

# Empowering Green Mobility: The Role Of Semiconductors On The Diffusion Of Electric Vehicles In India

Babu A\*\*, Biplab Sarkar<sup>b</sup>

<sup>a</sup>Research Scholar, Department of Management Studies, PES University, Bengaluru, India

<sup>b</sup>Professor, Department of Management Studies, PES University, Bengaluru, India

---

## Abstract

This research examines the crucial role of semiconductor availability on accelerating diffusion of electric vehicle (EV) in Indian market. It examines how the semiconductor availability influences other manufacturing side EV diffusion barriers, including battery technology, motor technology, charging infrastructure, charging time, and battery life. Through the application of DEMATEL methodology, semiconductors availability is identified as a primary barrier affecting others, while expert feedback using the Delphi method confirms that limited semiconductor availability is a most influential barrier in EV manufacturing. The study advocates for developing a robust domestic semiconductor ecosystem that incorporates improved infrastructure, financial incentives, and strengthened collaboration between public and private sectors. Furthermore, it stresses the importance of international partnerships to enable technology transfer and fast-track skill development, thereby attracting foreign direct investments. These efforts are essential to mitigate supply chain disruptions and enhance semiconductor availability.

Considering India's ambitious goals for EV expansion, addressing the semiconductor shortage is imperative to overcome structural challenges such as high vehicle costs, insufficient charging facilities, and heavy reliance on imports. By presenting practical policy recommendations, this research highlights the essential role of semiconductors in driving EV diffusion, providing a strategic roadmap to reduce barriers, stimulate industry growth, and promote environmental sustainability in India.

**Key words:** Electric Vehicles; Diffusion of Innovation; Semiconductor Availability; DEMATEL; Supply Chain Barriers, and Delphi Technique.

---

## INTRODUCTION

The global automotive sector has recently undergone a significant shift towards sustainable and environmentally friendly transportation options, driven by growing concerns about environmental degradation and energy security (Mittelstaedt et al. 2014). Electric Vehicles (EVs), which operate on electricity instead of traditional fossil fuels, have emerged as a viable solution to reduce greenhouse gas emissions and decrease dependence on oil (Alanazi 2023; Al-Ghaili et al. 2022; Babu and Sarkar 2024; Challa, Kamath, and Anctil 2022; Kumar et al. 2024). As the world strives for a more sustainable future, the widespread diffusion of EVs has become increasingly crucial.

India, with its dense population and rapid urbanization, faces unique challenges. According to IQAir's air quality and pollution city rating, India ranked third globally in population-weighted PM2.5 concentration in 2023, trailing only Bangladesh and Pakistan, with a concentration of 54.4  $\mu\text{g}/\text{m}^3$  (IQAir 2024). Additionally, Delhi ranked first among capital cities, with a population-weighted PM2.5 concentration of 92.7  $\mu\text{g}/\text{m}^3$  (IQAir 2024). To combat air pollution, the Indian government has set a target of achieving 30% EV diffusion by 2030 (Ministerial 2017; Niti Aayog et al. 2022). The trend of BEV diffusion in India over the past decade is illustrated in Figure 1, based on data from Niti Aayog 2025.

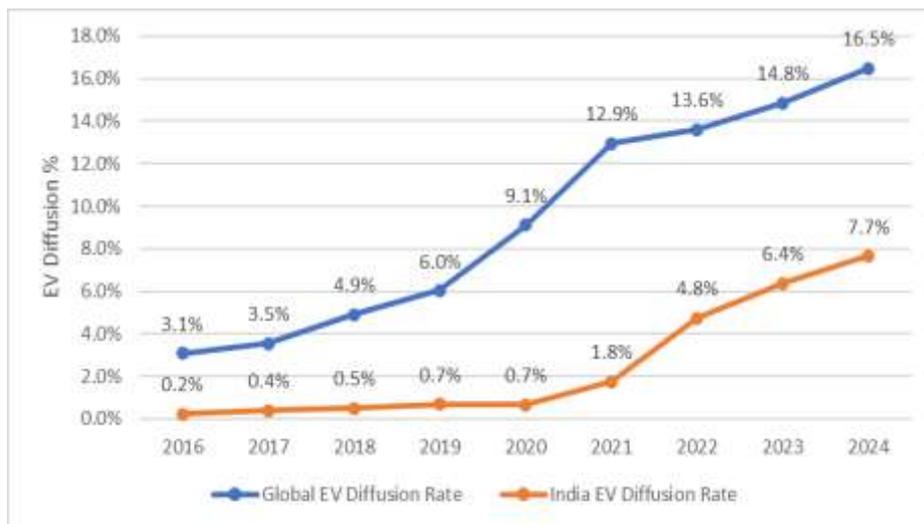


Figure 1. Trend of BEV diffusion in the Indian market

Source: Authors' compilation

**Barriers to the diffusion of electric vehicles**

The barriers to EV diffusion have been classified in various ways depending on the scope of the particular research paper. The taxonomy shown in the Figure 2 is extensive in nature and covers almost all types of EV diffusion barriers. The basic structure is adopted from Tarei et al. (2021) and further classified into manufacturer, consumer, and other barriers.

In examining barriers to EV diffusion, much of the focus has traditionally been on the battery, given its crucial role in determining vehicle performance. However, semiconductors have emerged as equally vital components, particularly as the complexity of modern vehicles has increased. Recent advancements in automotive technology have largely been driven by the computational capabilities provided by semiconductors, making them indispensable in the industry. The global semiconductor shortage, most notably during the COVID-19 pandemic, has severely impacted the automotive sector, disrupted production schedules and limited output. These challenges highlight the urgent need for a more resilient semiconductor supply chain to mitigate such vulnerabilities in the future.

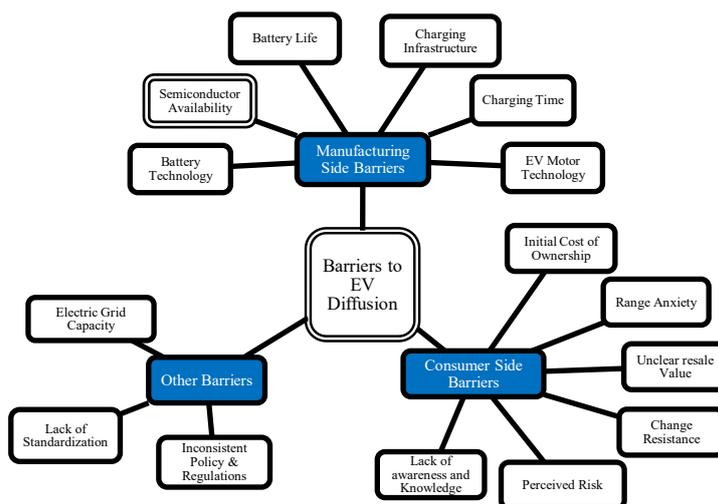


Figure 2. Classification of EV diffusion barriers

Source: Authors' compilation

**Semiconductors**

Semiconductors, often regarded as the "brains" of modern vehicles, are essential for both traditional internal combustion engine vehicles and EVs. These components have revolutionized communication

and data processing, significantly reducing the time and effort required for these operations. In the digital age, semiconductors continue to be pivotal, driving technological advancements and shaping future innovations in unprecedented ways (SIA 2023).

#### Why is study of semiconductor availability being important?

Semiconductor availability plays a critical role in modern transportation systems, with the supply chain characterized by cycles of shortages and surpluses. These fluctuations are closely tied to macroeconomic indicators, reflecting the dynamic and sensitive nature of the semiconductor industry. Understanding this industry's intricacies highlights the persistent interplay between scarcity and surplus.

The semiconductor industry's dependence on macroeconomic trends and global geopolitics is evident, as semiconductor manufacturing is concentrated in a few Southeast Asian countries. Historical disruptions, such as the oil crises of 1975, 1982 and 1991, exemplify how external shocks influence this industry. Similarly, the Asian financial crisis of 1998 and the bursting of the dot-com bubble caused significant upheavals (Young 2021; Liu 2005; Tan and Mathews 2010). More recently, the global recession of 2008 and the COVID-19 pandemic in 2020 have left lasting impacts.

Looking ahead, the semiconductor content per vehicle (excluding aftermarket and commercial vehicles) is projected to rise significantly, reaching USD 1,542 by 2029 from USD 854 in 2022 (IHS Markit 2023). The automotive sector is expected to become the fastest-growing market for semiconductors, with demand potentially tripling due to applications like autonomous driving and e-mobility. By 2030, the semiconductor cost for a Society of Automotive Engineers (SAE) Level 4 EV may reach USD 4,000, compared to USD 500 for an SAE Level 1 internal combustion engine vehicle. While the automotive industry accounted for only 8% of semiconductor demand in 2021, this share is expected to grow to 13%–15% by the end of the decade, contributing up to 20% of industry growth (Burkacky, Dragon, and Lehmann 2022).

#### Semiconductors and Electric Vehicles

Semiconductors are central to transforming EV from traditional internal combustion engine vehicles into advanced computational platforms capable of processing vast amounts of sensor data in real time. This technology underpins the development of critical EV components, including battery management systems (BMS), motor control units (MCU), vehicle control units (VCU), and advanced driver assistance systems (ADAS). These advancements enhance both the performance and efficiency of EVs. Notably, EVs require nearly three times the semiconductor content of conventional vehicles, emphasizing their integral role in modern automotive innovation (Verma 2023). According to the World Semiconductor Trade Statistics (WSTS) report, the global demand for semiconductors is projected to increase from 8% in 2020 to 14% by 2023, as illustrated in Figure 3.

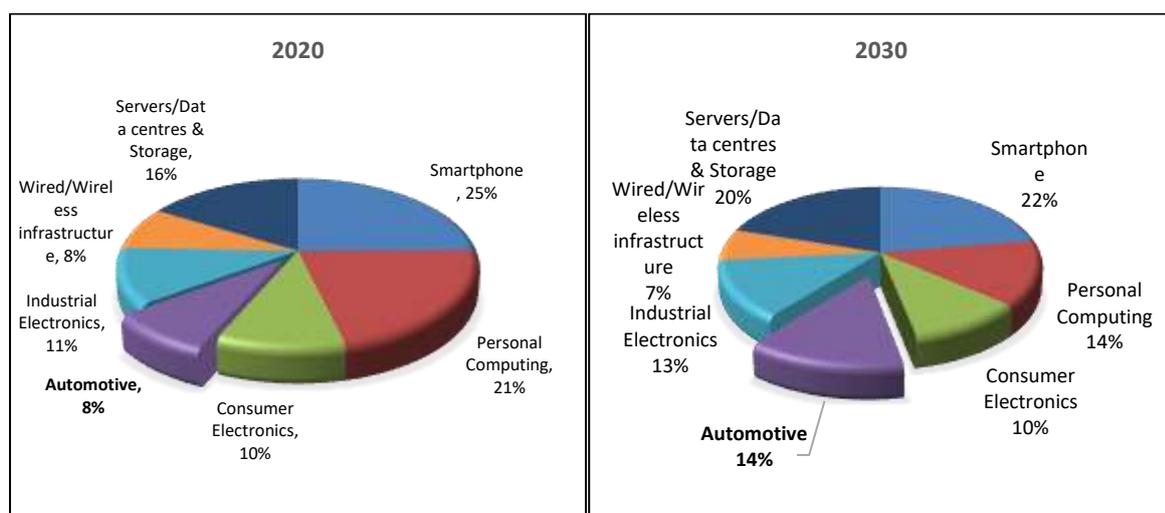


Figure 3. Semiconductor market share growth from 2020 to 2030

Source: World Semiconductor Trade Statistics, <https://www.wsts.org/>

**Semiconductor and India's EV journey**

India finds itself in a challenging position, heavily reliant on imports for 91% of its semiconductor needs (Parashar 2022). This heavy dependence poses not only economic risks but also threatens India's technological sovereignty and competitiveness on the global stage. The challenges facing India's semiconductor sector significantly influence the country's capacity to support the transition to EVs, translating directly into barriers to widespread EV diffusion.

**Objectives of the study**

- To examine the influence of semiconductor availability on other EV diffusion barriers.
- To investigate the role of semiconductor availability in supporting India's transition towards electrified transportation.
- To offer strategic recommendations to stakeholders, policymakers, and industry players on the critical importance of semiconductors in advancing India's EV revolution.

The remainder of this paper presents the methodology, analyses the interdependencies among EV diffusion barriers, reports the outcomes of the thematic analysis with key themes, and discusses the conclusions, limitations, and future research scope.

**METHODOLOGY**

The methodology employed in this research comprises a two-stage process. In the first stage, the Multi-Criteria Decision-Making (MCDM) technique, specifically the Decision-Making Trial and Evaluation Laboratory (DEMATEL), is utilized to identify and analyse the causal relationships among the barriers to EV diffusion, highlighting their interdependencies (Addae et al. 2019; Asadi et al. 2022; Nilashi and Abumalloh 2024; Shieh, Wu, and Huang 2010). The second stage involves the Delphi technique, leveraging a panel of experts to facilitate systematic data collection and detailed analysis aimed at achieving consensus.

**DEMATEL**

The DEMATEL methodology, adapted from Shieh et al. (2010), was applied to analyse barriers to EV diffusion from a manufacturing perspective. Five prominent barriers were identified using a forward selection method, informed by insights from the literature review to assess the influence of semiconductor availability (A). These variables include battery technology (B), charging infrastructure (C), charging time (D), EV motor technology (E), and battery life (F).

*Determining number of questions for DEMATEL*

To determine the number of questions, the theory of pairwise comparison has been used. It was developed by Marie Jean Antoine Nicolas de Caritat, better known as the Marquis de Condorcet, an 18th-century French philosopher and mathematician. The pairwise comparison is used to evaluate and prioritize multiple factors by comparing them in pairs. Each element is assessed relative to another, enabling researchers to determine preferences, rankings, or relative importance. Widely used in decision-making methods like AHP and DEMATEL, it helps structure complex, multi-criteria problems (Jaroslav Ramik 2020). The pairwise comparison simplifies complex comparisons by breaking them down into manageable pairs. The results of pairwise comparisons can be represented in a matrix format, where rows and columns correspond to the entities being compared. Each entry in the matrix indicates the comparison outcome between the pair.

*Equation for determining number of Pairs*( $N = n(n - 1)$ ), equation (1)

$$N = 6(6 - 1) = 6 \times 5 = 30 \text{ number of questions}$$

**Delphi Technique**

The Delphi Technique is a structured, iterative method for gathering expert opinions to reach a consensus on complex issues. The Delphi Technique is used where expert knowledge is needed to inform decision-making or to understand a phenomenon in greater depth. A field where it has been regularly used is public policy, as it helps in better understanding policy design and implementation (Brady 2015; Rossi, Frank, and Wilke 2021; Habibi and Izadyar 2014). It involves multiple rounds of questionnaires, where feedback is provided anonymously to refine responses. This approach is particularly useful in forecasting and decision-making for emerging fields (Brady 2015; Rossi et al. 2021; Sarafrazi et al. 2014). We have used the Delphi Technique to gather insights from experts to conduct thematic analysis.

**Thematic Analysis**

Thematic analysis, introduced by Gerald Holton in the 1970s, is a widely used qualitative method for identifying, analysing, and reporting patterns, themes within data. It organizes and describes data in rich detail, enabling researchers to uncover underlying meanings (Brady 2015; Braun and Clarke 2006; Vaismoradi et al. 2016). Thematic analysis was employed to examine the qualitative data collected through the Delphi Technique, allowing for an in-depth exploration of recurring patterns and key themes across expert responses. This method helped categorize insights, identify underlying issues, and clarify perspectives, providing a comprehensive understanding of factors impacting EV diffusion barriers (Brady 2015; Braun and Clarke 2006; Vaismoradi et al. 2016).

Thematic analysis can be an essentialist or realist method, which reports experiences, meanings, and the reality of participants, or it can be a constructionist method, which examines the ways in which events, realities, meanings, and experiences are the effects of a variety of discourses operating within society (Braun and Clarke 2006; Vaismoradi et al. 2016).

**Data Collection Methods**

Data were collected through a structured questionnaire using a Google Form, designed to efficiently capture respondents' insights and feedback. Data collection spanned three rounds. The first round served a dual purpose: identifying interdependencies among EV diffusion barriers for DEMATEL and gathering expert knowledge on the role of semiconductors in EV diffusion for thematic analysis using Delphi Round 1. In the second round of the Delphi Technique, responses from the first round were used to delve deeper into selected codes for further insights. The third round aimed to achieve expert consensus on the themes generated in the second round, reaching a final agreement on key findings.

The timeline of the survey across all three rounds of data collection is shown in Figure 4.

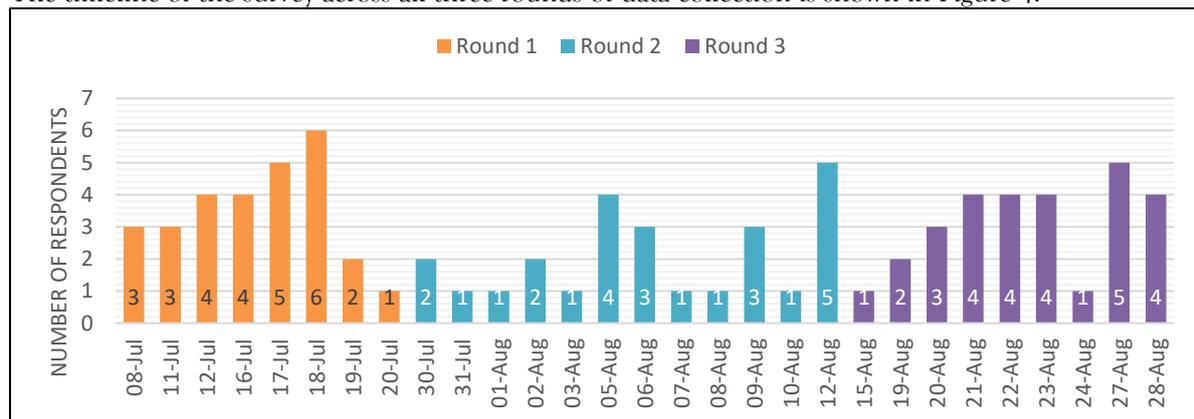


Figure 4. Timeline of the survey for data collection and responses

Source: Survey data

**Sample Size**

Based on Mason's 2010 research paper titled "Sample Size and Saturation in PhD Studies Using Qualitative Interviews," which indicated a median sample size of 28 and a mean sample size of 31, we have adopted a sample size of 28 (Mason 2010). Although the target sample size was set at 28, a total of 45 experts were initially invited to account for potential non-responses. In the first and second rounds, 28 experts responded, while in the third round, the number of respondents increased to 33.

**Selection of Experts**

Experts were identified through the professional network of one of the authors, who has over 16 years of experience in the automotive industry, with expertise spanning both ICE powertrain components and EV drive motors. Over more than a decade, the author has established connections with industry experts and is also an active LinkedIn member promoting EVs. The experts selected comprised individuals with knowledge and experience in EVs, semiconductors, automotive, and other relevant industries and services.

**Sampling Frame**

Table 1: Sampling frame of the targeted population

Criteria	Details
----------	---------

Demographic Criteria	Experts from the automobile and semiconductor industries
Education	Experts in the automotive and semiconductor industries, largely including engineers and management degree holders
Gender Representation	Both male and female participants were included to explore gender-specific preferences or concerns. Female – 3, Male – 25
Sampling Method	Convenience sampling.
Data Collection Methods	Quantitative and qualitative data were gathered through an online survey.
Duration of the Study	Cross-sectional study, with data collected at a single point in time.
Questionnaire Type	Semi-structured, featuring both closed-ended and open-ended questions.

## RESULTS AND DISCUSSION

This section presents the profile of participating experts, followed by an analysis of interdependencies among EV diffusion barriers using the DEMATEL method. It concludes with a thematic analysis derived from the Delphi Technique, which identifies key themes based on expert insights gathered during data collection.

### Profile of participating experts

- **Age:** The respondents' age ranges from 23 to 57, with an average age of approximately 39 years. This diversity ensures a broad range of perspectives from early-career professionals to highly experienced individuals.
- **Educational back ground:** There are 15 respondents with a graduate-level education, making up roughly 54% of the sample, and 13 respondents with postgraduate or higher qualifications, accounting for around 46%. This mix of educational backgrounds adds depth to the analysis as it includes insights from both graduates and those with advanced educational qualifications.
- **Industry Representation:** The respondent profile is predominantly composed of individuals from the automobile sector (68%), providing critical insights closely aligned with the focus on EV diffusion. Additionally, representation from IT and services (11%) introduces perspectives on technological and service-oriented support for EV infrastructure, while the manufacturing sector (11%) offers valuable input on production and supply chain challenges tied to EV components. Notably, the inclusion of a respondent from the semiconductor industry (4%) is particularly relevant to the study, considering the importance of semiconductors in EV technology. This diverse mix of industries ensures a comprehensive view of factors impacting EV adoption.
- **Work experience:** The respondents' average work experience of 16 years reflects a mature group with a comprehensive understanding of industry practices and challenges. With experience ranging from 1 to 35 years, the group brings a blend of fresh perspectives and seasoned insights, supporting a nuanced view of evolving opinions on EV adoption shaped by industry tenure.

### Interdependency among barriers

The diffusion of EVs in the Indian market is heavily influenced by the interdependency among key EV diffusion barriers such as semiconductor availability, battery technology, charging infrastructure, charging time, EV motor technology, and battery life. Identifying the interplay between these barriers is crucial for understanding their respective influences, and DEMATEL is the most suitable process for this analysis. This approach quantifies the influence of each factor on the others, highlighting how semiconductor availability can significantly impact advancements in battery and motor technologies, while infrastructure and charging times also play critical roles in shaping the overall diffusion landscape. To follow the DEMATEL procedure, 28 6×6 non-negative matrices were first constructed.

The mathematical formulas used for determining the interdependencies among EV diffusion barriers are elaborated below.

Direct Relation Matrix (X):

- Represents the initial direct influence of each factor on the others.
- Each element  $x_{ij}$  in matrix  $X$  is determined by expert evaluations.

$$X = x_{ij}, \text{ equation } 2)$$

Where  $x_{ij}$  is the direct influence of  $i$  on factor  $j$

1. **Normalized Direct Relation Matrix (D)**

Normalizes the Direct Relation Matrix so that the sum of the maximum row or column equals 1.

$$\alpha = \max \left( \max_i \sum_{j=1}^n x_{ij}, \max_j \sum_{i=1}^n x_{ij} \right)$$

$$D = \frac{X}{\alpha} = [d_{ij}] = \left[ \frac{x_{ij}}{\alpha} \right], \text{ equation (3)}$$

2. **Identity Matrix (I):** An  $n \times n$  matrix with 1s on the diagonal and 0s elsewhere.

$$I = [\delta_{ij}], \text{ equation (4)}$$

Where  $\delta_{ij} = 1$ , if  $i = j$  and  $\delta_{ij} = 0$  other wise

3. **Total Relation Matrix (T):**

Combines the direct and indirect influences of factors.

Calculated using the normalized direct relation matrix  $D$  and the identity matrix  $I$ .

$$T = D(I - D)^{-1}, \text{ equation (5)}$$

where  $T = [t_{ij}]$  and  $t_{ij}$  represents the total (direct + indirect) influence of factor  $i$  on factor  $j$ .

**Explanation:**

- $D$ : The normalized direct relation matrix, derived by normalizing the initial direct relation matrix  $X$ .
- $I$ : The identity matrix, used in calculating the total relation matrix.
- $T$ : The total relation matrix, showing the combined direct and indirect effects between factors.

As Step 1, the average matrix is constructed from the formula given in Equation 2.

$$X = \begin{bmatrix} 0.000 & 4.714 & 4.500 & 4.393 & 4.321 & 4.286 \\ 2.286 & 0.000 & 3.357 & 4.143 & 2.750 & 4.179 \\ 1.821 & 3.357 & 0.000 & 3.929 & 1.964 & 3.750 \\ 2.071 & 4.071 & 3.286 & 0.000 & 2.071 & 3.893 \\ 2.143 & 2.214 & 2.143 & 1.893 & 0.000 & 2.321 \\ 1.571 & 3.607 & 3.214 & 3.679 & 2.143 & 0.000 \end{bmatrix}$$

Step 2: The normalized direct relation matrix is calculated as per Equation 3.

$$D = \begin{bmatrix} 0.000 & 0.212 & 0.203 & 0.198 & 0.195 & 0.193 \\ 0.103 & 0.000 & 0.151 & 0.186 & 0.124 & 0.188 \\ 0.082 & 0.151 & 0.000 & 0.177 & 0.088 & 0.169 \\ 0.093 & 0.183 & 0.148 & 0.000 & 0.093 & 0.175 \\ 0.096 & 0.100 & 0.096 & 0.085 & 0.000 & 0.105 \\ 0.071 & 0.162 & 0.145 & 0.166 & 0.096 & 0.000 \end{bmatrix}$$

Step 3: The total relation matrix is calculated as per Equation 4.

$$T = \begin{bmatrix} 0.257 & 0.612 & 0.572 & 0.606 & 0.486 & 0.611 \\ 0.291 & 0.338 & 0.443 & 0.500 & 0.357 & 0.508 \\ 0.255 & 0.437 & 0.282 & 0.461 & 0.305 & 0.461 \\ 0.271 & 0.473 & 0.422 & 0.322 & 0.318 & 0.477 \\ 0.223 & 0.320 & 0.300 & 0.311 & 0.171 & 0.331 \\ 0.239 & 0.433 & 0.397 & 0.440 & 0.302 & 0.303 \end{bmatrix}$$

The resultant cause-effect relationship matrix (or Impact-Relation Map), derived from the analysis, is given in Table 2 and interpreted as follows:

Table 2. DEMATEL cause-effect relationship matrix

<i>EV diffusion Barriers</i>	Ri	Ci	Ri + Ci	Ri - Ci	Identification
Semiconductor Availability(A)	3.14	1.54	4.68	1.61	Cause +ve Ri-Ci
Battery Technology(B)	2.44	2.61	5.05	-0.18	Effect -ve Ri-Ci
Charging Infrastructure (C)	2.20	2.42	4.62	-0.22	Effect -ve Ri-Ci
Charging Time(D)	2.28	2.64	4.92	-0.36	Effect -ve Ri-Ci
EV Motor Technology (E)	1.66	1.94	3.59	-0.28	Effect +ve Ri-Ci
Battery Life (F)	2.11	2.69	4.81	-0.58	Effect -ve Ri-Ci

Source: Survey data

**Key findings:** As presented in Table 2, the cause-and-effect relationship analysis identifies semiconductor availability as the most critical barrier to the diffusion of EVs in India, with the highest positive  $R_i - C_i$  value of +1.61, categorizing it as a strong causal factor. In contrast, other barriers, including battery technology, charging infrastructure, charging time, battery life, and EV motor technology, are primarily classified as effect factors, as indicated by their negative  $R_i - C_i$  values, signifying their dependence on causal factors such as semiconductors. Notably, battery technology emerges with the highest combined influence and dependence ( $R_i + C_i = 5.05$ ) underscoring its overall significance while highlighting its limited role in driving systemic changes independently.

**Impact-degree graph (or impact–relation graph):**

The DEMATEL impact-degree graph visually highlights the relative importance and influence of each factor, helping to identify key drivers and their interconnections. Barriers that are highly influential but have fewer connections, with a positive value of  $R_i - C_i$ , are marked in red. As presented in Table 3, semiconductor availability and EV motor technology show the lowest centrality, while all other barriers are influenced by semiconductor availability.

Table 3. The impact relation map

<i>Impact-Relation Map</i>	<b>R<sub>i</sub></b>	<b>C<sub>i</sub></b>
<i>Semiconductor Availability (A)</i>	3.14	1.54
<i>Battery Technology (B)</i>	2.44	2.61
<i>Charging Infrastructure (C)</i>	2.20	2.42
<i>Charging Time (D)</i>	2.28	2.64
<i>EV Motor Technology (E)</i>	1.66	1.94
<i>Battery Life (F)</i>	2.11	2.69

Source: Survey data

$R_i$  represents the "influence" or "prominence" score of a factor in the total relation matrix. The  $R_i$  score helps identify factors that act as strong influencers within the network. Semiconductor availability has the highest  $R_i$  value of 3.14, indicating the greatest influence. The centrality index ( $C_i$ ) value denotes how much each variable is influenced by other variables, and thus its relative centrality in the network of relationships. Semiconductor availability, with a  $C_i$  value of 1.54, ranks lowest among the barriers. By combining the influence ( $R_i$ ) and centrality index ( $C_i$ ) scores, the impact–relation graph is constructed to visualize these dynamics in Figure 5.

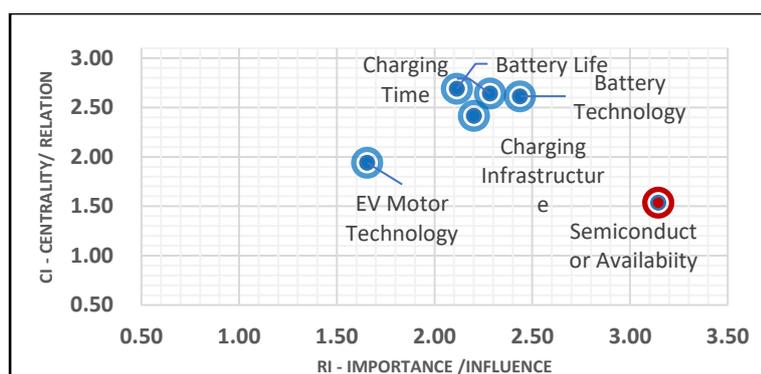


Figure 5. Impact–relation graph

Source: Survey data

**Directed Graph (digraph):**

The DEMATEL directed graph provides a visual representation of the relative importance and influence of each factor, highlighting the causal relationships among them. By analysing this graph, decision-makers can identify key drivers, assess their impact on the system, and formulate targeted strategies to address complex issues, ultimately enhancing overall performance and efficiency.

The threshold alpha ( $\alpha$ ) value is applied to determine the strength of relationships between factors, setting a cutoff to retain only significant influence values within the influence matrix. As shown in Table 4, the threshold alpha for this study is set at 0.36, with 15 elements exceeding this threshold. These significant elements form the basis of the directed graph illustrated in Figure 6.

Table 4. Total relation matrix for the study

Total Relation Matrix	A	B	C	D	E	F
A	0.26	0.61	0.57	0.61	0.49	0.61
B	0.29	0.34	0.44	0.50	0.36	0.51
C	0.26	0.44	0.28	0.46	0.30	0.46
D	0.27	0.47	0.42	0.32	0.32	0.48
E	0.22	0.32	0.30	0.31	0.17	0.33
F	0.24	0.43	0.40	0.44	0.30	0.30
Threshold (Alpha) Value	0.38					

Source: Survey data

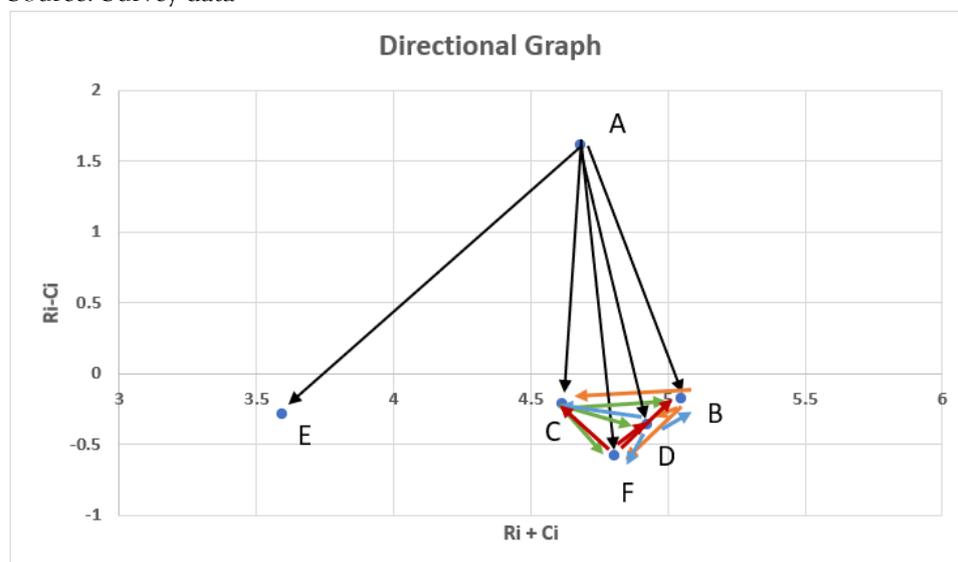


Figure 6. Directed graph showing the causal relationships

Source: Survey data

The DEMATEL results reveal that semiconductor availability is a key driver in the BEV ecosystem, exerting significant influence over other critical factors. Battery technology and charging infrastructure also emerge as prominent factors, playing crucial roles as both influencers and influenced variables. Charging time, while important, is predominantly affected by other factors, indicating areas for potential improvement. EV motor technology has the least overall influence and prominence, suggesting a lesser role in the current diffusion of BEVs in India. Lastly, battery life is a moderately significant factor, primarily influenced by other elements. These insights emphasize the central role of semiconductor availability in accelerating the diffusion of BEVs in India, guiding strategic decisions and research focus areas to enhance the EV diffusion process.

#### Thematic analysis

The thematic analysis was conducted using the Delphi Technique, revealing valuable insights into the influence of semiconductor availability on the diffusion of EVs in the Indian market. Through iterative rounds of surveys, a consensus emerged on several key themes that elucidate the complex relationship. The thematic analysis identified four primary themes:

1. Impact of Semiconductor Availability on EV Development and Performance - encompassing four sub-themes.
2. Critical Factors Influencing Semiconductor Availability - consisting of two sub-themes.

3. Barriers and Challenges – including two sub-themes.
4. Strategic Recommendations for Enhancing Semiconductor Availability – incorporating eight sub-themes.

Based on these themes, a radial cluster representing the thematic analysis, along with the main themes and their sub-themes, was developed and is depicted in Figure 7.

*Main Theme 1: Impact of Semiconductor Availability on EV Development and Performance*

### **1.1 Sub-Theme: Mixed Effects on Development and Performance**

The analysis indicates that semiconductor availability has a nuanced impact on the development and performance of EVs in India. Among the 28 experts surveyed, a significant portion recognized the dual nature of this influence. While semiconductors have been instrumental in driving technological advancements within the EV sector, they have also introduced complexities and challenges. For instance, some experts highlighted that semiconductors enable enhanced functionalities such as improved BMS and ADAS. Moreover, semiconductors play a crucial role in the EV transformation; efficient and advanced semiconductors enable EVs to gain 10–15% more range, recharge batteries twice as fast, and optimize the total cost of the electric powertrain (ST Micro Electronics 2023). A few experts also mentioned that dependencies on semiconductors create vulnerabilities in EV production and supply chains, driven by recurring shortages related to geopolitical tensions, pandemics, long lead times, and complex supply chains. Research publications also highlight these concerns (Panchal, Topre, and Kabir 2024; Ramachandran 2022).

This divergence in perspectives likely stems from varying focuses within the EV market, including production capacity, technological readiness, and market dynamics. The mixed responses underscore the necessity for a deeper exploration into how specific semiconductor technologies can either facilitate or obstruct progress in the Indian EV landscape.

### **1.2 Sub-Theme: Future Evolution of Semiconductor Technology**

Experts expressed a strong consensus regarding the anticipated evolution of semiconductor technology over the next 5–10 years and its implications for EVs in India. A prevalent view among respondents is that increasing local semiconductor production is crucial for reducing costs and enhancing supply chain resilience. This sentiment reflects a broader understanding that localized manufacturing can mitigate risks associated with global supply chain disruptions.

Additionally, advancements in silicon carbide (SiC) and gallium nitride (GaN) technologies are expected to make power electronics more compact and affordable, which could significantly enhance EV efficiency. This was also discussed in various research papers (Panchal et al. 2024; ST Micro Electronics 2023). Furthermore, experts foresee that integrating artificial intelligence (AI) into BMS will improve both performance and user experience in autonomous driving scenarios. However, a minority viewpoint suggests that these advancements may have limited effects on overall EV growth, indicating a need for caution in expectations.

The Table 5 presents the results of the Delphi method, which was employed to achieve consensus among experts regarding the inclusion of key statements. These statements address the role of semiconductors in the diffusion of BEVs, as outlined by Rossi et al. (2021).

### **1.3 Sub-Theme: Semiconductor Availability vs. Other Barriers to EV Diffusion**

The survey results reveal a prevailing belief among experts that semiconductor availability is paramount compared to other factors influencing EV diffusion, such as battery technology and charging infrastructure. A substantial majority identifies semiconductors as critical enablers for essential components like BMS, MCUs, and VCUs. This highlights the integral role semiconductors play not only in performance but also in the overall viability of EVs (Clemson University 2014). In contrast, battery technology is considered less critical by some respondents, suggesting that while it remains important, it does not overshadow the necessity for robust semiconductor availability. This consensus emphasizes the need for stakeholders to prioritize investments in semiconductor technology to accelerate the adoption of EVs in India.

### **1.4 Sub-Theme: Vulnerability to Semiconductor Shortages**

The findings reveal a strong consensus among experts about the vulnerability of all EV components to semiconductor shortages. A vast majority emphasize that semiconductor dependence is pervasive throughout the EV ecosystem, impacting everything from BMS to ADAS. This widespread agreement

highlights the essential role of semiconductors across various components, indicating that shortages could disrupt the entire industry. Supporting this view, the literature also underscores the critical impact of semiconductor shortages, as noted by research publications (Liu 2005; Wakefield 2021; Bansal 2024; Wallach 2021; Panchal et al. 2024; Brown 2021).

While some experts point out that MCUs may be particularly susceptible due to their central role in powertrain operations, the general sentiment advocates for a comprehensive approach to addressing semiconductor shortages. This includes diversifying suppliers and investing in research and development to enhance supply chain resilience. Such strategies are essential for ensuring sustained growth within the Indian EV sector amidst ongoing global challenges.

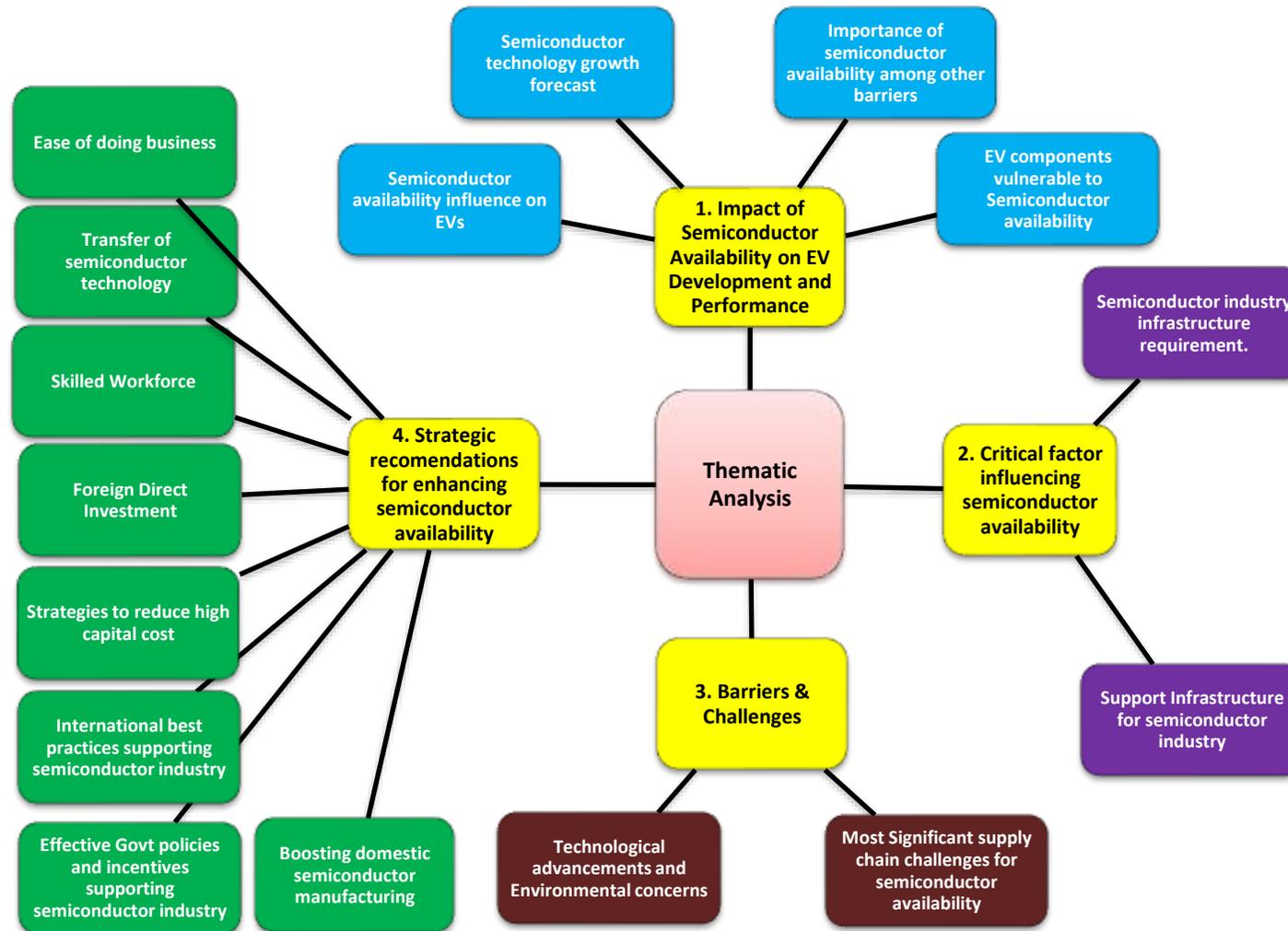


Figure 7. Radial cluster of thematic analysis with main themes and sub themes

Table 5. Consensus Statements on the Role of Semiconductor Availability and Development in Accelerating EV Diffusion in India

SL NO	QUESTION	CONSENSUS STATEMENT	CONSENSUS (%)
1	Impact of Semiconductor Availability on EVs in India	Semiconductor availability is crucial for EV development, enabling key components like BMS, MCUs, VCUs, ADAS, and LIDAR, which directly affect EV performance and adoption.	85%
2	Evolution of Semiconductor Technology in the Next 5-10 Years	Technological advancements in miniaturization, SiC, GaN, and AI integration will improve EV efficiency, reduce costs, and support autonomous driving features.	90%
3	Importance of Semiconductor Availability Compared to Other Factors	Semiconductor availability is as critical as battery and motor technologies in EVs, influencing motor performance, battery optimization, and advanced safety systems.	75%
4	Vulnerability of EV Components to Semiconductor Shortages	EV components like BMS, MCUs, VCUs and ADAS are highly vulnerable to semiconductor shortages due to their reliance on advanced technologies for functionality.	80%
5	Steps for Boosting Domestic Semiconductor Manufacturing	Government initiatives like financial incentives, infrastructure improvements, and tailored workforce programs are vital for ensuring semiconductor supply for EV production.	88%
6	International Best Practices for Semiconductor Manufacturing	Adopting global practices such as public-private partnerships, SEZs, and technology transfers will strengthen India's semiconductor capabilities for EV manufacturing.	82%
7	Supply Chain Challenges for Semiconductor Availability in India	EV production is hindered by supply chain issues, including reliance on imports, high costs, and limited domestic capacity, necessitating streamlined policies and local sourcing.	78%
8	Infrastructure Improvements for Semiconductor Industry Growth	EV manufacturing requires dedicated SEZs, reliable power supply, and efficient logistics to sustain a resilient semiconductor industry.	87%
9	Strategies to Reduce High Capital Costs in Semiconductor Manufacturing	Cost optimization through industry clustering, fab scaling, and R&D investments will lower barriers and support semiconductor availability for EVs.	86%
10	Strategies to Attract FDI into the Semiconductor Sector	Tax incentives, regulatory simplifications, and targeted campaigns will attract foreign investments to strengthen semiconductor support for EV growth.	85%
11	Measures to Develop a Skilled Workforce for the Semiconductor Industry	Training programs, partnerships with academia, and competitive salaries will build a skilled workforce essential for EV-focused semiconductor innovation.	89%
12	Strategies to Accelerate Semiconductor Technology Transfer	Collaborations, MOUs, and R&D partnerships with global leaders will enable rapid technology adoption, boosting EV-related semiconductor production.	83%

13	Actions to Improve Ease of Doing Business for Semiconductor Companies	Simplifying regulations, reducing bureaucratic barriers, and offering targeted support will create a favourable business environment for EV-related semiconductor companies.	84%
14	Strategies to Balance Environmental Concerns with Technological Advancement	Sustainable practices, recycling initiatives, and eco-friendly designs in semiconductor production will enhance EV adoption while mitigating environmental impact.	81%
15	Infrastructure Improvements to Support Semiconductor Industry	Establishing SEZs, ensuring uninterrupted power supply, and improving transportation networks will provide a robust infrastructure for EV-aligned semiconductor production.	88%
16	Key Factors for Promoting Sustainability in Semiconductor Manufacturing	Promoting sustainable practices, adhering to environmental regulations, and adopting circular economy principles will align semiconductor production with eco-friendly EV goals.	80%

Source: Survey data

*Main Theme 2: Critical Factors Influencing Semiconductor Availability*

### **2.1 Sub-Theme: Infrastructure Improvements to Support Semiconductor Industry Growth in India**

Experts agree that targeted infrastructure, especially semiconductor-focused SEZs with reliable utilities, is crucial to advancing India's semiconductor industry. Emphasis is also placed on strengthening R&D, developing skilled talent, and forming global joint ventures for technology transfer. Transportation and logistics are noted, but seen as secondary. A focused strategy combining SEZs, innovation, and international collaboration is key to sustainable growth (Saxena 2024).

### **2.2 Sub Theme: Key Infrastructure Developments**

Thematic analysis highlights the importance of establishing advanced fabrication plants (fabs) and production units as foundational to India's semiconductor industry growth. Experts emphasize that such facilities are essential for efficient, high-quality manufacturing. Reliable power and water supply are identified as critical operational needs, along with the development of a robust industrial ecosystem that includes downstream industries to enhance collaboration and resilience. Improving supply chain infrastructure and material availability, along with efficient logistics and transportation networks, is also seen as a key enabler. Together, these elements form the backbone of a strong semiconductor industry. Literature supports the role of infrastructure development in advancing India's semiconductor sector (Kempanna 2024; Brown 2021; Saxena 2024).

*Main Theme 3: Barriers and Challenges Affecting Semiconductor Availability*

### **3.1 Sub Theme: Supply Chain Challenges**

The analysis highlights India's heavy reliance on imported raw materials—particularly from China—as a major supply chain vulnerability in the semiconductor sector. Experts stress the urgent need for domestic sourcing to reduce this dependence.

Secondary challenges include restrictive trade policies, complex customs procedures, and inadequate logistics infrastructure, which together further strain the supply chain. While gaps in local R&D and skilled workforce development are noted, they are viewed as less critical than raw material dependency. Overall, a comprehensive approach focused on boosting domestic production and strengthening logistical networks is essential for overcoming these challenges (Nathan Associates 2016; Wallach 2021; Panchal et al. 2024).

### **3.2 Sub Theme: Balancing Environmental Concerns with Technological Advancement**

Thematic analysis reveals strong expert consensus on prioritizing strict environmental regulations in the semiconductor industry to ensure long-term sustainability. Key recommendations include adopting sustainable manufacturing practices, investing in eco-friendly R&D, and promoting recycling and waste management. While circular economy principles and green product design are

noted, they are seen as secondary to immediate environmental standards. Overall, integrating sustainability with technological advancement is viewed as essential for the industry's future growth.

*Main Theme 4: Strategic Recommendations for Enhancing Semiconductor Availability*

#### **4.1 Sub-Theme: Indian Government Actions to Boost Domestic Semiconductor Manufacturing**

Experts emphasize the need for a multi-faceted strategy to develop India's semiconductor sector. Most (89.3%) support an integrated approach combining public-private partnerships, infrastructure development (e.g., SEZs), and financial incentives. Only 3.6% favour singular strategies, highlighting broad consensus on the importance of a coordinated plan aligned with EV industry needs (Kempanna 2024; International Trade Administration 2023; Meity 2022; Saxena 2024).

#### **4.2 Sub Theme: Effective Government Policies and Incentives for the Semiconductor Industry**

A majority of experts recommend financial incentives—such as subsidies and PLI schemes—as key to attracting investment in semiconductors. Sixteen out of 28 also highlighted the importance of FDI-friendly policies, strong infrastructure, streamlined regulations, and skill development. These insights suggest a multi-layered policy approach is essential for strengthening India's semiconductor ecosystem (International Trade Administration 2023; ISM 2022; Meity 2022; Bansal 2024; Saxena 2024).

#### **4.3 Sub Theme: Adoption of International Best Practices for Sector Competitiveness and Growth**

Experts emphasize the need for India to adopt global best practices in semiconductors, especially through partnerships with leading firms and technology transfer from advanced nations. These collaborations are seen as vital for global integration. Supporting measures include R&D investment and strong IP frameworks. This view aligns with Stephen Ezell (2020), who advocates a collaborative approach to semiconductor leadership.

#### **4.4 Sub Theme: Strategies to Mitigate High Capital Costs in Semiconductor Manufacturing**

Experts unanimously stress the need for government support—through grants, subsidies, and low-interest loans to address the high capital costs of semiconductor manufacturing. They also highlight public-private partnerships, increased R&D, fab scaling, and supply chain localization as key cost-reduction strategies. These views are supported by the literature (International Trade Administration 2023; Clark and Gibson 2022; Meity 2022).

#### **4.5 Sub Theme: Attracting Foreign Direct Investment (FDI) into the Semiconductor Sector**

To attract more FDI, 97% of experts prioritize regulatory simplification and improvement of the ease of doing business as key steps. Financial incentives, infrastructure development, and a comprehensive marketing campaign to position India as a favourable investment destination are also highly recommended. Although a skilled workforce and policy stability were considered important by some, they were viewed as longer-term strategies. The responses collectively indicate that regulatory and financial incentives should be the immediate focus areas for enhancing India's FDI appeal (STEPHEN EZELL 2020; Saxena 2024).

#### **4.6 Sub Theme: Developing a Skilled Workforce for India's Semiconductor Industry**

The thematic analysis shows a strong preference for foundational educational initiatives, with 96.7% of experts recommending the introduction of specialized semiconductor courses. Additionally, 90% emphasize the importance of industry-academia partnerships.

Other measures, like vocational training centres and government-backed training programs, were acknowledged but seen as secondary to foundational education. Competitive salaries were also mentioned, though with less consensus, suggesting that while remuneration is relevant, structural educational support remains paramount.

The need for developing a skilled workforce was highlighted by the IISc and has created a custom program to upskill the professional for the semiconductor industry with the name India Semiconductor Workforce Development Program (ISWDP) (Nimitha 2024; Pathak 2024).

#### **4.7 Sub Theme: Accelerating Technology Transfer from Other Nations**

Experts strongly endorse strategic partnerships with global semiconductor firms, with 96.7% supporting this approach to accelerate technology transfer. Formal agreements with developed nations are seen as critical, while joint R&D and IP protections are viewed as supportive but

secondary. The consensus underscores that global collaborations and structured technology transfers are essential to fast-track semiconductor localization in India (Little et al. n.d.; Varadarajan and Weser 2024).

#### 4.8 Sub Theme: Creating a Business-Friendly Environment for Semiconductor Firms

Simplifying regulations and minimizing bureaucratic challenges emerged as top recommendations for creating a supportive business environment, with nearly all experts (96.7%) agreeing on its importance. Experts also emphasized tax incentives and sector-specific policies as fundamental to attracting semiconductor companies. Additionally, investments in key infrastructure, such as reliable power and transportation networks, along with the implementation of industry-specific programs like the India Semiconductor Mission, were recognized as supportive strategies, though of slightly lower priority. The researchers and industry experts stressed the similar views (Little et al. n.d.; Bansal 2024; Panchal et al. 2024; Varadarajan and Weser 2024; ST Micro Electronics 2023).

## CONCLUSION

This study emphasizes the pivotal role of semiconductor availability in accelerating the diffusion of BEVs in India, consistent with global findings (IEA 2023; Burkacky and Deichmann 2022). Using the DEMATEL method, the research identifies semiconductors as a key driver influencing critical factors such as battery technology and charging infrastructure, echoing international studies that highlight semiconductor shortages as major barriers to EV adoption (World Economic Forum 2022). Thematic analysis supports this result, with 75% of experts recognizing semiconductor availability as the most critical barrier to EV growth. To address this, the study recommends a comprehensive strategy, emphasizing the importance of public-private partnerships, infrastructure investment, financial incentives, and workforce skill development, in line with successful initiatives like the U.S. CHIPS Act and the European Chips Act (European Commission 2023; U.S. Department of Commerce 2022). International collaboration is also essential. Strategic alliances with global semiconductor leaders and technology transfer agreements can help India accelerate its capabilities, similar to practices observed in leading semiconductor hubs (Burm 2022).

Overall, this research offers critical insights into the role of semiconductors in India's EV transition and proposes strategic actions to strengthen the semiconductor ecosystem through domestic initiatives, global collaboration, and sustainable practices.

## LIMITATIONS AND SCOPE OF FUTURE RESEARCH

The sample size of 28 experts limits generalizability and may not capture the full spectrum of perspectives. Convenience sampling may also introduce bias. Future studies should include a larger, more diverse expert pool and broader stakeholder input to provide a more comprehensive understanding of the sector's challenges and opportunities.

## REFERENCES

- Addae, Bismark Appiah, Ling Zhang, Peng Zhou, and Fandi Wang. 2019. "Analyzing Barriers of Smart Energy City in Accra with Two-Step Fuzzy DEMATEL." *Cities* 89:218–27. doi:10.1016/J.CITIES.2019.01.043.
- Alanazi, Fayez. 2023. "Electric Vehicles: Benefits, Challenges, and Potential Solutions for Widespread Adaptation." *Applied Sciences (Switzerland)* 13(10). doi:10.3390/app13106016.
- Al-Ghaili, Abbas M., Hairoladenan Kasim, Hazleen Aris, and Naif M. Al-Hada. 2022. "Can Electric Vehicles Be an Alternative for Traditional Fossil-Fuel Cars with the Help of Renewable Energy Sources towards Energy Sustainability Achievement?" *Energy Informatics* 5.
- Anil Kempanna. 2024. "Crucial Role of Semiconductors in India's EV Journey." <https://cleanmobilityshift.com/industry/crucial-role-of-semiconductors-in-indias-ev-journey/>.
- Asadi, Shahla, Mehrbakhsh Nilashi, Mohammad Iranmanesh, Morteza Ghobakhloo, Sarminah Samad, Abdullah Alghamdi, Ahmed Almulihi, and Saidatulakmal Mohd. 2022. "Drivers and Barriers of Electric Vehicle Usage in Malaysia: A DEMATEL Approach." *Resources, Conservation and Recycling* 177:105965. doi:10.1016/J.RESCONREC.2021.105965.
- Babu, A., and Biplab Sarkar. 2024. "Redefining EV Diffusion Strategies in India: Insights from a Multi-Country Socioeconomic Analysis." *Ecological Engineering and Environmental Technology* 25(6):273–90. doi:10.12912/27197050/187164.
- Brady, Shane R. 2015. "Utilizing and Adapting the Delphi Method for Use in Qualitative Research." *International Journal of Qualitative Methods* 14(5). doi:10.1177/1609406915621381.

- Braun, Virginia, and Victoria Clarke. 2006. "Using Thematic Analysis in Psychology." *Qualitative Research in Psychology* 3(2):77-101. doi:10.1191/1478088706qp0630a.
- Carter Young. 2021. "The Semiconductor Shortage: An Analysis of Potential and Ongoing Remediation Efforts and Their Implications on the Industry & Macroeconomy." Portland State University.
- Challa, Rohan, Dipti Kamath, and Annick Anctil. 2022. "Well-to-Wheel Greenhouse Gas Emissions of Electric versus Combustion Vehicles from 2018 to 2030 in the US." *Journal of Environmental Management* 308:114592. doi:10.1016/J.JENVMAN.2022.114592.
- Clemson University. 2014. "Clemson Vehicular Electronics Laboratory." <https://cecas.clemson.edu/cvel/auto/systems/auto-systems.html>.
- Dr. Nimitha. 2024. "India Semiconductor Workforce Development Program."
- European Commission. 2023. *European Chips Act*. [https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act\\_en](https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en).
- Glenn Burm. 2022. *State of the Semiconductor Industry Trends and Drivers Shaping the Semiconductor Landscape*. <https://www.pwc.com/gx/en/industries/technology/state-of-the-semiconductor-industry-report.pdf>.
- IEA(2023). 2023. *Global EV Outlook 2023*. Paris.
- IHS Markit. 2023. "Automotive Semiconductor Market Tracker - January 2023." <https://autotechinsight.ihsmarkit.com/shop/product/5003356/automotive-semiconductor-market-tracker-january-2023>.
- International Trade Administration. 2023. "India - Semiconductor and Electronics Industry." <https://www.trade.gov/market-intelligence/india-semiconductor-and-electronics-industry>.
- IQAir. 2024. *2023 World Air Quality Report*. <https://www.iqair.com/in-en/world-most-polluted-cities>.
- ISM. 2022. "India Semiconductor Mission." <https://ism.gov.in/>.
- Jaroslav Ramik. 2020. *Pairwise Comparisons Method Theory and Applications in Decision Making*.
- Kumar, Rohan, Ammara Kanwal, Muhammad Asim, Mohsin Pervez, M. A. Mujtaba, Yasser Fouad, and M. A. Kalam. 2024. "Transforming the Transportation Sector: Mitigating Greenhouse Gas Emissions through Electric Vehicles (EVs) and Exploring Sustainable Pathways." *AIP Advances* 14(3). doi:10.1063/5.0193506.
- Lincoln Clark, and Mark Gibson. 2022. *Semiconductor Industry Pulse Report*. United States. <https://assets.kpmg/content/dam/kpmg/es/pdf/2022/06/semiconductor-industry-pulse-gsa.pdf>.
- Little, Arthur D., Shinichi Akayama, Daniel Chow, and Subrat Gupta. n.d. *Strategizing for Growth While Building Resilience in the Rapidly Evolving Industry 2024*.
- Liu, Wen Hsien. 2005. "Determinants of the Semiconductor Industry Cycles." *Journal of Policy Modeling* 27(7). doi:10.1016/j.jpolmod.2005.05.009.
- Mark Wakefield. 2021. *SEMICONDUCTOR SHORTAGES TO COST THE AUTO INDUSTRY BILLIONS*. Newyork. <https://www.alixpartners.com/media-center/press-releases/press-release-shortages-related-to-semiconductors-to-cost-the-auto-industry-210-billion-in-revenues-this-year-says-new-alixpartners-forecast/>.
- Mason, Mark. 2010. "Sample Size and Saturation in PhD Studies Using Qualitative Interviews." <https://www.qualitative-research.net/index.php/fqs/article/view/1428/3028>.
- Mehrbakhsh Nilashi, and Rabab Ali Abumalloh. 2024. "Using DEMATEL, Clustering, and Fuzzy Logic for Supply Chain Evaluation of Electric Vehicles: A SCOR Model." *AIMS Environmental Science* 11.
- Meity. 2022. "Indian Semiconductor Mission." <https://ism.gov.in/>.
- Ministerial, Clean Energy. 2017. "EV30@ 30 Campaign." *Beijing* 19:2018.
- Mittelstaedt, John D., Clifford J. Shultz, William E. Kilbourne, and Mark Peterson. 2014. "Sustainability as Megatrend: Two Schools of Macromarketing Thought." *Journal of Macromarketing* 34(3):253-64.
- Nathan Associates. 2016. *Beyond Borders Global Semiconductor Supply Chain*. [www.semiconductors.org](http://www.semiconductors.org).
- Neeraj Bansal. 2024. "Why India Needs an Indigenous Semiconductor Ecosystem to Fuel Its EV Transition?" <https://kpmg.com/in/en/blogs/home/posts/2024/11/why-india-needs-an-indigenous-semiconductor-ecosystem-to-fuel-its-ev-transition.html?form=MG0AV3>.
- Niti Aayog, BCG, ADB, Natarajan Sankar, Sushma Vasudevan, and Sabhyasachi Mitra. 2022. *Promoting Clean Energy Usage Through Accelerated Localization of E-Mobility Value Chain*.
- Odrej Burkacky, Julia Dragon, and Nikolaus Lehmann. 2022. "The Semiconductor Decade: A Trillion-Dollar Industry." <https://www.mckinsey.com/industries/semiconductors/our-insights/the-semiconductor-decade-a-trillion-dollar-industry#/>.
- Omri Wallach. 2021. "Visualizing The Global Semiconductor Supply Chain." <https://www.visualcapitalist.com/sp/visualizing-the-global-semiconductor-supply-chain/>.
- Ondrej Burkacky, and Johannes Deichmann. 2022. *Semiconductor Shortage: How the Automotive Industry Can Succeed*.
- Panchal, Nishi, Pranav Topre, and Golam Kabir. 2024. "Evaluation of Semiconductor Risk Mitigation Strategies in the Electric Vehicle Supply Chain." P. 30 in *ICIMP 2024*. Basel Switzerland: MDPI.
- Peter Brown. 2021. "Semiconductor Spending in Cars to Rise 55.6% by 2026." <https://electronics360.globalspec.com/article/17216/semiconductor-spending-in-cars-to-rise-55-6-by-2026#:~:text=A%20car%20today%20features%20an%20average%20of%20%24450,%E2%80%94%20according%20to%20new%20research%20from%20Yole%20D%C3%A9veloppement>.

- Raj Varadarajan, and Jacob Koch-Weser. 2024. *Emerging Resilience in the Semiconductor Supply Chain*. <https://www.bcg.com/publications/2024/emerging-resilience-in-semiconductor-supply-chain>.
- Rossi, Luciano Andrés, Rachel M. Frank, and David Wilke. 2021. "Evaluation and Management of Glenohumeral Instability With Associated Bone Loss: An Expert Consensus Statement Using the Modified Delphi Technique." *Arthroscopy - Journal of Arthroscopic and Related Surgery* 37(6):1719-28. doi:10.1016/j.arthro.2020.12.237.
- Sarafrazi, Azam, Arash Habibi, and Sedigheh Izadyar. 2014. *Delphi Technique Theoretical Framework in Qualitative Research*. [www.theijes.com](http://www.theijes.com).
- Shieh, Jiunn I., Hsin Hung Wu, and Kuan Kai Huang. 2010. "A DEMATEL Method in Identifying Key Success Factors of Hospital Service Quality." *Knowledge-Based Systems* 23(3). doi:10.1016/j.knosys.2010.01.013.
- Shivani Parashar. 2022. *Consumption of Indian Semiconductor Components to Climb to \$300-Billion Cumulative Revenue During 2021-2026*. New Delhi. <https://www.counterpointresearch.com/indian-semiconductor-components-market-300bn-2021-2026/>.
- SIA. 2023. "Stages of Semiconductor Production." <https://www.semiconductors.org/semiconductors-101/what-is-a-semiconductor/>.
- ST Micro Electronics. 2023. "How Semiconductor Technology Is Accelerating Electric Vehicle Growth."
- STEPHEN EZELL. 2020. *An Allied Approach to Semiconductor Leadership*. <https://www2.itif.org/2020-allied-approach-semiconductor-leadership.pdf>.
- Sunil Pathak. 2024. "Building an Industry Ready Workforce ." *ETHR World*, November.
- Tan, Hao, and John A. Mathews. 2010. "Cyclical Industrial Dynamics: The Case of the Global Semiconductor Industry." *Technological Forecasting and Social Change* 77(2). doi:10.1016/j.techfore.2009.08.003.
- U.S. Department of Commerce. 2022. *VISION FOR SUCCESS: COMMERCIAL FABRICATION FACILITIES*. [https://www.nist.gov/system/files/documents/2023/02/28/Vision\\_for\\_Success-Commercial\\_Fabrication\\_Facilities.pdf](https://www.nist.gov/system/files/documents/2023/02/28/Vision_for_Success-Commercial_Fabrication_Facilities.pdf).
- Vaismoradi, Mojtaba, Jacqueline Jones, Hannele Turunen, and Sherrill Snelgrove. 2016. "Theme Development in Qualitative Content Analysis and Thematic Analysis." *Journal of Nursing Education and Practice* 6(5). doi:10.5430/jnep.v6n5p100.
- Vidushi Saxena. 2024. "Semiconductor Industry in India: Incentives and Key Players." <https://www.bisinfotech.com/semiconductor-industry-in-india-incentives-and-key-players/?form=MG0AV3>.
- Vinodkumar Ramachandran. 2022. *Way Ahead for Global Automotive Industry amid Semiconductor Chip Shortage*.
- World Economic Forum. 2022. *When the Chips Are down: How the Semiconductor Industry Is Dealing with a Worldwide Shortage*. <https://www.weforum.org/stories/2022/02/semiconductor-chip-shortage-supply-chain/>.