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Research Article

Segmental Electrification Dynamics in Uttar Pradesh: A Decadal Analysis of Hybrid and Electric Vehicle Adoption (2015–2025)

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Abstract

This study examines the adoption of hybrid and electric vehicles in Uttar Pradesh from 2015–16 to 2024–25, using official registration data. We used secondary data from the VAHAN portal and applied methods like compound annual growth rate (CAGR), market share analysis, structural transition ratios, and cumulative growth indices. Electric vehicles have grown quickly, especially among three-wheelers and two-wheelers, while hybrid vehicles are mostly in the light motor vehicle category. The structural transition ratio shows a clear shift toward electric vehicles after 2021. In Uttar Pradesh, electrification is mainly for commercial use, with three-wheelers leading and two-wheelers growing strongly in recent years.

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KEYWORDS: Electric vehicles; Hybrid vehicles; Uttar Pradesh; Electrification; CAGR; Market share; Structural transition

1. INTRODUCTION

The transportation sector is a major source of greenhouse gas emissions and urban air pollution worldwide. As more vehicles appear in developing countries, worries about air quality, fossil fuel use, and climate change have increased. Hybrid vehicles (HVs) and electric vehicles (EVs) can help address these issues. Hybrids use both internal combustion engines and electric motors, which improves fuel efficiency and lowers emissions. Electric vehicles, especially battery electric vehicles (BEVs), do not produce tailpipe emissions and can further reduce overall emissions if they use cleaner electricity.

The move to electric vehicles has accelerated worldwide over the last 10 years. According to the International Energy Agency (IEA, 2023) [16], global EV sales exceeded 10 million units in 2022, accounting for almost 14% of all vehicle sales. Countries like China, Norway, and the United States have led this change by offering financial incentives, building more infrastructure, and making supportive rules. While hybrids played a key role early on in some developed countries, recent trends show a clear shift toward fully electric vehicles. India, which has one of the largest car markets and high urban air pollution, has made electric mobility a priority. The Indian government launched the National Electric Mobility Mission Plan (NEMMP) in 2013 and the FAME scheme in 2015. FAME-I supported early adoption, while FAME-II (from 2019) focused on the large-scale electrification of public transport and high-use segments such as two- and three-wheelers. Other steps include lower GST rates on EVs and tax breaks for EV loans.

State-level policies have also supported the adoption of electric vehicles. Uttar Pradesh, India's most populous state and a major vehicle market, introduced the Electric Vehicle Manufacturing and Mobility Policy to encourage both EV production and use. With crowded cities, expanding suburbs, and a large informal transport sector, Uttar Pradesh is an important location to study how electrification occurs across different vehicle types.Looks at five types of vehicles using official VAHAN registration data: Light Goods Vehicles (LGV), Light Motor Vehicles (LMV), Light Passenger Vehicles (LPV), Three-Wheelers (T), and Two-Wheelers (NT). These categories include both commercial transport and private commuting. By studying electrification within each group, we can better understand how the transition is unfolding.

Earlier research has examined consumer behaviour or policy effects, but few studies have explored long-term trends by vehicle category using state-level data. This study addresses that gap by analysing ten years of hybrid and electric vehicle registrations in Uttar Pradesh. By examining growth, market share, transition ratios, and cumulative growth, we show which segments are leading electrification and how the shift from hybrids to pure-electric vehicles is unfolding.

2. REVIEW Of LITERATURE

Research on electric mobility falls into four main areas: environmental impact assessment, behavioural adoption studies, policy evaluation, and diffusion modelling.

Environmental studies show that EVs can help lower carbon emissions and urban air pollution (IEA, 2023; World Bank, 2022) [16, 17]. Lifecycle analyses suggest strong potential for emissions reductions as electricity generation shifts toward renewables. However, these studies typically examine national or global data and do not break down results by vehicle segment.

Behavioural research examines what drives consumers to adopt EVs. Rezvani *et al*. (2015) [4] found that perceived usefulness, environmental concern, and financial incentives are key factors in EV adoption. Kumar and Alok (2020) [2] used structural equation modelling in India and highlighted price sensitivity and the availability of charging infrastructure. While these studies offer detailed insights, they do not examine long-term trends in actual registration data.

Policy evaluation studies examine financial incentives such as FAME. NITI Aayog (2021) [3] points out that the two- and three-wheeler segments respond well to subsidies. Sierzchula *et al*. (2014) [6] show that financial incentives are closely linked to EV market share in European countries. However, these studies often do not provide long-term state-level evidence in developing countries. examine technological adoption curves. International research indicates that EV adoption is concentrated in early adopters, particularly in high-utilisation fleets or premium segments (Rogers, 2003; Sierzchula *et al*., 2014) [5, 6]. In developing countries, three-wheelers and shared mobility segments often act as early adopters due to operational cost savings.

Despite more research in this area, three main gaps remain:

1. Limited state-level decadal analysis of EV registration trends.
2. Insufficient comparison between the hybrid and pure EV structural transition.
3. Lack of empirical identification of segmental drivers of electrification in large Indian states.

This study aims to fill these gaps by using long-term administrative data.

3. RESEARCH OBJECTIVES AND HYPOTHESES

3.1 OBJECTIVES

1. To analyse total growth trends of hybrid and electric vehicles in Uttar Pradesh (2015–2025).
2. To examine category-wise adoption patterns across five vehicle segments.
3. To identify which segment drives electrification.
4. To calculate hybrid-to-electric structural transition ratios.
5. To assess market share shifts and cumulative growth indices.

3.2 HYPOTHESES

H1: Electric vehicles exhibit significantly higher growth rates than hybrid vehicles over the study period.

H2: Electrification in Uttar Pradesh is primarily driven by the two- and three-wheeler segments.

H3: The share of pure EVs in total electrified vehicles has increased significantly over time.

4. RESEARCH METHODOLOGY

This study uses a quantitative, long-term research design with secondary data from the VAHAN portal, managed by the Ministry of Road Transport and Highways, Government of India. The data covers 2015–16 to 2024–25 and includes yearly registration numbers for hybrid and electric vehicles in five categories: LGV, LMV, LPV, Three-Wheelers (T), and Two-Wheelers (NT).heelers (NT).

The study period starts in 2015–16, which matches the early phase of FAME-I, and runs through 2024–25, covering the rapid growth phase of FAME-II and state-level EV policies.

The data was cleaned, converted to numeric values, and organised by category, type, and year.

The following analytical tools were employed:

1. Total Growth Analysis – Annual totals for EV and hybrid registrations were computed.
2. Category × Type Analysis – Separate time-series trends were analysed for each category.
3. Compound Annual Growth Rate (CAGR)

CAGR = [(Vf / Vi) ^(1/n)] − 1

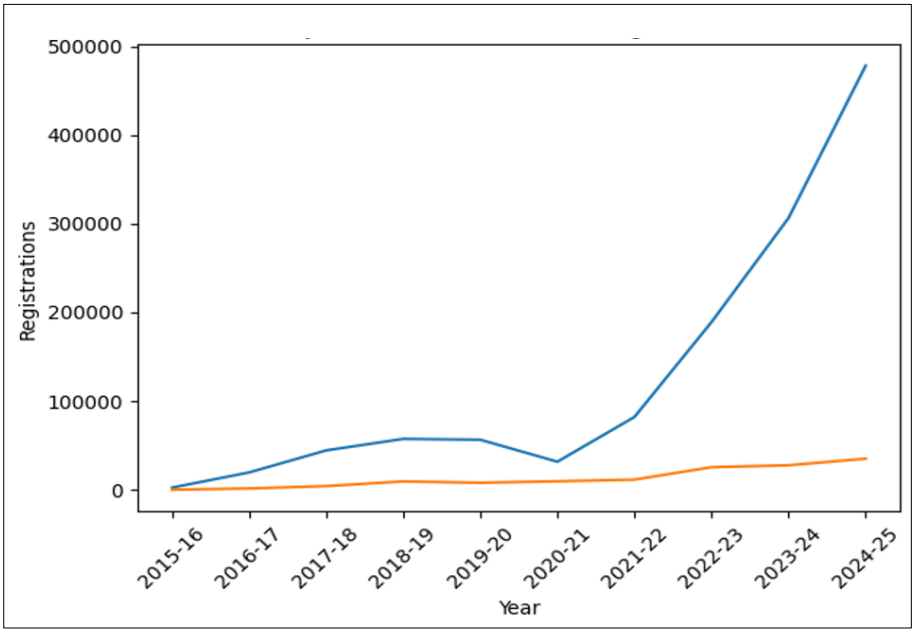
where Vf = final year value, Vi = base year value, n = number of intervals (9).

1. **Market Share Analysis**
   Market Share = Category EV / Total EY (for 2015–16 and 2024–25).
2. **Structural Transition Ratio**
   Transition Ratio = EV / (EV + Hybrid)
3. **Cumulative Growth.**
   Growth Index = (Current Year EV / Base Year EV) × 100
   Graphs and tables were produced to facilitate visual interpretation of the results**.**

5. RESULTS AND ANALYSIS

This section analyses hybrid and electric vehicle registrations in Uttar Pradesh from 2015–16 to 2024–25 using official VAHAN data. The results are based on total numbers, category trends, compound annual growth rates (CAGRs), market shares, and structural transition ratios.

5.1 Aggregate Growth Dynamics: Electric vs Hybrid Vehicles



(Figure: Total Hybrid vs Electric Vehicle Trend)

Fig 1: Total Hybrid vs Electric Vehicle Registrations (UP)

The time-series graph comparing total electric and hybrid vehicle registrations shows two different growth patterns. Electric vehicle registrations rise quickly, especially after 2021–22. In contrast, hybrid vehicle registrations grow slowly and follow a steady, straight trend during the study period.

In 2015–16, electric vehicle registrations were very low, but by 2024–25, total EV registrations were close to half a million units. From 2015–16 to 2019–20, growth was steady but moderate, showing early adoption. There was a clear drop in 2020–21, likely because of the pandemic. After 2021–22, EV registrations rose sharply, moving from early adoption to rapid growth.

Hybrid vehicles, in contrast, do not show the same rapid growth. Although hybrid registrations have increased over time, especially in the Light Motor Vehicle segment, their overall numbers are much lower than those of electric vehicles. The widening gap between EV and hybrid totals since 2021 shows that electric vehicles have outpaced hybrids in growth and points to a shift toward pure electrification rather than a transition mainly supported by hybrids.

The EV growth graphs for each category (LGV, LMV, LPV, Three-Wheeler, and Two-Wheeler) show distinct adoption patterns across segments.

The Three-Wheeler (T) segment is the main driver of electrification in terms of total numbers. Registrations grew from 2,326 units in 2015–16 to 366,806 units in 2024–25. Growth was steady until 2019–20, dipped in 2020–21, and then surged after 2021–22. This sharp increase shows strong adoption in commercial passenger transport and last-mile delivery.

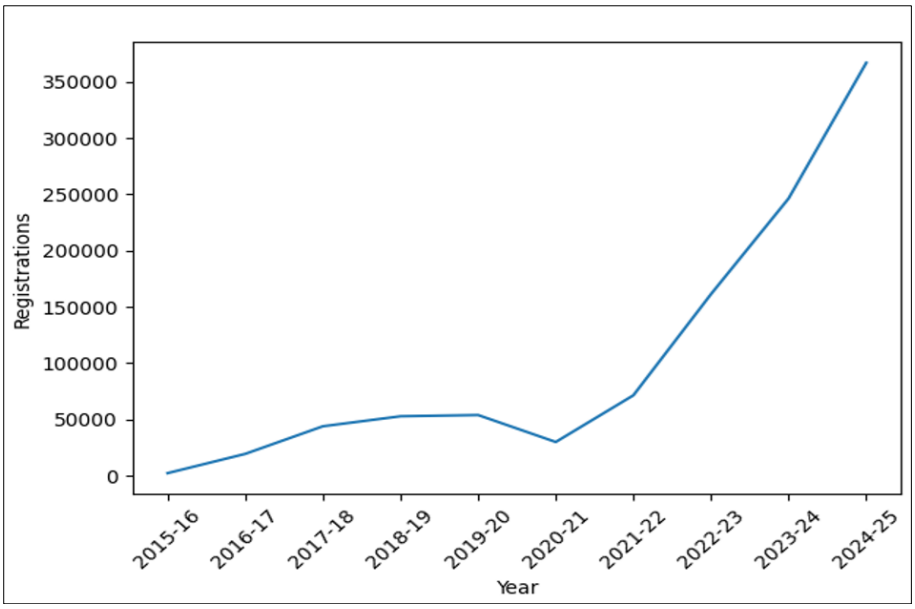


Fig 2: EV Growth - Three Wheeler (T)

Two-Wheeler (NT) electrification shows a similar but slightly later growth pattern. Registrations went from 97 units in 2015–16 to 102,861 units in 2024–25. Growth was slow at first, but after 2021, it became much faster and steadier. The sharp rise after 2022 suggests more people are buying these vehicles, helped by lower prices and subsidies.

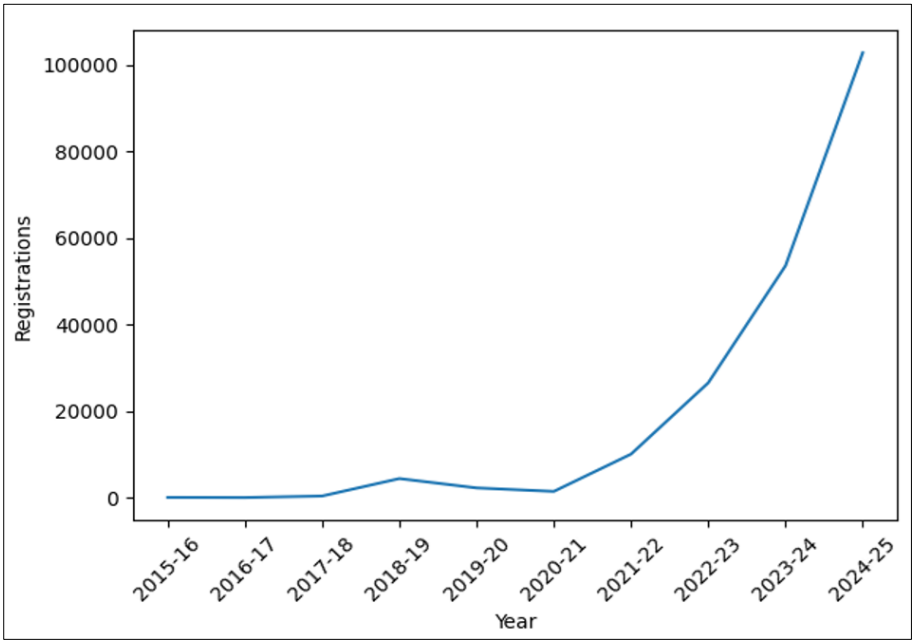


Fig 3: EV Growth - Two Wheeler (NT)

Light Motor Vehicle (LMV) EVs have the highest CAGR (170.9%), growing from 1 unit in 2015–16 to 7,861 units in 2024–25. However, their total numbers are still much lower than those of Three-Wheelers and Two-Wheelers. This shows that private passenger EVs are growing fast, but are not yet the main segment.

Light Goods Vehicle (LGV) electrification increased from 3 to 182 units during the study period, showing moderate but small-scale adoption.

These trends show that electrification in Uttar Pradesh is mainly led by commercial vehicles. Three-Wheelers were the first to adopt, and now Two-Wheelers are growing the fastest.

5.3 Compound Annual Growth Rate (CAGR) Analysis

The table called "CAGR Comparison – Electric Vehicles (2015–2024)" compares long-term growth rates across different segments.

Table 1: Compound Annual Growth Rate (CAGR) Analysis

Category	2015 EV	2024 EV	CAGR
Light Goods Vehicle	3	182	57.8%
Light Motor Vehicle	1	7,861	170.9%
Three-Wheeler	2,326	366,806	75.5%
Two-Wheeler	97	102,861	116.8%

The calculated CAGR values show that Light Motor Vehicles have the highest CAGR at 170.9%, mainly because they started from a very small base. Two-Wheelers have a high CAGR of 116.8%, showing rapid growth in recent years. Three-Wheelers have a strong CAGR of 75.5%, and, given their large numbers, they are the most important segment for electrification.

Even though Light Motor Vehicles have the highest percentage growth, the biggest change in total numbers comes from Three-Wheelers, which lead the segment.

5.4 Market Share Transformation

The 2024–25 market share bar graph shows that Three-Wheelers make up about 75–77% of all EV registrations. Two-Wheelers account for about 20–22%, while Light Motor Vehicles and other categories together make up less than 5%.

In 2015–16, Three-Wheelers accounted for almost 95% of all EV registrations, indicating a high degree of concentration. By 2024–25, the market is more diverse, with Two-Wheelers accounting for a larger share.

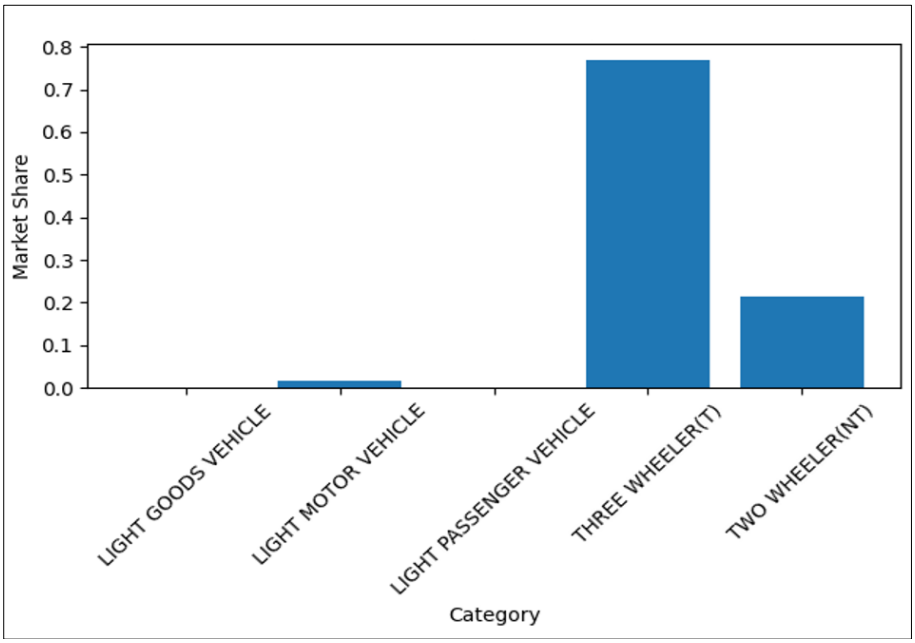


Fig 4: EV Market Share by Category (2024-25)

This change shows that EVs are slowly gaining traction in personal transport, even though commercial vehicles still lead the way.

5.5 Hybrid Vehicle Growth Patterns

Hybrid growth graphs show a different pattern. Most hybrid registrations are in the Light Motor Vehicle segment, which has grown steadily over time. There is very little hybrid adoption in the Three-Wheeler and Two-Wheeler segments.

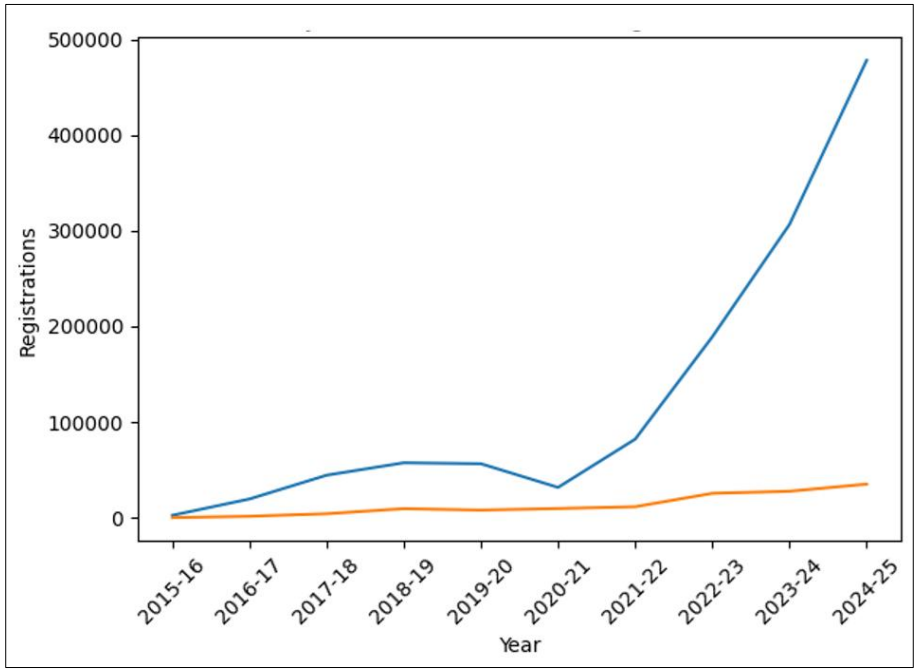


Fig 5: Total Hybrid vs Electric Vehicle Registrations (UP)

Hybrid adoption in Light Passenger Vehicles is unstable and remains small, without steady growth. Hybrid technology did not spread to commercial vehicle segments in Uttar Pradesh. Instead, pure electric vehicles seem to have skipped the hybrid stage in high-use segments.

5.6 Structural Transformation Ratio

The structural transition graph (EV / (EV + Hybrid)) shows that electric vehicles are becoming more dominant among all electrified vehicles. In the early years, hybrids made up a large share of registrations, but after 2021, the share of EVs rose quickly and came close to dominating.

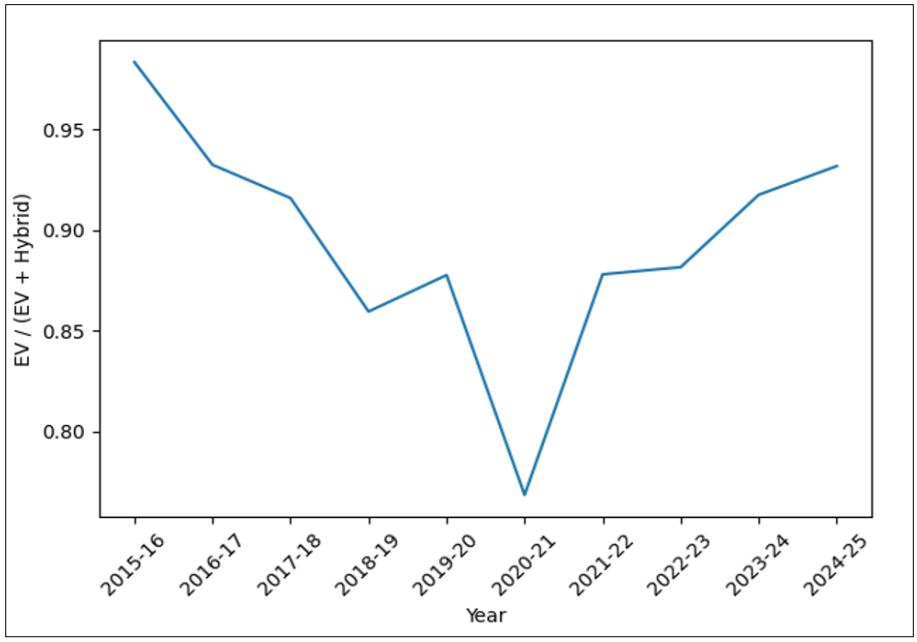


Fig 6: Structural Transformation Ratio

This confirms that the state has shifted from a hybrid-assisted electrification model to one focused on electric vehicles.

5.7 Cumulative Growth Index

The index rises slowly until 2019–20, drops in 2020–21, and then climbs sharply after 2022. This strong upward trend in recent years marks the start of rapid technology adoption. The pattern matches innovation diffusion theory and suggests that Uttar Pradesh has moved past early adoption and is now in a phase of rapid growth.

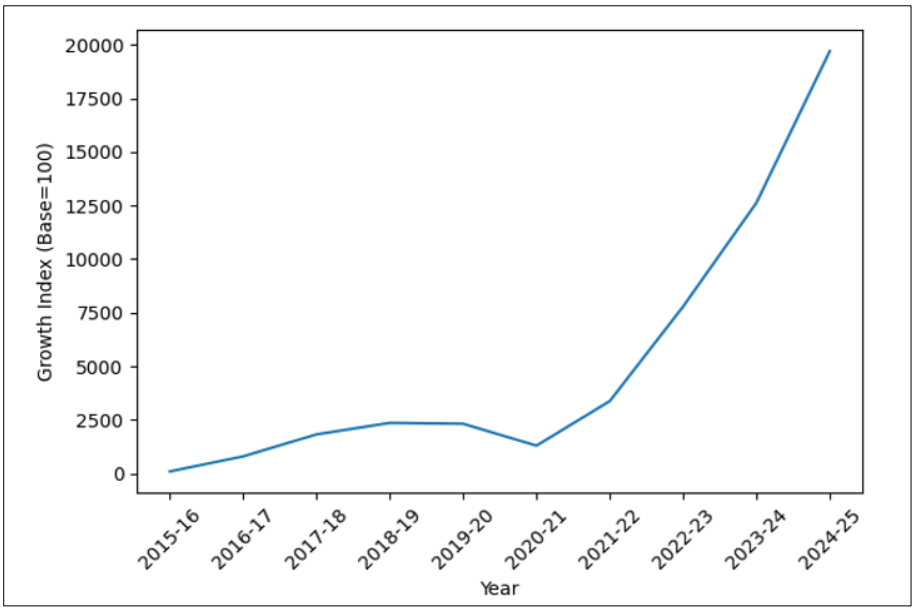


Fig 7: Cumulative EV Growth Index (Base 2015-16 = 100)

This S-shaped pattern aligns with innovation diffusion theory, suggesting that Uttar Pradesh has moved beyond early adoption into rapid expansion.

6. DISCUSSION AND CONCLUSION

Electrification in Uttar Pradesh is mainly driven by commercial use. Three-wheelers were the first to adopt electric technology because they are widely used and help reduce operating costs. Two-wheelers are now growing quickly, supported by lower prices and more charging options. Hybrid vehicles first appeared in the Light Motor Vehicle segment but did not spread to other types. This means hybrid technology was only a temporary step, not a main alternative to electric vehicles. The structural transition ratio shows that since 2021, pure electric vehicles have become dominant in Uttar Pradesh. Stronger subsidies, lower battery costs, and better state policies drive this shift.

In summary, electrification in Uttar Pradesh follows a bottom-up model, with commercial vehicles leading and private cars following. The state is now seeing rapid growth in electric-vehicle adoption, which aligns with the theory of innovation diffusion. However, this study does not examine district-level differences, consumer behaviour, or cause-and-effect relationships. Limited data on fuel prices, income, or infrastructure makes it hard to draw firm conclusions. Future research could use panel regression models, district-level analysis, and multi-state comparisons to understand better policy effects and how electrification spreads.

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