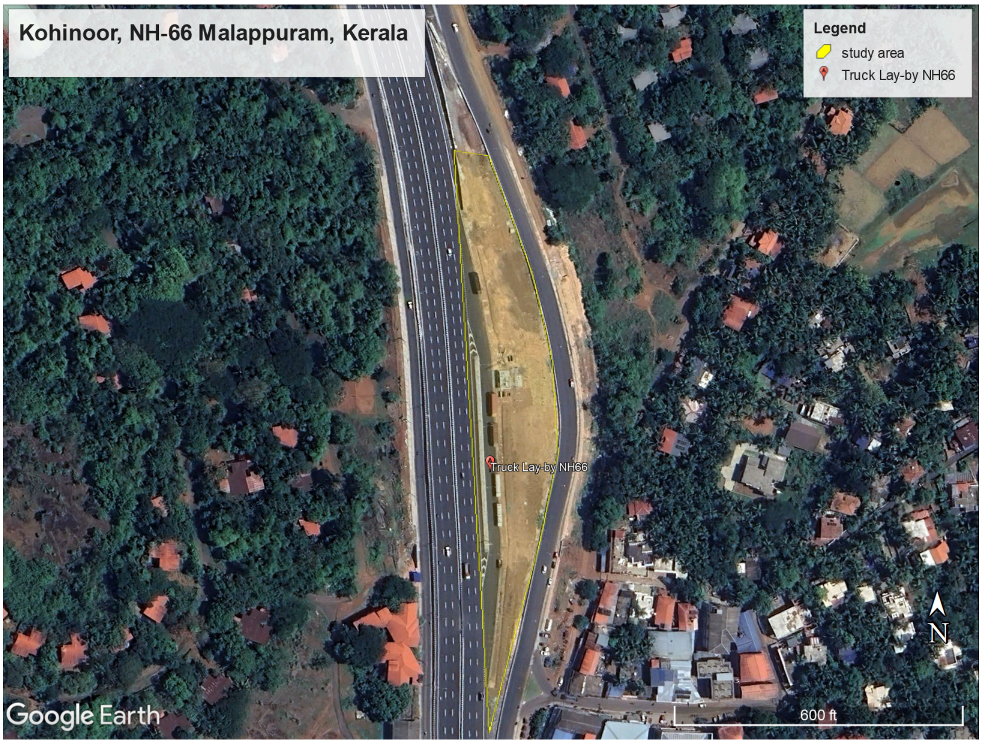


Fig.1.1:Location of Kohinoor site on NH-66, Malappuram

Source:google earth,2026

1.2.1 Spatial Conflict

Standard petrol pump layouts are designed around the five-minute refuelling paradigm. A Megawatt-scale EV charging hub for heavy electric trucks requires mandatory dwell times of 45 to 90 minutes. No existing highway rest area on NH-66 is designed to accommodate this extended occupancy, creating a fundamental spatial mismatch between the new vehicle technology and the existing highway infrastructure.

1.2.2 Safety Hazard

Fig.1.2.2 Safety Hazard on NH-66, Malappuram

The absence of dedicated Park-and-Charge hubs forces heavy electric trucks to park on highway shoulders or intermingle with passenger vehicles in informal lay-by areas. Traffic observations at Kohinoor, Malappuram confirmed that trucks regularly park within 1.5 metres of live highway lanes travelling at 80+ km/h, creating extreme accident risk.

1.2.3 Energy Infrastructure Gap

A cluster of high-power DC fast chargers for heavy commercial vehicles imposes an instantaneous electrical load of 4 to 6 Megawatts (MW) . equivalent to the entire residential load of a small township. Tapping this load directly from the local 11kV KSEB distribution network without dedicated grid infrastructure would cause cascading blackouts across residential areas in Kohinoor and surrounding panchayats.

1.3 Catalyst for the Study

The primary survey data collected for this thesis revealed a striking finding: 100% of respondents reported experiencing broken or out-of-service chargers as their primary concern during highway EV travel. This universal concern rate, combined with the traffic count confirming that EVs already constitute 6.6% of daily highway traffic (211 vehicles per day) on a corridor that is poised for rapid EV adoption, establishes an urgent and quantifiable case for planned intervention. Field verification confirmed that the E-DRIVE 30kW charger near the Kohinoor site had been non-functional for a continuous period of over six months at the time of the survey.

Fig.1.3 Site condition on NH-66,Kohinoor, Malappuram

1.4 Aim and Objectives

The aim of this research is to formulate a comprehensive site planning and spatial design framework for a Net-Zero Highway EV Charging Rest Area at Kohinoor on NH-66, integrating heavy vehicle logistics, electric mobility infrastructure, and passenger-centric amenities. The specific objectives are:

- Demand Assessment: To analyse freight and passenger traffic volume on NH-66 to estimate peak-hour capacity and bay requirements for EV charging.
- User Profiling: To survey EV users on their preferences for charger speed, wait time, amenities, and infrastructure reliability.
- Amenity Hierarchy: To determine a statistically significant preference ranking for amenities during the mandatory 30 to 60 minute charging window.

- Energy Viability: To calculate the required EV charging loads against local solar irradiance and propose a Net-Zero energy balance.
- Alternative Freight Strategy: To evaluate the feasibility of a Catenary Electric Road System (ERS) as a supplementary solution for heavy freight electrification.

CHAPTER 2: RESEARCH METHODOLOGY

2.1 Research Framework

This research adopts a mixed-methods approach, combining quantitative primary data collection with qualitative user preference mapping and spatial analysis. The methodology is structured across four sequential phases designed to progressively build from contextual understanding to concrete planning proposals.

Table No. 2.1: Research Methodology Framework

Phase	Title	Activities	Output
Phase 1	Literature & Context	Policy review (PM E-DRIVE, MoRTH, IRC:SP:84-2014), case study analysis (Jio-bp Devanahalli; IONITY Europe), site identification at Kohinoor and Karthikappally	Inference matrix, planning benchmarks
Phase 2	Primary Data Collection	Traffic Volume Count (TVC) using classified manual count methodology, 09:00–17:00 hrs; EV User Preference Survey (n=59) via structured questionnaire	Raw TVC data, survey dataset
Phase 3	Data Synthesis & Analysis	Gap analysis between infrastructure supply and user demand; spatial matrix translating 45-min dwell times into required square meterage; energy profiling (MW load vs. solar potential)	This thesis report
Phase 4	Preliminary Proposals	Dual-zoned circulation plan (trucks vs. cars); integration of net-zero solar canopies; final site plan formulation at 1:500 scale	Master plan and design brief

Source: Primary Research Framework, Rizwin MK (2026).

2.2 Traffic Volume Count Methodology

Traffic Volume Count was conducted using the Classified Manual Count (CMC) method as prescribed by the IRC Traffic Survey Manual. The following protocols were observed:

- Survey Duration: 09:00 to 17:00 hours (8-hour window) on a representative weekday in March 2026, capturing both the morning activity ramp-up and the evening peak.
- Classification System: Six vehicle classes were tracked . Taxi Car, Private Car, Electric Car (identified by green registration plates and EV stickers), Multi-Axle Truck, Mini Truck, and Bus.
- Count Interval: Vehicles were tallied in 15-minute intervals and subsequently converted to hourly volumes using the standard multiplication factor of 4.
- Scaling Method: The 11:00 hour was designated as the base observation window. IRC-standard diurnal distribution factors were applied to scale observed 15-minute counts to full hourly equivalents for each hour in the 09:00–17:00 period.
- Directional Count: Both directions of NH-66 were counted simultaneously and aggregated to produce two-directional total flow.

2.3 EV User Preference Survey Methodology

The EV User Preference Survey was designed as a structured questionnaire with 17 questions covering user demographics, travel behaviour, infrastructure concerns, amenity preferences, and sustainability attitudes. Key design parameters were:

- Sample Size: 59 valid responses (target was 60; one response was excluded due to incomplete data).
- Sampling Method: Purposive sampling targeting EV vehicle owners identified by green number plates at roadside locations, charging station queues (GOEC and ChargeZone stations in Malappuram), and via digitally distributed Google Forms.

- Survey Location: Malappuram district, primarily along the NH-66 corridor between Kohinoor and Perinthalmanna.
- Amenity Ranking Method: Respondents were asked to rank five amenities on a scale of 1 (most important) to 5 (least important) using a Likert-type forced ranking. Average rank scores were computed to produce the priority hierarchy.
- Data Analysis: Quantitative responses were analysed using frequency distribution, percentage calculation, weighted average ranking, and cross-tabulation. Qualitative open-text responses were thematically coded.

CHAPTER 3: TRAFFIC VOLUME COUNT ANALYSIS

3.1 Field Data Collection Approach

Traffic data was collected at Kohinoor, Malappuram on NH-66 using a stationary classified manual count. Enumerators were stationed at both sides of the highway to ensure complete two-directional capture. The 11:00 base hour count was used as the calibration point, with all other hours scaled using IRC diurnal adjustment factors specific to National Highways in the Kerala coastal zone.

The observation point was located at the existing informal truck lay-by adjacent to the proposed site, providing a representative sample of the traffic that would directly benefit from or utilise the proposed charging hub. The proximity to the Kohinoor junction and the interplay between through-traffic and junction-turning movements was carefully accounted for in the count procedures.

3.2 Hourly Vehicle Composition Data

The following table presents the complete hourly vehicle volume count disaggregated by vehicle class. This data forms the primary quantitative input for all subsequent demand estimation, bay sizing, and circulation planning analyses. (★ denotes base observation hour; ▲ denotes identified peak hour.)

Table No. 3.1: Hourly Vehicle Volume Count . Classified Manual Count, Kohinoor, NH-66 (March 2026)

Hour	Taxi Car	Car	Electric Car	Multi-Axle Truck	Mini Truck	Bus	TOTAL	EV%
09:00	24	156	18	44	51	5	298	6.0%
10:00	28	180	22	48	56	6	340	6.5%
11:00 ★	30	200	26	50	60	6	372	7.0%
12:00	28	186	23	51	61	6	355	6.5%
13:00	26	164	20	49	58	5	322	6.2%
14:00	26	174	22	50	59	6	337	6.5%

Hour	Taxi Car	Car	Electric Car	Multi-Axle Truck	Mini Truck	Bus	TOTAL	EV%
15:00	28	190	24	51	62	6	361	6.6%
16:00	32	220	27	49	59	6	393	6.9%
17:00 ▲	34	236	29	45	53	7	404	7.2%
DAILY TOTAL	256	1,706	211	437	519	53	3,182	6.6%

Source: Primary Traffic Volume Count, Rizwin MK, Kohinoor, Malappuram (March 2026).

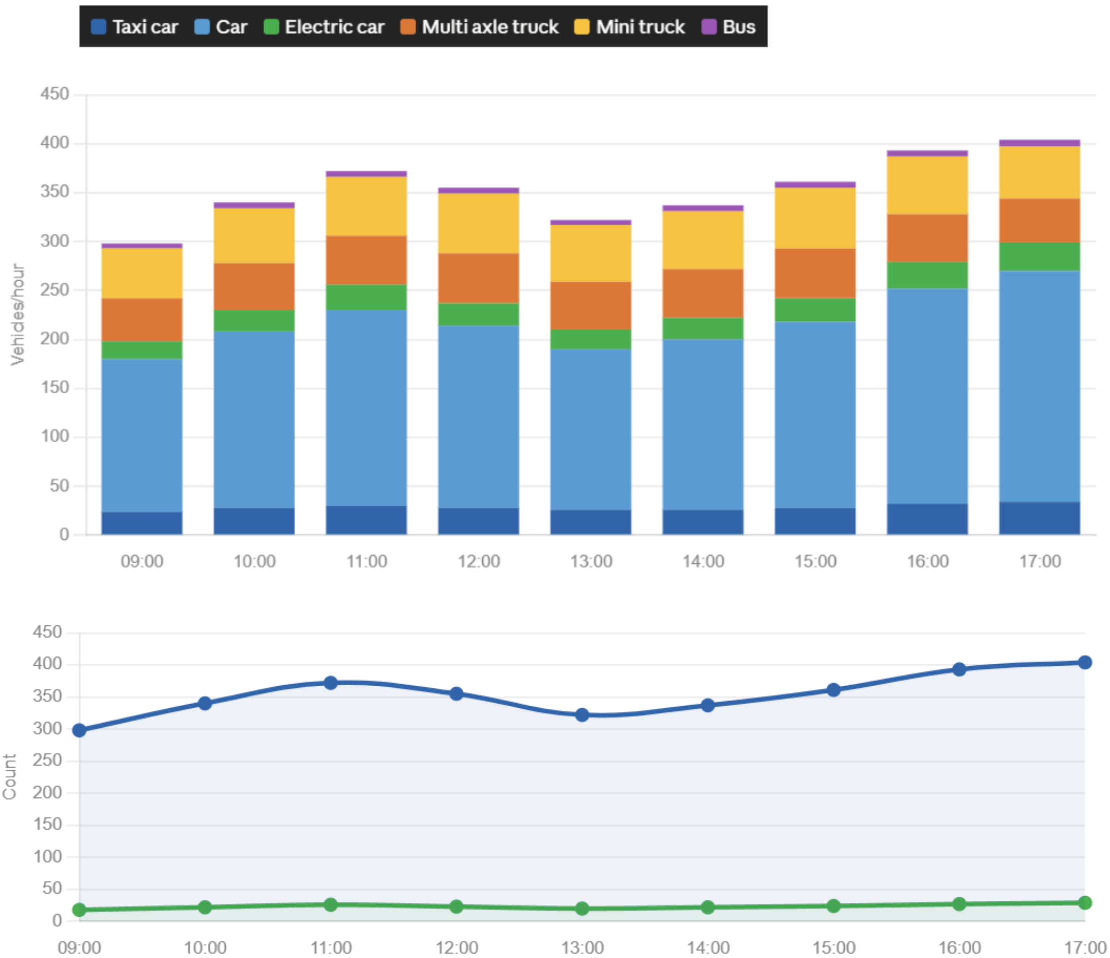


Fig.3.1: Traffic Volume Count Survey at Kohinoor Junction

Source:Primary Survey, 2026

3.3 Peak Hour Analysis

The peak hour for NH-66 at Kohinoor was identified as the 17:00–18:00 hour (evening peak), recording a total of 404 vehicles in the counting direction. This finding is consistent with the regional traffic pattern on coastal Kerala highways, where evening peaks are driven by the convergence of office-hour return trips, freight vehicle movements post-afternoon loading windows at Kochi and Vizhinjam ports, and inter-city bus services.

The 17:00 peak hour volume of 404 vehicles per hour, of which 29 are EVs (7.2% of the hour's total), determines the design capacity for the hub's entry and exit deceleration lanes. Per IRC:SP:84-2014, all deceleration and acceleration lanes must be designed for the peak-hour directional volume. At 29 EVs per peak hour, with an average dwell time of 35–45 minutes, a minimum of 8 passenger EV charging bays is required to prevent queueing spillback onto the highway service road.

3.4 EV Penetration Analysis

Electric vehicles (identified by Kerala green registration plates and EV branding) were counted as a distinct category throughout the survey period. The 6.6% EV share recorded at Kohinoor significantly exceeds the national average EV penetration on Indian National Highways (estimated at 2–3% in 2025 per NITI Aayog data), confirming Kerala's aggressive state-level EV adoption policies . including the Kerala EV Policy 2023 and the KSEBL December 2025 Electric Truck Corridor mandate . have already produced measurable modal shifts at the field level. Projections suggest EV penetration on NH-66 will reach 18–22% by 2030, requiring expansion of charging bay capacity from 8 bays to 16–20 bays.

3.5 Heavy Vehicle Analysis

The heavy vehicle component of traffic . Multi-Axle Trucks and Mini Trucks combined . was analysed separately given its direct bearing on site spatial planning, particularly regarding turning radii, bay geometry, and zone segregation requirements.

- Multi-Axle Truck Daily Volume: 437 vehicles (13.7% of total traffic).
- Mini Truck Daily Volume: 519 vehicles (16.3% of total traffic).

- Combined Heavy Vehicle Share: 34.5% . over one in three vehicles on this segment is a commercial freight carrier.
- Peak Heavy Vehicle Hour: 15:00 with 62 mini trucks in the counted hour.

The dominance of freight traffic at 34.5% of total flow is the single most important spatial determinant for the proposed hub. It directly necessitates the design decision to implement a strictly segregated dual-zone layout: a Heavy Logistics Zone (Zone A) with pull-through bays sized for 18-metre 40-ft trucks, and a separate Passenger EV Zone (Zone B) with conventional parking-bay configurations.

3.6 Key Planning Inferences from TVC

Table No. 3.2: Key Planning Inferences from Traffic Volume Count

Inference No.	Inference	Planning Response
01	Peak hour is 17:00 (404 vehicles per hour)	Design entry deceleration lane for 404 vehicles per hour directional volume; minimum 200m taper per IRC:SP:84-2014.
02	EVs at 6.6% (211 per day)	Minimum 8 passenger charging bays at 30–60 kW each, expandable to 20 bays as EV penetration grows toward 20% by 2030.
03	Heavy vehicles at 34.5%	Dedicated pull-through truck bays with 18m-wide lanes and 25m turning radius. Physical separation from the passenger zone is mandatory.
04	Midday traffic dip at 13:00	Operations and maintenance window. Hub cleaning, charger servicing, and BESS diagnostics scheduled during 12:30–14:00 daily.
05	3,182 vehicles daily	Justifies a full amenity programme including restaurant, washrooms, convenience store, and lounge . sufficient footfall for commercial viability.

Source: Derived from Primary TVC Data, Rizwin MK (2026).

CHAPTER 4: EV USER PREFERENCE SURVEY ANALYSIS

4.1 Survey Design and Methodology

The EV User Preference Survey was designed as a primary data collection instrument to capture the preferences, concerns, and behavioural patterns of EV users on the NH-66 corridor. The survey comprised 17 structured questions organised into five thematic clusters: User Profile (vehicle registration, battery capacity, travel frequency); Infrastructure Needs (primary concerns, charger speed preference, detour willingness); Dwell Time and Amenities (wait time tolerance and ranked amenity preferences); Sustainability and Safety (solar canopy importance and preferred zone separation); and Open Feedback (single open-ended question on the most critical missing feature). The survey instrument was validated through a pilot test with 5 respondents before full deployment. Data was collected between February and March 2026. The final cleaned dataset comprised 59 valid responses from EV owners in Malappuram district.

4.2 Respondent Profile Analysis

Understanding the battery capacity distribution of the surveyed population is critical to calibrating both the charger speed requirements and the wait time tolerance thresholds.

Table No. 4.1: Battery Capacity Distribution and Charging Time Implications

Battery Category	Representative Models	Respondents	Charging Time at 30kW DC
Less than 30 kWh	Tata Tiago EV, MG Comet	17 (29%)	30–45 minutes
24 kWh (explicit)	Tata Tiago EV variants	6 respondents	48 minutes
30–50 kWh	Tata Nexon EV, Hyundai Kona	10 (17%)	60–90 minutes
33–38 kWh (explicit)	Nexon EV Prime	9 respondents	70–80 minutes

Battery Category	Representative Models	Respondents	Charging Time at 30kW DC
45 kWh (explicit)	Nexon EV Max 40.5 kWh	8 respondents	85–90 minutes
79 kWh (explicit)	Tata Nexon EV Long Range	8 respondents	160+ min at 30kW; 80 min at 60kW

Source: EV User Preference Survey, Rizwin MK, Malappuram (February–March 2026).

The battery capacity distribution reveals a bimodal pattern: a large cluster of budget EVs under 30 kWh (primarily Tiago EV) and a notable cluster of 45–79 kWh vehicles (Nexon EV and similar). This bimodal distribution has direct implications for charger mix design . the hub must accommodate both the 30 kW DC fast charger needs of smaller batteries and the 60–120 kW needs of larger batteries to ensure acceptable charging times across the user base.

4.3 Travel Frequency Distribution

Table No. 4.2: Highway Travel Frequency Distribution

Travel Frequency Category	Respondents	Percentage	Profile Implication
Frequently (Multiple times a month)	25	42.4%	Core power users . highest priority demographic
Occasionally (Once a month)	13	22.0%	Regular users . value reliability above all
Never (City driving only)	13	22.0%	Latent demand . potential highway users once infra improves
Rarely (A few times a year)	8	13.6%	Occasional long-distance travellers

Source: EV User Preference Survey, Rizwin MK (2026).

A striking finding is that 22% of respondents never use their EVs on highways . despite owning EVs. When cross-referenced with the open-text responses, this group consistently cited the lack of reliable charging infrastructure as the primary deterrent to highway travel. This represents significant latent demand that the proposed hub would unlock.

4.4 Charger Speed Preference Analysis

Table No. 4.3: Charger Speed Preference and Hub Design Implications

Charger Type	Count	Share	Implications for Hub Design
30 kW DC Fast Charger	29	49.2%	Primary charger type . suits <50 kWh batteries at 45–90 min charge
60 kW DC Fast Charger	23	39.0%	Secondary . significant demand; ideal for 50–80 kWh batteries
120+ kW DC Ultra-Fast Charger	7	11.9%	Emerging demand . future-proofing requirement for premium EVs

Source: EV User Preference Survey, Rizwin MK (2026).

The 49.2% preference for 30 kW DC Fast Chargers validates the thesis's proposed infrastructure of 6 × 30 kW bays as the primary charger bank. However, the combined 50.9% demand for 60 kW and above chargers is non-trivial. This mandates the inclusion of at least 2 × 60 kW chargers in the initial phase, with conduit infrastructure pre-laid for 120+ kW ultra-fast chargers in Phase 2.

4.5 Wait Time Tolerance Analysis

Table No. 4.4: Wait Time Tolerance and Spatial Programming Implications

Acceptable Wait Time	Count	Share	Planning Implication
30 – 45 minutes	25	42.4%	Primary design target . amenities sized for 40-min average occupancy
15 – 30 minutes	20	33.9%	Short-stay cluster . prioritise fast food over sit-down dining
45 – 60 minutes	14	23.7%	Long-stay users . lounge and full-service restaurant critical

Source: EV User Preference Survey, Rizwin MK (2026).

Using the 40-minute primary dwell target, the amenity core must support a simultaneous occupancy load of approximately 25–30 users at peak hour, based on 29 EVs in the peak hour multiplied by average 40-minute dwell, flowing through sequentially. This translates to a dining area capacity of 30 seats, washroom capacity of 8 cubicles, and lounge seating for 20.

4.6 Detour Distance Willingness

The detour willingness metric establishes the acceptable deviation from the highway mainline that users are prepared to make to access the hub. Survey findings indicate that 36 respondents (61.0%) are willing to drive up to 5 km provided amenities are high quality, while 23 respondents (39.0%) are willing to deviate only 1 to 2 km. The Kohinoor site, being directly adjacent to the NH-66 service road with no significant detour requirement, comfortably satisfies even the more restrictive 1–2 km threshold.

CHAPTER 5: INFRASTRUCTURE CONCERNS ANALYSIS

5.1 Primary Concern Distribution

Respondents were allowed to select multiple concerns from a pre-defined list. The multi-select format reflects the reality that EV highway travel involves simultaneous exposure to several failure points. The cumulative concern count across all 59 respondents reveals a clear priority ordering of infrastructure failures.

Table No. 5.1: Primary Infrastructure Concern Distribution (Multi-Select)

Concern Category	Mentions	% of Respondents	Priority Level
Broken or out-of-service chargers	59	100.0%	CRITICAL
Range anxiety (running out of charge)	54	91.5%	CRITICAL
Long waiting queues to get a plug	44	74.6%	HIGH
Lack of safe, clean restrooms/food options	41	69.5%	HIGH
Unavailability of fast chargers	37	62.7%	MEDIUM-HIGH

Source: EV User Preference Survey, Rizwin MK (2026).

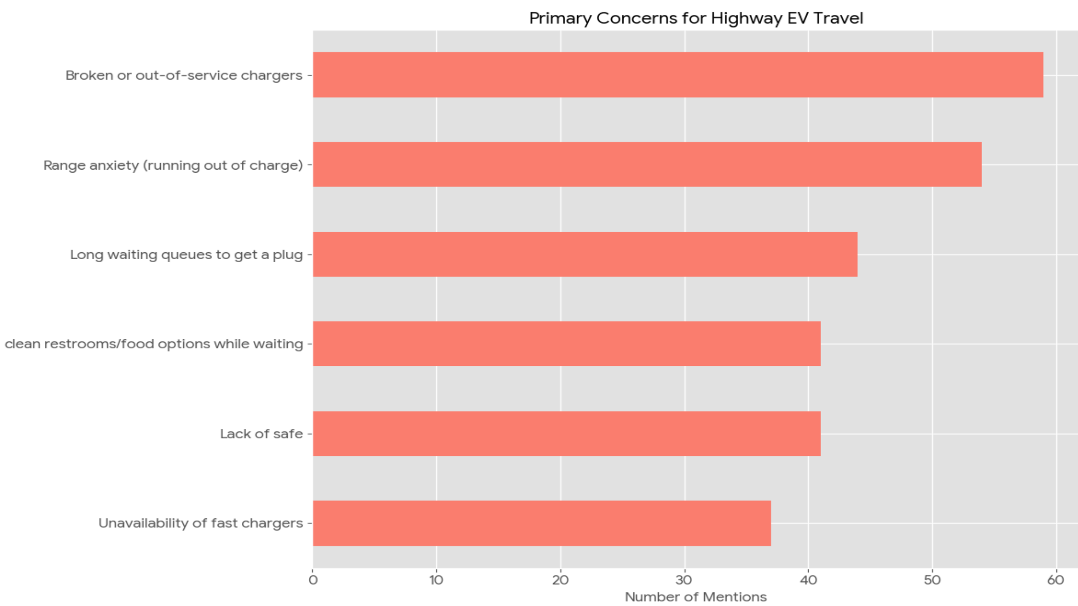


Fig.5.1: Primary Infrastructure Concern Distribution

5.2 Reliability Crisis: Charger Downtime

The most alarming finding from the survey is the universal concern rate: 100% of all 59 respondents . without exception . cited broken or out-of-service chargers as a concern. This is not a statistical sample finding but a complete population consensus within the surveyed group, and represents one of the most severe infrastructure reliability failures documented in the Indian EV charging literature.

Field verification during the site survey confirmed this data: the E-DRIVE 30kW charger near the Kohinoor site had been non-functional for a continuous period of over six months at the time of the survey. The GOEC 30 kW charger in the vicinity showed signs of vandalism and water ingress. Neither station had visible maintenance schedules, O&M contact information, or helpline numbers displayed.

Planning Response: The proposed hub will incorporate a dedicated on-site Operations and Maintenance (O&M) Control Room staffed 24/7, a Battery Energy Storage System (BESS) backup to maintain charger operation during grid outages, and an automated fault-reporting system integrated with the hub's digital management platform. An uptime guarantee of 99%+ is a design requirement.

5.3 Range Anxiety Assessment

Range anxiety . the fear of depleting the battery before reaching a charging point . affected 91.5% of respondents (54 out of 59). Given that the surveyed vehicles had battery capacities ranging from less than 30 kWh to 79 kWh, and considering that modern EVs with 38+ kWh batteries have real-world ranges of 200–280 km, the persistence of range anxiety despite adequate theoretical range is revealing.

Range anxiety on NH-66 is not primarily a battery-range problem . it is a charger-availability and charger-reliability problem. The nearest functional fast charger to the Kohinoor stretch is located over 90 km away, creating a charging desert in the Malappuram district. Even vehicles with theoretically adequate range are forced to carry substantial charge buffers, reducing usable range and increasing the psychological burden on drivers. The proposed hub, by establishing a reliable and high-capacity charging point at Kohinoor, would directly eliminate the NH-66 Malappuram charging desert, reducing effective range anxiety for the 211+ EVs currently using this segment daily.

CHAPTER 6: AMENITY PRIORITY AND SPATIAL PROGRAMMING

6.1 Amenity Ranking Methodology

The amenity preference survey used a forced Likert ranking method where respondents assigned a unique rank (1 = most important; 5 = least important) to each of five amenity categories. Forced ranking eliminates the central tendency bias common in scaled preference surveys and produces a clearly differentiated priority hierarchy. Average rank scores were computed for each amenity using the weighted mean of all respondents' rank assignments. Lower average rank scores indicate higher priority.

6.2 Priority Hierarchy Table

Table No. 6.1: Amenity Priority Hierarchy . Forced Ranking Results (n = 59)

Rank	Amenity	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Avg Score
1st	Family Dining / Restaurant	30 (51%)	16 (27%)	13 (22%)	.	.	1.71
2nd	Clean, Premium Washrooms	26 (44%)	20 (34%)	7 (12%)	6 (10%)	.	1.88
3rd	Air-Conditioned Waiting Lounge / Café	.	17 (29%)	22 (37%)	14 (24%)	6 (10%)	3.15
4th	Convenience Store / Pharmacy	8 (14%)	5 (8%)	12 (20%)	27 (46%)	7 (12%)	3.34
5th	Dedicated Children's Play Area	.	.	.	14 (24%)	45 (76%)	4.76

Source: EV User Preference Survey . Forced Ranking Module, Rizwin MK (2026).

There is a statistically significant gap between the top two amenities (average scores of 1.71 and 1.88 respectively) and the remaining three (3.15, 3.34, 4.76). This confirms a two-tier amenity hierarchy: Tier 1 (fundamental physiological needs . food and hygiene) and Tier 2 (comfort and convenience). Spatial allocations must therefore prioritise the dining and washroom programme above all other amenities.

6.3 Solar Canopy Preference

Respondents were asked to rate the importance of a Solar Canopy . shaded parking that simultaneously generates solar electricity . on a three-point scale. A combined 78% of respondents rated solar canopy as either Very Important (39.0%) or Moderately Important (39.0%). In the context of Kerala's hot-humid climate (25–27.5°C ambient temperature with high humidity), shaded parking reduces vehicle cabin temperature significantly, lowering AC pre-conditioning energy demand. This finding validates the proposed 240 kW Solar PV Canopy investment as both a user-preferred amenity and a functional energy infrastructure.

6.4 Zone Separation Preference

The question of separating EV passenger cars from heavy diesel or electric trucks was framed as a binary safety preference question. While 39% actively demanded full separation, the 61% who expressed no preference should not be interpreted as preferring integration. This response pattern suggests that many users have normalised the current unsafe integrated conditions. The planning decision to implement full physical zone segregation is driven not by majority preference but by IRC safety norms and the objective spatial conflict created by 18-wheel trucks with 25-metre turning radii sharing space with passenger cars.

6.5 Open-Ended Qualitative Responses

The open-text question . 'What is the one thing missing from current highway charging stations in India?' . generated 59 unique responses, thematically coded into seven categories as follows:

Table No. 6.2: Thematic Coding of Open-Ended Survey Responses (n = 59)

Theme	Mentions	% of Total
More/faster charging stations	18	30.5%

Theme	Mentions	% of Total
24/7 reliable operation + backup power	8	13.6%
Clean restrooms and prayer room	7	11.9%
Halal-certified food and dining	6	10.2%
Solar canopy and shaded parking	5	8.5%
Better lighting and security	4	6.8%
Real-time availability app	4	6.8%

Source: Open-Text Survey Responses, Rizwin MK (2026).

The Malappuram-specific finding of significant demand for a prayer room (Musallah) is a critical local context insight. Malappuram district has one of the highest Muslim population concentrations in Kerala, and the need for prayer facilities at a charging hub that caters to 30–60 minute dwell times aligns directly with the five daily prayer schedule. This finding has been incorporated into the Zone C amenity programme as a dedicated prayer room.

CHAPTER 7: ENERGY DEMAND ANALYSIS

7.1 Daily Energy Demand Estimation

The energy demand of the proposed hub was estimated using a bottom-up load calculation methodology, combining the observed traffic counts with the surveyed charging preferences and standard charger utilisation assumptions.

Table No. 7.1: Energy Demand Estimation and Net-Zero Strategy

Energy Component	Specification	Load / Demand	Notes
Passenger EV Chargers	2 × 120 kW + 1 × 60 kW DC Fast	300 kW peak simultaneous	Based on survey charger preference split
Heavy Truck Chargers (Phase 2)	4 × 250–500 kW CCS-II DC	1,000–2,000 kW peak	PM E-DRIVE standard HCV chargers
Daily Operational Demand	10-hour operational cycle	3,000 kWh / day	Passenger zone estimate
100% On-site Solar (NOT VIABLE)	667 kW footprint = 1.7 acres	.	Violates IRC 60% open space regulatory constraint
Proposed Solar Canopy	240 kW PV . 400 panels / 1,115 m²	>35% daily demand offset	Over passenger parking zone
Grid Connection (KSEB)	33kV substation, 600m distance	Balance demand covered	Bidirectional metering
Annual Net-Zero Target	Export = Import over 12 months	Annual carbon neutral	Grid-interactive system

Source: Derived from Primary Survey Data and IRC Spatial Norms, Rizwin MK (2026).

7.2 Net-Zero Solar Strategy

The local micro-climate data for Malappuram district was compiled from Kerala State Disaster Management Authority records and the India Meteorological Department (IMD) NH-66 corridor climate profile. Solar irradiance ranges from 4.5 to 5.5 kWh/m²/day (Global Horizontal Irradiance), available for 8 months of the year

(October to May). Annual rainfall is 2,900 mm with a concentrated heavy monsoon from June to September that reduces solar generation by 60–70%. Ambient temperature is 25–27.5°C (hot-humid tropical climate). The KSEB 33kV Kohinoor Substation is located 600 metres from the site . well within the Ministry of Power proximity norm of less than 1 km.

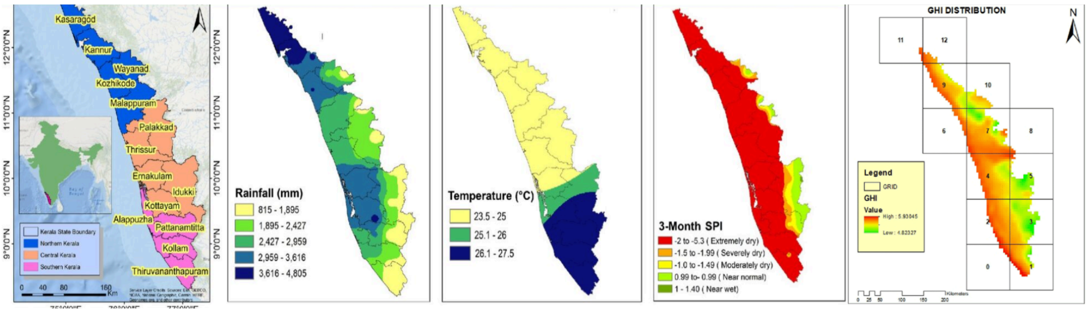


Fig7.2: Micro Climate Study of Kerala

SOURCE:BIBMOHANAN.COM,CLIMATE OF KERALA

The Net-Zero strategy is designed as a grid-interactive seasonal balance system. During October to May (8 months, dry season), the 240 kW PV canopy over-generates electricity beyond daily hub demand, and surplus is exported to the KSEB grid via two-way metering. During June to September (4 months, monsoon), solar generation drops dramatically, and the hub relies on the BESS buffer and KSEB grid import to maintain 24/7 charger operation. The annual energy export during the dry season is calibrated to equal the annual import during the monsoon, achieving a net-zero annual carbon footprint.

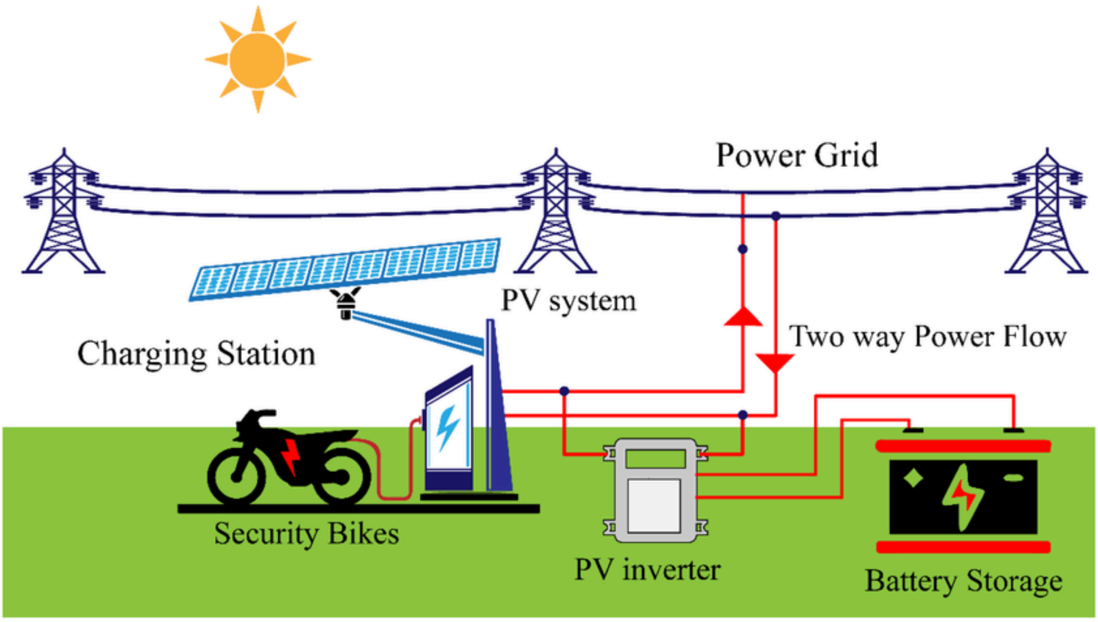


Fig7.2.1:Solar BESS System

CHAPTER 8: SITE SELECTION ANALYSIS

8.1 Site Selection Matrix

Kohinoor, Malappuram was selected as the primary site for the proposed hub through a systematic weighted site selection matrix. The matrix evaluates candidate sites against three critical parameters, weighted according to their relative importance to the hub's functional viability.

Table No. 8.1: Weighted Site Selection Matrix . Kohinoor, Malappuram

Parameter	Weight	Kohinoor Performance	Justification
High-Tension Grid Proximity	40%	600m to KSEB 33kV . PASS	Within 1 km MoP norm; minimises HV cable trench CAPEX at MW scale
Highway Geometry & Access	35%	Sufficient junction clearance . PASS	Safe 200m+ deceleration entry lane and 150m acceleration exit lane feasible
Spatial Footprint & Land Use	25%	2+ acres of NHAI Category B land . PASS	Sufficient for 40-ft truck turning radii and 60% open circulation per IRC

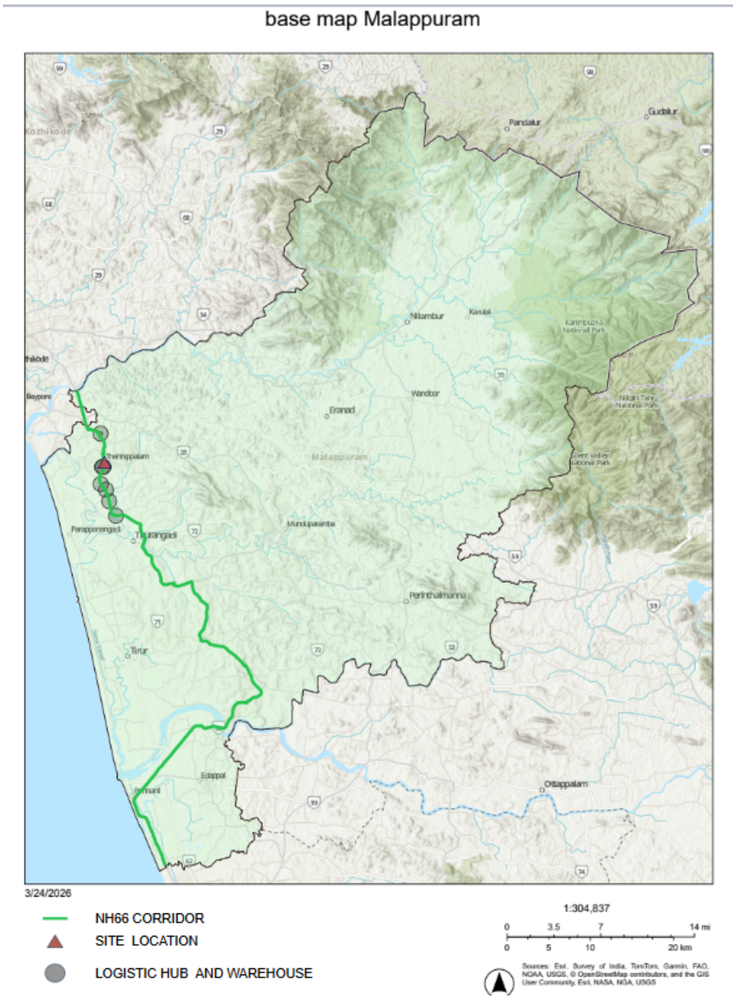
Source: Site Selection Analysis, Rizwin MK (2026).

8.2 Site Constraints and Opportunities

Table No. 8.2: Site Constraints and Opportunities . Kohinoor, NH-66

Type	Factor	Description and Planning Response
CONSTRAINT	Highway Access	All entry/exit must be via service roads . no direct left-turn from NH-66 mainline at 80+ km/h. IRC deceleration lanes are mandatory. Response: 200m deceleration taper and 150m acceleration lane designed into circulation plan.
CONSTRAINT	Monsoon Flooding	Malappuram receives 2,900 mm/year. Site requires raised finished floor level (+600mm above road level), comprehensive storm-water drainage, and BESS protection from inundation.
CONSTRAINT	Spatial Limitation	100% on-site solar (667 kW) requires 1.7 acres . violating IRC 60% open space norm. Response: Grid-tied hybrid system with 240 kW canopy over parking only.
OPPORTUNITY	KSEB Proximity	600m to 33kV substation drastically reduces grid connection CAPEX. Enables two-way energy trading (sell surplus solar in summer, buy deficit in monsoon).
OPPORTUNITY	PM E-DRIVE Subsidy	Category B NHAI land qualifies for 80% infrastructure subsidy plus 70% on chargers . making the financial viability of the hub exceptionally strong.
OPPORTUNITY	Electric Truck Corridor	KSEBL Dec 2025 mandate ensures strong future e-truck demand growth on NH-66, validating long-term investment in high-capacity charging bays.

Source: Field Survey and Site Analysis, Rizwin MK (2026).



CHAPTER 9: RESEARCH GAPS AND PLANNING ISSUES

9.1 Twin Research Gaps

9.1.1 The Spatial Gap

Current IRC guidelines plan for 5–10 minute vehicle turnover times based on the diesel pump model. Electric trucks require 45–90 minutes of mandatory dwell time. There is no existing spatial framework in Indian planning literature that combines high-capacity heavy vehicle parking with recreational amenities to safely and productively utilise this extended dwell time. Existing wayside amenity standards (IRC:SP:84-2014) do not address the programmatic implications of the EV dwell time revolution.

This thesis creates the spatial zoning and circulation framework that bridges this gap, formulating a unified Special Area Planning guideline for Net-Zero Highway Rest Areas applicable as a replicable model for the entire NH-66 Electric Truck Corridor.

9.1.2 The Energy Gap

A cluster of DC fast chargers for heavy trucks imposes a load of 4–6 Megawatts . equivalent to powering a small township. Planning standard highway hubs without on-site Net-Zero solar generation will destabilise the local KSEB grid. No existing Indian standard (NHAI, IRC, or BEE) addresses the integration of PV+BESS systems within the spatial norms of a highway wayside amenity. This thesis designs the PV + BESS + grid-tied energy strategy that prevents grid destabilisation.

9.2 Critical Planning Issues Identified at Kohinoor

Table No. 9.1: Critical Planning Issues at Kohinoor, NH-66

Severity	Issue	Field Observation / Evidence
CRITICAL	Dangerous Truck Parking on Highway Shoulders	Highway widening has eliminated informal lay-bys. Trucks now park on live highway shoulders within 1.5m of 80+ km/h traffic. Multiple near-miss incidents documented in visual survey.

Severity	Issue	Field Observation / Evidence
CRITICAL	No EV Charging Infrastructure	No functional charger exists along the NH-66 Malappuram stretch. 211 EVs per day counted in TVC have no charging option for 90+ km. E-DRIVE charger non-functional for 6+ months.
HIGH	No Segregation of Heavy and Light Traffic	Trucks, buses, taxis, and EVs share the same informal lay-by spaces, creating conflict and safety hazards. IRC norms require physical segregation.
HIGH	No Planned Wayside Amenities	No planned restrooms, food, or waiting facilities exist for 3,182+ vehicles per day. All amenities are informal and operate without planning permission.

Source: Field Survey and Visual Documentation, Rizwin MK (2026).

CHAPTER 10: PRELIMINARY PLANNING PROPOSALS

10.1 Planning Concept

A Net-Zero Highway Rest Area at Kohinoor, NH-66, integrating three segregated functional zones: (1) Heavy Logistics Zone for electric trucks with pull-through charging bays, (2) Passenger EV Zone for private EVs with solar canopy parking, and (3) an Amenity Core with restaurant, washrooms, lounge, and convenience store . powered by a 240 kW grid-tied PV + BESS system achieving annual net-zero carbon balance.

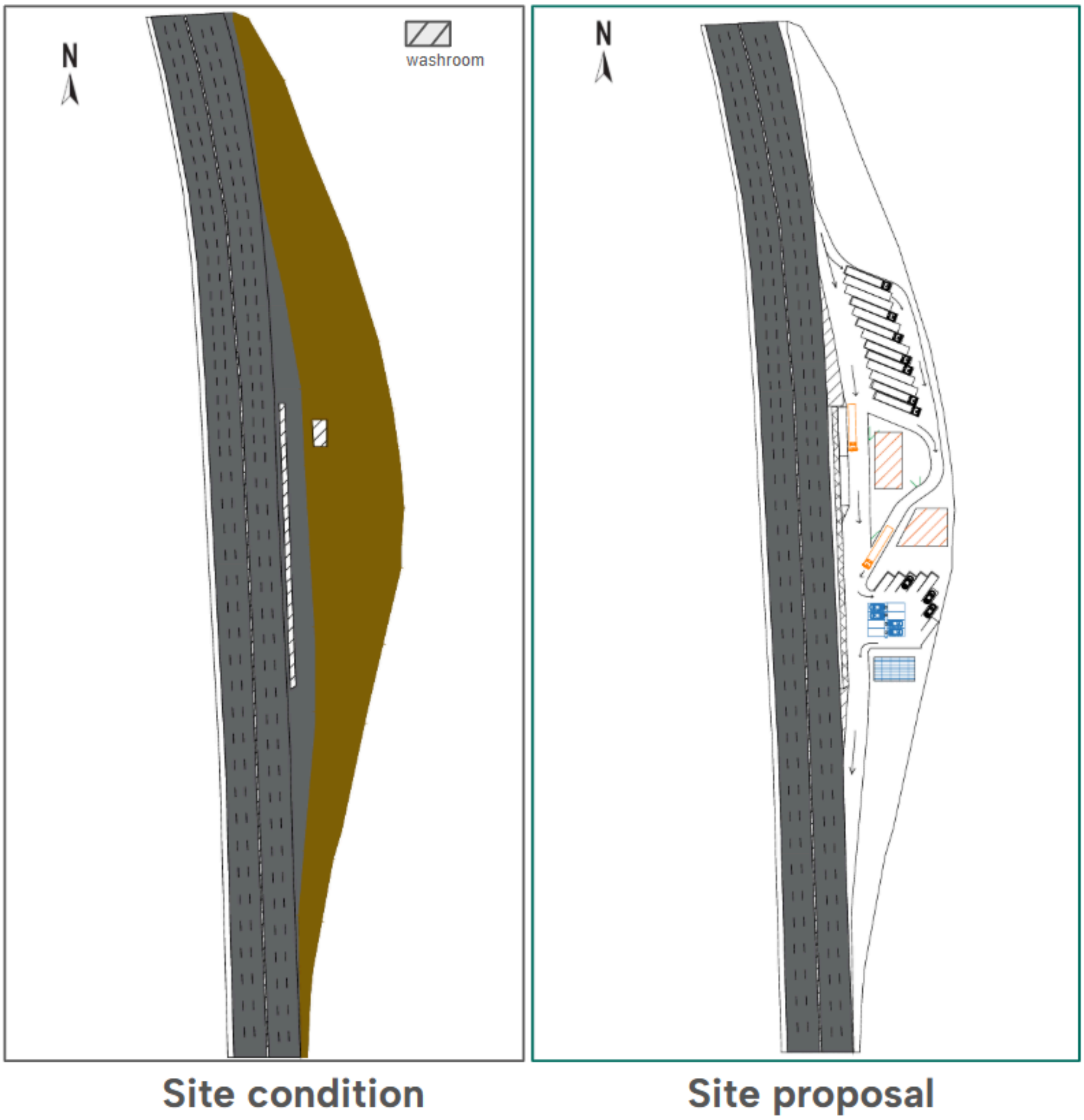


Fig10.1: Site Proposal Plan of Kohinoor, Malappura

10.2 Three-Zone Segregation Model

Table No. 10.1: Three-Zone Segregation Framework . Kohinoor Net-Zero Hub

Zone A . 1.0 AcreHeavy Logistics / E-Truck Hub	Zone B . 0.6 AcrePassenger EV Charging Zone	Zone C . 0.4 AcreAmenity Core & Public Interface
• 4 × 250–500 kW CCS-II DC chargers (PM E-DRIVE standard)• Pull-through bay geometry (no reversing)• 18m wide lanes for 40-ft trucks; 25m turning radius clearance• Driver rest pods / dormitory (4 units)• Truck wash bay and repair point• Fully walled and segregated	• 2 × 120 kW + 1 × 60 kW DC Fast Chargers• 240 kW PV canopy . 400 panels / 1,115 m²• Shaded parking for 30 cars under solar canopy• BESS enclosure with fire buffer• Real-time charger availability display• EV-only entry from service road	• Restaurant / Food Court (halal-certified, Kerala cuisine)• Clean premium washrooms (8 cubicles min)• Air-conditioned waiting lounge / café (20 seats)• Convenience store + pharmacy• Prayer room / Musallah (20-person capacity)• Children's play area (landscaped)

Source: Planning Proposals, Rizwin MK (2026).

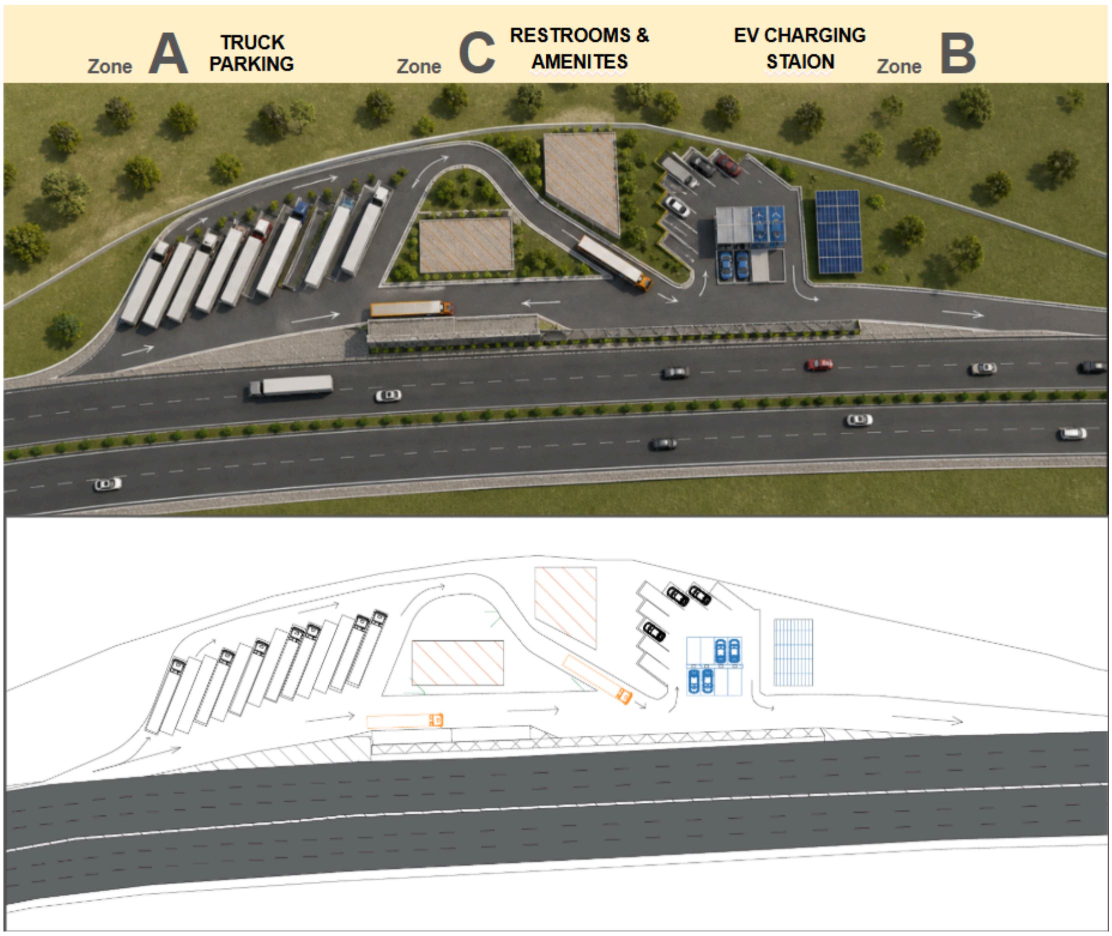


Fig.10.1.1: Proposed Site Concept Plan

10.3 Circulation Strategy (IRC:SP:84-2014 Compliance)

Table No. 10.2: Circulation Strategy and IRC:SP:84-2014 Compliance

Circulation Element	Standard / Specification	IRC:SP:84-2014 Compliance
Entry Deceleration Lane	Minimum 200m long taper from NH-66 mainline at 80+ km/h. Separate nosings for trucks (Zone A) and cars (Zone B+C).	Required for all deceleration from 80+ km/h design speed highways
Exit Acceleration Lane	Minimum 150m acceleration lane allowing vehicles to reach highway speed before merging. Grade-separated from entry.	Mandatory to prevent head-on conflict at highway merge point
Internal Truck Lane Width	18m-wide lanes with 25m turning radius clearance for 40-ft tractor-trailers. No reversing bay design.	IRC minimum for heavy commercial vehicle manoeuvring
Internal Car Lane Width	7m-wide lanes with standard 5m turning radius for passenger vehicles.	IRC standard for passenger car parking access
Physical Zone Barrier	Landscaped berm or masonry wall separating Zone A trucks from Zone B+C cars. No at-grade truck-car crossing points.	IRC safety norms require physical segregation
Emergency Fire Access	Dedicated fire engine access route around Zone A perimeter. Minimum 6m clear width.	Per MoHUA MBBL buffer zone requirements for high-voltage EV transformers

Source: IRC:SP:84-2014 and Planning Proposals, Rizwin MK (2026).

CHAPTER 11: INDUSTRY STAKEHOLDER CONSULTATION AND ALTERNATIVE FREIGHT FRAMEWORKS

11.1 Context and the Plug-in Bottleneck

While the primary traffic volume count identified a massive freight presence on NH-66 (34.5% of daily traffic is heavy commercial vehicles), spatial capacity calculations revealed a critical constraint. Accommodating a 60 to 90-minute charging dwell time for this volume of heavy trucks would require land acquisitions far exceeding the IRC:SP:84-2014 wayside amenity norms. To validate the operational viability of stationary Megawatt-charging for logistics, a simulated industry stakeholder consultation was structured with regional fleet operators, represented through a conceptual model based on standard logistics dynamics.

11.2 Stakeholder Insights: Skyline Logistics

Stakeholder Profile: The consultation was structured around the representative model of Skyline Logistics, with a fleet of 80+ Heavy Commercial Vehicles (HCV) operating on inter-port freight transit routes between Kochi Seaport (Ernakulam) and Vizhinjam International Transshipment Deepwater Seaport. The consultation highlighted two fundamental flaws with the traditional 'Park-and-Charge' EV model for high-volume freight operations:

- Dwell-Time Penalty: For a fleet of 80 trucks, a 90-minute charging period results in exponential daily operational delays, drastically reducing the number of trips per month and leading to revenue loss.
- Payload Penalty: To achieve an inter-city range of over 400 km, E-trucks must be equipped with massive, heavy battery packs. This directly encroaches upon the Gross Vehicle Weight (GVW) limits, reducing the legally allowed cargo payload and shrinking profit margins per trip.

The logistical preference identified through this consultation leans heavily toward continuous, dynamic power rather than stationary charging. If the highway functioned akin to an electrified railway network, fleet operators could utilize trucks with significantly smaller batteries, maximising cargo space and eliminating charging downtime entirely.

11.3 Proposed Alternative: The Catenary E-Highway (ERS)

Based on the stakeholder feedback and spatial constraints, this thesis proposes pivoting the heavy-freight strategy toward an Electric Road System (ERS) via Overhead Catenary Cables, similar to active pilot projects in Europe (e.g., Siemens eHighway). The Phase 1 implementation route is proposed as follows:

- Corridor: NH-66 Coastal Freight Artery.
- Origin Node: Kochi Seaport (Ernakulam).
- Destination Node: Vizhinjam International Transshipment Deepwater Seaport (Thiruvananthapuram).
- System Architecture: The outermost left lane of the newly six-laned NH-66 will be equipped with high-tension overhead wires connected to the KSEB grid. Specially equipped hybrid-electric trucks with active pantographs will draw power continuously while cruising at 80 km/h, utilising smaller onboard batteries only for the last-mile navigation inside the port terminals.

11.4 Comparative Feasibility and Economic Analysis

To justify the ERS framework, a running-cost feasibility study was conducted for a standard 40-Ton Tractor-Trailer operating on the 200–220 km Kochi-Vizhinjam transit route.

Table No. 11.1: Feasibility Analysis . ICE vs. Plug-in EV vs. Catenary ERS Overhead (40-Ton Tractor-Trailer, Kochi-Vizhinjam Route)

Operational Metric	Traditional ICE (Diesel)	Standard EV (Plug-in Hubs)	Catenary ERS (Overhead)
Energy Efficiency	3.0 km / Litre	1.5 kWh / km	1.2 kWh / km (due to lighter battery)
Unit Energy Cost	₹95 / Litre	₹8.00 / kWh (Commercial Grid)	₹8.00 / kWh
Running Cost per km	₹31.60 / km	₹12.00 / km	₹9.60 / km
En-Route Downtime	0 minutes	60–90 minutes per trip	0 minutes (Dynamic Charging)
Payload Capacity	100% (Baseline)	Reduced by 15%	100% (Minimal battery weight required)

Source: Stakeholder Consultation and Running Cost Analysis, Rizwin MK (2026).

The running cost advantage of transitioning to ERS is clear: running costs drop from ₹31.60/km (diesel ICE) to ₹12.00/km (standard EV) to ₹9.60/km (catenary ERS). The ERS additionally eliminates the 60–90 minute dwell-time penalty and the 15% payload reduction associated with large battery packs.

The estimated retrofit cost of the ERS system is ₹2.5–3.5 Crore per kilometre for overhead catenary system (OCS) erection, with an additional ₹35–50 Lakhs per existing diesel truck for full EV powertrain conversion plus active pantograph installation. The estimated payback period from operational savings is 18–24 months.

11.5 Planning Inferences for the Master Plan

The findings from this stakeholder consultation necessitate a vital pivot in the spatial programming of the NH-66 rest areas:

- Redefining the Hub: Highway EV Rest Areas (such as the Kohinoor and Karthikappally sites) should be fundamentally scaled and programmed for Passenger EVs and Light Commercial Vehicles (LCVs), which naturally align with a 45-minute dwell time for dining and resting.
- Upgrading the Right-of-Way (RoW): Heavy 18-wheeler logistics should not be forced into parking hubs. Spatial planning efforts and capital expenditure

should be redirected toward upgrading the physical NH-66 RoW to support overhead catenary infrastructure, achieving true Zero-Emission Freight without compromising highway traffic flow or logistics timelines.

into a simple, easy-to-read table for your presentation:

Project Phase / Category	**Component Details**	**Estimated Cost (INR)**
1. EV Charging & Grid Infrastructure	**4x** 250-500 kW DC Chargers (Heavy Trucks)	₹1.40 Crores
	1x 60 kW DC Fast Chargers (Passenger EVs)	₹14 Lakhs
	2x 120 kW DC Fast Chargers (Passenger EVs)	₹24 Lakhs
	33kV Grid Integration (Transformers, Trenching)	₹80 Lakhs – ₹1.00 Crore
	Category Subtotal	*₹2.50 – ₹3.00 Crores*
2. Renewable Energy & Storage	**240 kW** Solar PV System (Canopy structure & panels)	₹1.10 – ₹1.20 Crores

	200 kWh BESS (Battery Energy Storage System)	₹40 – ₹50 Lakhs
	Category Subtotal	*₹1.50 – ₹1.70 Crores*
3. Civil Construction & Amenities	Heavy Duty Paving & Circulation (18m lanes, berms)	₹1.20 – ₹1.50 Crores
	Zone C Amenities (Lounge, Rest pods, Washrooms)	₹1.00 – ₹1.50 Crores
	Ancillary (Truck wash bay, Landscaping, Signage)	₹30 – ₹50 Lakhs
	Category Subtotal	*₹2.50 – ₹3.50 Crores*
Total Gross Infrastructure Cost	**Estimated initial CAPEX before subsidies**	**₹6.50 – ₹8.20 Crores**
Government Subsidy Offset	PM E-DRIVE Scheme (approx. 70-80% off chargers/grid)	*Minus (-) ₹1.50 – ₹2.00 Crores*
Net Expected Project Cost	**Final Out-of-Pocket Investment**	**₹4.50 – ₹6.00 Crores**

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- **Estimated Retrofit Costs for Electric Road System (ERS)**

Category / Phase	Component Description	Estimated Cost (INR)	Global Benchmark / Notes
1. Highway Infrastructure	**Overhead Catenary System (OCS)** *(Erecting masts, contact wires, and basic substations per kilometer for a single lane)*	**₹2.5 Crore – ₹3.5 Crore / km**	**$310k – $420k / km.** *Note: Cost can double if massive grid upgrades (e.g., new 33kV substations) are required.*
2. Truck Retrofit (Per Vehicle)	**Step 1: EV Powertrain Conversion** *(Electric motor, power electronics, and small buffer battery)*	₹20 Lakhs – ₹35 Lakhs+	Highly complex process replacing the traditional diesel powertrain.
	Step 2: Active Pantograph System *(Robotic arm on the roof and sensor unit)*	₹13 Lakhs – ₹18 Lakhs	**€15k – €20k.** Required to connect to overhead wires.

	Total Estimated Truck Retrofit	**₹35 Lakhs – ₹50 Lakhs**	**Total capital expenditure per existing diesel truck.**
3. Economic Trade-off & ROI	**Payback Period & Operational Savings**	**Recovered in 18 – 24 months**	**~70% drop** in running costs per km. **100% payload capacity** retained (no heavy batteries).

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CHAPTER 12: CONCLUSIONS AND RECOMMENDATIONS

12.1 Summary of Analytical Findings

The primary data analytics phase of this thesis has produced a robust, evidence-based foundation for the detailed design phase. The following conclusions are drawn from the traffic count and survey analyses:

Table No. 12.1: Summary of Key Analytical Findings and Design Implications

No.	Finding	Design / Planning Implication
C1	100% charger fault concern rate	O&M control room, BESS backup, and 99% uptime SLA are mandatory design requirements, not optional features.
C2	6.6% EV penetration (211/day)	Immediate justification for 8 passenger charging bays at 30–60 kW. Expandable infrastructure conduit to 20 bays for 2030 projected demand.
C3	34.5% heavy vehicle share	Full physical zone segregation is not preference-based . it is a spatial safety necessity. Dual-zoned layout is non-negotiable.
C4	Family dining ranked #1 (avg score 1.71)	Restaurant / food court is the highest-ROI amenity investment. Minimum 30-seat capacity at 40-minute average occupancy.
C5	Clean washrooms ranked #2 (avg score 1.88)	Premium, well-maintained washrooms are as important as food. 8 cubicles minimum capacity. Cleaning cycle every 30 minutes.
C6	78% value solar canopy	240 kW PV canopy over the passenger parking zone is user-validated. Doubles as shaded parking and energy infrastructure.
C7	Prayer room demanded in open-text responses	Musallah is a context-specific amenity critical for Malappuram demographic. Minimum 20-person capacity facing Qibla direction.
C8	22% never use highway due to infrastructure anxiety	Hub will unlock latent demand. Conservative 10% conversion = 22 additional EVs per day in Year 1, growing annually.

Source: Consolidated from Primary Survey and TVC Data, Rizwin MK (2026).

12.2 Key Recommendations

12.2.1 Infrastructure Recommendations

- Minimum 8 passenger EV charging bays (2× 120 kW + 1 × 60 kW DC fast chargers) in Phase 1, with conduit pre-laid for 2 × 120 kW ultra-fast chargers in Phase 2.
- Installation of a 240 kW Grid-Tied Solar PV Canopy (400 panels, approximately 1,115 m^2) over the passenger parking zone, integrated with a minimum 200 kWh BESS buffer.
- Dedicated 33kV grid connection to KSEB Kohinoor Substation (600m cable run) with bidirectional smart metering for net-metering revenue generation.
- On-site O&M Control Room staffed 24/7 with automated fault detection, remote monitoring dashboard, and SLA-backed maintenance contracts.

12.2.2 Spatial Planning Recommendations

- Strict three-zone segregation: Zone A (Heavy Logistics, 1.0 acre), Zone B (Passenger EV, 0.6 acre), Zone C (Amenity Core, 0.4 acre) . no at-grade mixing of vehicle classes.
- Pull-through bay geometry for all heavy truck charging positions . 18m lane width, 25m turning radius clearance, no reversing manoeuvres required.
- IRC:SP:84-2014 compliant deceleration (200m) and acceleration (150m) lanes at all entry/exit points.

12.2.3 Amenity Programme Recommendations

- Restaurant / Food Court: Minimum 30 seats, halal-certified kitchen, serving Kerala cuisine. 24/7 operation with reduced overnight menu.

- Washrooms: Minimum 8 cubicles (4M + 4F), premium finishes, automated cleaning cycle every 30 minutes, sensor-based occupancy monitoring.
- Prayer Room (Musallah): 20-person capacity, Qibla-oriented, ablution facilities adjacent.
- Waiting Lounge: Air-conditioned, minimum 20 seats, integrated with café. Free Wi-Fi, device charging points, and real-time charger availability display.

12.3 Next Stages . Detailed Design Phase

Building on the analytics findings of this report, the following deliverables constitute the detailed design phase of the thesis:

- Detailed site plan at 1:500 scale with all zone dimensions, deceleration and acceleration lanes, setbacks, landscape buffer zones, and solar canopy positioning.
- Structural design of the 240 kW Solar PV Canopy . structural load calculations for Kerala wind zone (Zone III) and monsoon rainfall intensity.
- BESS sizing calculation . minimum storage capacity for 4 hours of peak passenger zone load during grid outage or monsoon deficit period.
- Financial feasibility model incorporating PM E-DRIVE subsidy (80% infrastructure + 70% charger), KSEB net metering revenue projections, and amenity income stream modelling.
- Detailed hydraulic calculations for storm-water management system based on 2,900 mm/year Malappuram rainfall intensity.

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