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Designing the Future of Electric Mobility: A Product Design Study of Charging Infrastructure Gaps on the Delhi–Jaipur Corridor

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I. INTRODUCTION

Electric mobility is emerging as a major direction for India's transportation future. Government policy documents and industry reports frequently promote electric vehicles as cleaner and more affordable alternatives to conventional fuel-based vehicles [1]. Among these options, e-scooters are expected to play a larger role than electric cars because they match the economic background of a large section of Indian households [2]. An e-scooter costs less, occupies less space and can be charged at home, making it more practical for everyday mobility needs across the country [3].

Figure 1. Electric scooter used for the Delhi–Jaipur study.

National EV charging infrastructure guidelines recommend that public charging stations be available every 3 kilometres in cities and every 25 kilometres along major highways [4]. If this guideline is implemented as planned, a long-distance journey such as Delhi to Jaipur should be achievable without any difficulty for an e-scooter rider.

However, policy statements do not always translate into real-world experience. A successful electric journey depends on the availability, visibility and reliability of charging stations along the route [5]. If chargers are missing, located too far apart or not functioning properly, even a well-designed e-scooter cannot ensure a confident travel experience. This difference between what is promised on paper and what is experienced on the road becomes a critical issue for the future of electric mobility in India.

For a product design student, this situation is not just a transportation problem. It is a real opportunity to analyse how existing products and systems fail and how design can improve them. A missing charging point can lead to ideas for portable power units. Limited charging information can inspire improved dashboard navigation systems. Inadequate comfort along long rides can lead to ergonomic seat design, weather protection elements and improved shock absorption systems tailored for Indian road conditions without increasing cost [6][7]. Each problem acts as a reference point for a new design direction.

This study treats the Delhi–Jaipur corridor as a practical testing environment where policies, infrastructure limitations and user needs intersect. By comparing the policy expectations with on-ground observations, this work aims to identify the design challenges faced by long-distance e-scooter users and translate them into product design opportunities, contributing to the evolving landscape of electric mobility in India.

II. POLICY BACKGROUND AND PROMISES

India's national electric mobility strategy aims to reduce dependence on fossil fuels and encourage the use of electric vehicles for both urban and intercity travel. The Government of India has issued consolidated guidelines for establishing public EV charging stations, which specify that chargers should be placed every 3 kilometres inside cities and every 25 kilometres along national highways [1][4]. These guidelines intend to create a predictable charging network that removes range anxiety and makes electric travel practical.

Delhi, being one of the leading regions promoting electric vehicles, has introduced its own EV policy to support the installation of chargers in residential areas, workspaces and public parking zones [2]. This regional support adds strength to national standards and positions Delhi as a significant electric mobility hub. National mobility programmes have also identified important road corridors that require charging facilities, particularly those connecting major cities. The Delhi–Jaipur highway is one such corridor used extensively by daily commuters, tourists and commercial vehicles. Due to its strategic importance, it is expected to demonstrate the impact of these policies in real-world conditions. These policy promises create strong expectations. According to the guidelines, a rider should be able to start from Delhi, travel towards Jaipur and find charging points at regular intervals without detours or uncertainty. If implemented successfully, such infrastructure would allow e-scooter users and electric vehicle owners to travel with confidence.

However, policies alone do not ensure readiness. The actual state of infrastructure depends on execution, monitoring and sustained business incentives for operators. Understanding how closely the Delhi–Jaipur corridor follows these guidelines becomes essential to identify whether the promised EV ecosystem is functioning as intended.

The next section explains how this corridor was studied to evaluate the difference between policy expectations and the on-ground reality of electric charging infrastructure.

III. METHODOLOGY

This study followed a structured approach to understand the actual charging infrastructure available along the Delhi–Jaipur corridor and to identify design-related challenges faced by long-distance e-scooter users. The methodology combined policy comparison, field observation and user-experience evaluation to highlight gaps between expected infrastructure and real conditions.

A. Route Selection

The Delhi–Jaipur National Highway (NH 48) was selected as the study route because it is frequently identified as an electric corridor and forms a major connection between the national capital and a major commercial city. The route contains multiple petrol bunks and potential charging points, making it suitable for examining long-distance EV travel expectations [1][4].

B. Mode of Travel

An e-scooter was chosen for observation because its cost, range and usability match the needs of average Indian riders more closely than electric cars [2]. The aim was to understand what a typical user might experience when attempting this journey using currently available charging infrastructure.

C. Data Collection Approach

The study collected data through:

- Physical observation of charging stations along the route
- Checking availability of chargers using digital maps and EV charging locator applications

- Photographs of charging station presence, absence or non-functionality
- Noting distances between stations and identifying stretches without any visible charging support
- Observing user movement patterns at petrol bunks and potential charging locations
- Recording environmental, comfort and accessibility conditions at each identified point

D. Evaluation Parameters

Observations were made based on the following criteria:

1) Presence of charging station – whether a charger was available at the expected 25 km interval [4]
2) Visibility – whether the station could be easily identified from the highway
3) Accessibility – ease of entry, parking and scooter docking arrangements
4) Functionality – whether the charger was working or out of service
5) User Comfort – availability of shelter, seating, shade or basic amenities
6) Wait Time Factors – whether riders had any activities or services available while charging
7) Information Availability – whether users had access to charging status, distance to next point or station operating hours

E. Policy-to-Ground Comparison

A direct comparison was made between:

1) Government guidelines specifying station placement [1]
2) Observations recorded along the corridor

This allowed identification of areas where policy expectations were met or missed. The comparison also helped detect whether riders could travel confidently based on existing infrastructure or whether uncertainty remained.

F. Product Design Lens

All findings were analysed from a product design perspective. Instead of only reporting gaps, the methodology focused on understanding how these gaps affect rider experience and exploring what design modifications, tools or systems could transform the journey positively [6]. This approach ensures that observations contribute directly to innovation possibilities, rather than ending as mere problem statements.

G. Ethics and Scope

No personal data, interviews or identifiable user information were collected. The objective was to study publicly visible infrastructure and observe rider behaviour patterns at a distance.

The scope was limited to e-scooter feasibility, not four-wheeler EVs, as scooters represent a more common mode of electric mobility in India [3].

IV. OBSERVATIONS AND FINDINGS

This section presents the real conditions observed along the Delhi–Jaipur corridor and compares them with the expectations set by government guidelines. The aim is to identify where the infrastructure meets policy goals and where significant gaps remain. These findings form the core evidence supporting the need for design intervention.

A. Charger Availability

According to national guidelines, a charging station should be available every 25 kilometres along national highways [4]. However, field observations showed that:

- Several stretches along the Delhi–Jaipur highway had no visible charging stations for long distances
- Some stations marked on digital maps were non-functional when reached
- In certain locations, chargers existed inside bunk premises without any signage, making them impossible for new riders to locate

Figure 2. Route map of the Delhi–Jaipur corridor (NH 48).

These gaps increase range anxiety and force riders to reduce speed or take detours to search for electricity, which contradicts policy expectations.

B. Visibility and Access Issues

Even where chargers existed, many were:

- Hidden behind fuel pumps
- Not visible from the main road
- Lacking direction boards or indicators

This makes the rider unsure whether the location actually supports electric vehicles. Highways require immediate visibility, not discovery through trial and error.

C. Functional Challenges

In some cases, chargers were:

- Locked due to staff availability issues
- Out of service without any notice
- Having unclear instructions or incompatible connectors

These problems create hesitation among riders and reduce trust in the system. A charger present on paper but inaccessible in reality does not support the objective of long-distance electric travel.

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Figure 3: An HP E-Charge outlet marked as operational on digital platform but non-functional at the site, illustrating the gap between digital information and actual usability of charging infrastructure.

Figure 4: Attempt to charge an electric scooter at a public charging point revealing connector incompatibility and unclear plug types. The rider struggled to identify the correct interface, showing that although chargers are present, they are not designed for e-scooters, creating functional barriers for long-distance travel.

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D. Absence of User Comfort Elements

Electric vehicle users spend more time waiting than petrol users because charging takes significantly longer than refuelling. Observations showed:

• No proper seating arrangements
• No shade for weather protection
• No basic convenience services like water, rest areas or mobile charging points

This contradicts user-experience standards recommended for sustainable mobility systems [5]. The waiting period feels stressful rather than supportive.

Figure 5: Tata EV charging station accessible via app-based activation but without seating, shelter or rider conveniences, highlighting the mismatch between digital infrastructure and physical user needs during charging wait time

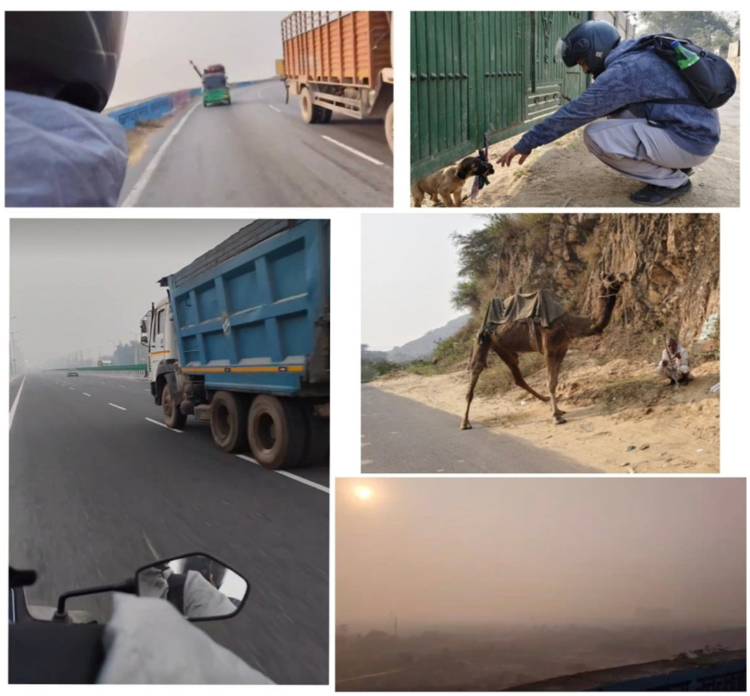

Figure 6: Visual evidence of the challenges faced during long-distance e-scooter travel on the Delhi–Jaipur highway, including harsh weather conditions, heavy vehicular traffic, and the need for frequent rest breaks due to rider discomfort. The absence of dedicated scooter-support infrastructure makes long journeys physically demanding and unsafe for users.

E. Lack of Information Systems

The most critical finding was information uncertainty. Riders did not have:

- Live updates about the next station
- Operational status of chargers
- Estimated wait times
- Charging duration or battery prediction tools

This lack of real-time data severely affects rider confidence. Policy promises infrastructure coverage, but infrastructure without information becomes incomplete and confusing.

F. Policy vs Reality Comparison

Element	Policy Expectation	Actual Observation
Distance between chargers	25 km intervals [4]	Large gaps beyond 40–60 km in several stretches
Visibility	Easy to locate	Many chargers hidden or without signboards
Functionality	Operational and ready	Locked or non-functional units found
User comfort	Safe, supportive environment	No seating, shade or rest options
Information	Clear guidance	Users unaware of charger status or wait time

V. DESIGN OPPORTUNITIES FOR EV CHARGING INFRASTRUCTURE

The observations along the Delhi–Jaipur corridor reveal clear mismatches between policy expectations and actual user experience. These mismatches open multiple opportunities for product design innovation. Each gap identified on the highway can be addressed through design interventions that improve usability, increase profitability for station owners and build trust among electric vehicle users. This section converts the problems observed into design opportunities for the future of EV charging in India.

A. Real-Time EV Charging Navigation System

One major challenge riders faced was uncertainty about the location, functionality and waiting time of charging stations. A real-time navigation system integrated into the scooter dashboard and connected to a mobile application can solve this. The system would:

- Show the nearest charging station based on current battery level
- Display distance remaining to the next station
- Indicate whether the station is open or closed
- Show the number of vehicles waiting
- Provide estimated waiting time before a charger becomes available
- Notify the rider when charging is complete

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EV Information		Current Travel		GPS	Overall		Other Signal Logos
Next E Stn	Sohnapur	Current Speed	42 km/hr	MAP DISPLAY	Odometer	30128 km	Headlight
Distance	10.2 km	Speed Mode	Eco		Ride Time	945 hr	Turn Signal
Stn Status	OPEN	Trip Distance	15 km				Horn
Vehicle in wait	2	Trip Avg Speed	35 km/hr		Avg Speed	42 km/hr	Outside Temp
Estm Wait Time	120 mins	Trip Duration	22 min		Max Speed	71 km/hr	Outside Humid
Battery %	72%	Trip Max Speed	65 km/hr		Alarms		Elevation
Battery Voltage	39 V	Energy Efficiency	\III-------/		Side Stand Beep		Tire Pressure
Battery Temp	23°C	Connectivity			Over Speed Beep		Time Display
Remaining Dist	63 km	Bluetooth	Vivo V25		Overload Beep		
Charging Alarm	NIL	Wifi	Symbol		Overheat Beep		
Braking Level	Moderate	Firmware update	Updated	Weather alert	Error Code	NIL	

Figure7: Conceptual Dashboard Display for E Scooter

This creates a predictable and confident journey without guesswork, anxiety or unnecessary stops. It also transforms the EV experience from uncertain to guided and intelligent.

B. E-Scooter Design Improvements for Long-Distance Comfort

The present generation of e-scooters is primarily designed for short urban trips. When used for long-distance travel, riders face physical discomfort and fatigue due to the limitations of current design features. Product design modifications can address these issues and make e-scooters suitable for intercity journeys. The improvements include:

• Ergonomic seating that supports the lower back and maintains correct posture during extended riding hours, reducing the risk of back pain [6]

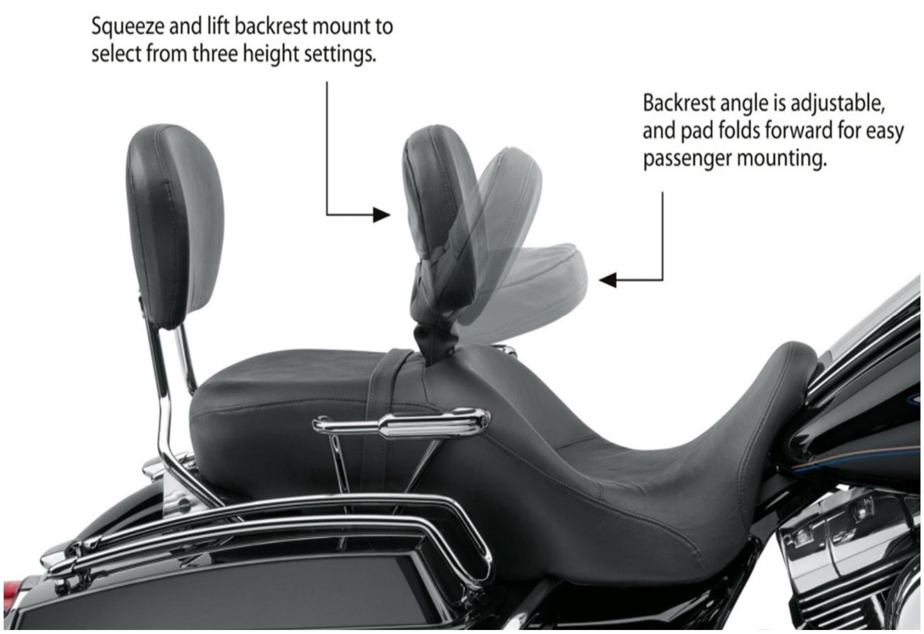

Figure 8: Comfortable Flexible and Foldable back rest for rider and pillion

• Enhanced suspension systems designed specifically for uneven Indian highways, decreasing vibration and shock transmission to the rider's spine, wrists and shoulders [7]

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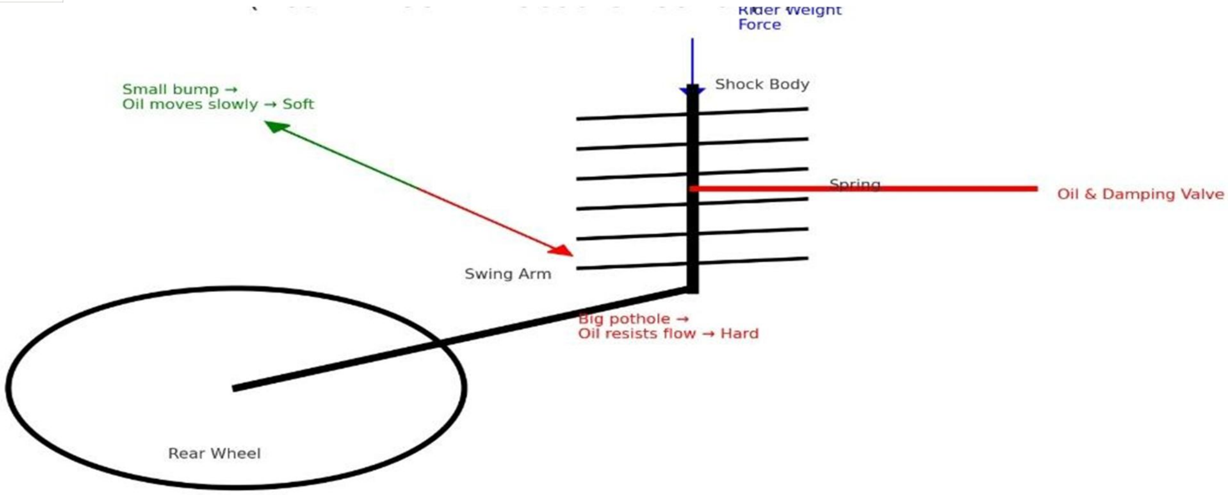

Figure 9: Linked mono-shock suspension with progressive hydraulic damping designed for electric scooters. Small road undulations allow the hydraulic oil to flow smoothly through the damping valve, creating a softer suspension response for rider comfort. During sudden impacts or deep potholes, oil movement is restricted, increasing resistance and making the suspension stiffer. This dual behaviour enables the same suspension system to remain comfortable on normal roads and stable on rough surfaces, improving rider safety and reducing fatigue during long-distance travel.

• Adjustable handlebar height to accommodate riders of different body proportions, creating a neutral arm and shoulder position
• Wind and weather protection shields attached to the front of the scooter to reduce fatigue caused by dust, wind pressure, heat and rain exposure during long travel

Figure 10: Reference example of a detachable, weatherproof riding shield used in international two-wheeler design. Such protective enclosures reduce wind, rain, and particulate exposure during long-distance travel, indicating the feasibility of integrating lightweight shield solutions for Indian e-scooter systems.

• Anti-slip and extended footboards for better leg support, preventing muscle strain over time

These design changes do not require major alterations to the core vehicle structure and can be implemented without significantly increasing manufacturing costs. Such improvements can transform e-scooters from city-focused mobility devices into comfortable long-distance travel options suitable for Indian highways.

C. Entertainment and Revenue Screens

Charging stations can include digital screens that:

- Play music, travel videos or infotainment content
- Display advertisements, earning revenue for station owners
- Show safety lessons and EV usage tips during idle time

This makes waiting enjoyable for users and profitable for owners, creating a business incentive to install more chargers along highways.

D. Intelligent Scooter Docking Systems

Current chargers are often placed without considering vehicle type or road vibration. A specially designed docking area for e-scooters can:

- Keep the scooter stable on uneven surfaces
- Reduce wire strain and connector damage
- Align scooter positioning for easy charging access
- Improve safety and prevent accidental fall or disconnection

Such docks enhance reliability and reduce maintenance issues.

E. Modular Retail and Service Integration

Waiting time can be monetized through micro-services that require minimal staff:

- Small snack counters
- Air pressure checking units
- Portable battery accessories

These services create a micro-economy around the charging station, improving station viability without increasing infrastructure cost.

F. Digital Information Kiosks

Kiosks placed near the charging point can:

- Display charging progress
- Provide route guidance
- Offer maps and emergency numbers
- Educate first-time EV riders

This makes the environment informative, not confusing.

G. Battery Condition and Ride-Care Alerts

By integrating sensors with the app and scooter display, riders can receive:

- Battery health status
- Optimal speed suggestions
- Maintenance reminders
- Alerts for abnormal power use

This improves range confidence and enhances battery life.

Summary of Design Opportunities

Gap Identified	Design Opportunity
No clear station location	Real-time navigation and app integration
Long waiting time	Rest and entertainment zones
Unclear operational status	Live charger status on dashboard
No business incentive	Advertisement and retail add-ons
Rider discomfort during long trips	Ergonomic seat, better suspension and weather shields

These solutions demonstrate how design does not only solve problems; it creates value for users and motivates operators to expand infrastructure. By transforming charging stations into experience centres, India can accelerate EV adoption beyond policy mandates.

VI. DISCUSSION

The findings from the Delhi–Jaipur corridor show a clear gap between the government's electric mobility intentions and the user experience on the ground. While policies aim to make long-distance EV travel simple and predictable [1][4], the absence of visible, reliable and user-friendly charging stations prevents riders from trusting the system. This reveals that infrastructure alone cannot create confidence; design intervention is necessary to bridge the gap between policy and practice.

Electric two-wheelers were originally created for short, city-based travel [2]. When riders attempt longer journeys, their physical needs, comfort level and information requirements change. The study shows that the lack of real-time information, uncertainty about station functionality and uncomfortable long ride experience are not simply operational issues; they are design issues. If riders are unsure where to go, how long to wait or whether their scooter can handle the journey, they hesitate to adopt electric mobility for intercity use.

The design opportunities proposed in Section 5 directly address these gaps. A real-time navigation and charging visibility system turns an unpredictable trip into a guided journey. Rest and entertainment zones transform idle waiting time into a positive, even profitable moment for both users and charging station operators. Advertisement-driven revenue converts charging stations from a cost centre into a business model, which encourages more bunk owners to adopt EV chargers. Ergonomic seat redesign, improved suspension and weather shields improve rider comfort and extend the usability of e-scooters beyond city limits [6][7].

This demonstrates an important insight: the future of electric mobility is not dependent solely on technology or policy, but on how well these elements are supported by product design. Design integrates the user, the vehicle and the charging environment into a single experience. Without design, infrastructure remains incomplete and policies remain unfulfilled promises.

Moreover, the ideas presented here align with India's economic and social context. The Indian market favours affordable mobility solutions, which means electric scooters must evolve to serve intercity travel without costing as much as cars. By improving comfort, usability and information access, designers can make e-scooters a reliable choice for long-distance journeys at a fraction of the cost.

The discussion therefore highlights a major shift in perspective: electric mobility is no longer only about charging batteries; it is about designing trust. Trust is built when:

1) Information is available
2) Comfort is assured
3) Waiting time has value
4) Travel feels safe and predictable

If these design improvements are implemented, the Delhi–Jaipur corridor can become a replicable model for other national highways, helping India transition into a truly electric mobility ecosystem that is practical, profitable and user-friendly.

VII. CONCLUSION

This study examined the Delhi–Jaipur corridor to understand whether current electric mobility infrastructure supports long-distance travel on e-scooters, which are more relevant to Indian users due to their affordability and practicality. The findings show that although government policies provide clear guidelines for charging station placement, the on-ground reality does not fully reflect these expectations. Missing chargers, lack of visibility, non-functional units and absence of basic user information create uncertainty and discourage riders from confidently choosing electric travel.

The gap identified is not merely infrastructural. It is a design gap. Long-distance electric mobility depends on how the vehicle, charging stations and user experience are connected through thoughtful design. The design opportunities identified in this paper—such as real-time navigation to charging stations, information-linked scooter dashboards, engagement zones at charging points and revenue-based add-ons—demonstrate that charging stations can evolve from simple power outlets into meaningful interaction spaces.

Equally significant is the requirement to rethink the e-scooter itself. The current scooter design addresses short urban commutes but struggles with comfort and usability on highways. Redesigning the scooter with ergonomic seating, suspension tuned for uneven Indian roads and weather protection elements enables riders to consider longer intercity journeys without physical discomfort or risk. The combination of redesigned scooters and supportive charging environments creates a complete ecosystem rather than isolated solutions.

This research shows that electric mobility cannot succeed through policies or chargers alone. It succeeds when every point in the journey—before, during and after charging—is supported by design. When riders have information, comfort and confidence, adoption accelerates. If the ideas presented here are implemented, the Delhi–Jaipur route can act as a model corridor demonstrating how policy and product design can work together to shape a practical and user-friendly electric mobility future.

Further research can explore user behaviour at redesigned stations, evaluate cost models for modular service units and develop prototypes for scooter-based navigation interfaces. With continued effort in design, India can not only meet its electric mobility goals but redefine how mobility systems are experienced by everyday riders.

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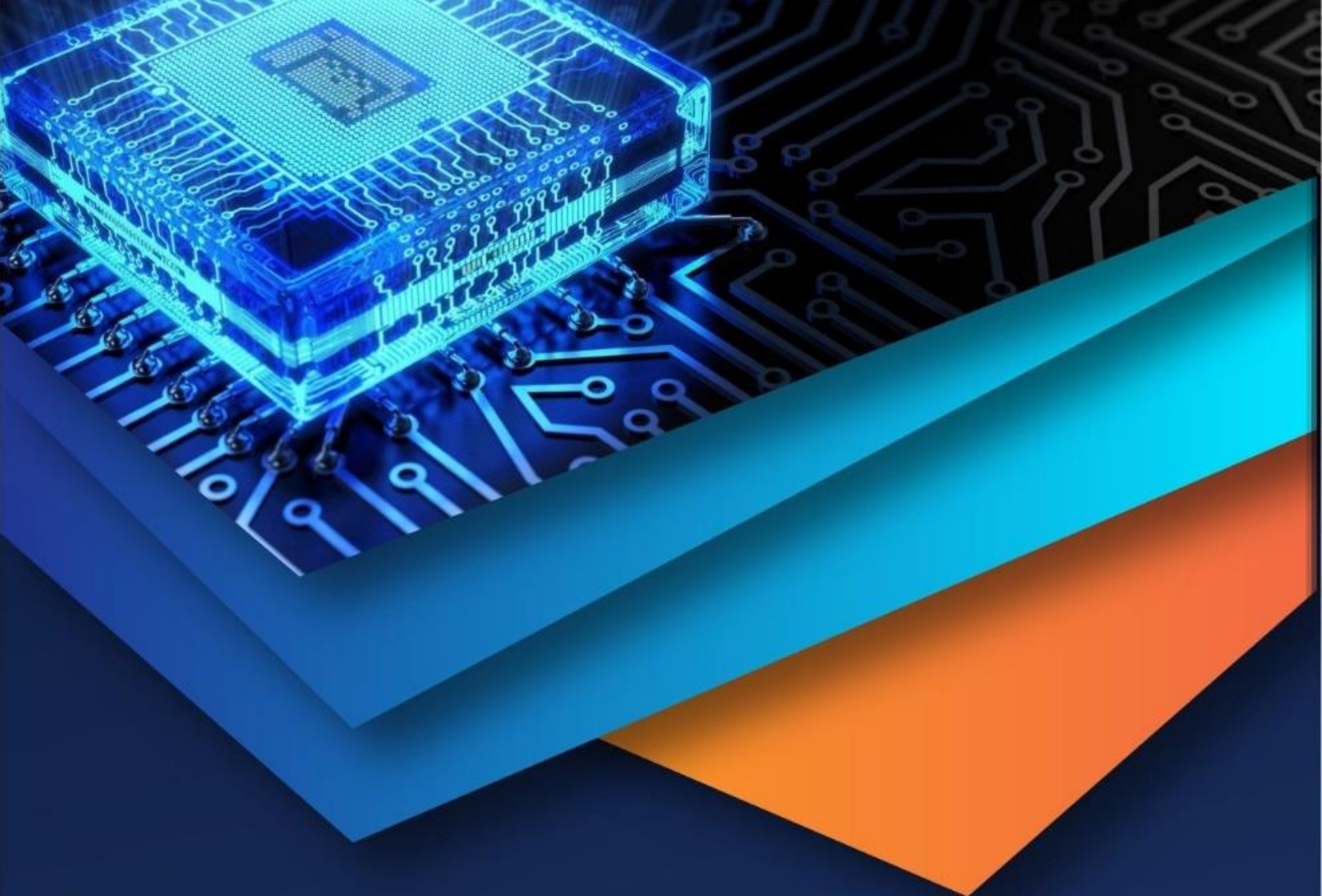

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