TU Delft

MASTER THESIS

BARRIERS AND STRATEGIES FOR THE MARKET DIFFUSION OF SOLAR ELECTRIC VEHICLES IN INDIA

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Barriers and Strategies for The Market Diffusion of Solar Electric Vehicles in India

by

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This thesis project marks the final phase of my journey in the MSc. Sustainable Energy Technology program at Delft University of Technology. As an enthusiast of automobiles, and sustainable energy, my interest and passion in combining these two technologies resulted in the idea of pursuing this thesis on Solar Electric Vehicles (SEV). Recognizing the imperative to integrate SEVs into our transportation networks, along with the escalating demand for electric vehicle innovation in India, led me to select this specific geographical context for my thesis.

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Executive Summary

The transportation sector has been known to be one of the most emission-intensive sectors. Within this sector, road transportation accounts for 45% of the total emissions. Switching to electric mobility is one of the solutions that could potentially cut down the emissions, especially in countries like India, which accounts for 7.3% of annual global emissions. However, technological challenges associated with Electric Vehicles (EVs) could potentially hinder the growth and slow down the transition to electric mobility. Solar Electric Vehicles (SEVs) have the potential and the ability to deal with the challenges EVs have encountered. In this thesis, their potential is studied by exploring the socio-technical conditions that affect the market diffusion of SEVs in India. Hence these socio-technical conditions are studied in detail through the Technological Innovation Systems (TIS) framework. In order to apply this framework, and identify the conditions which influence the market diffusion of SEVs, the following main research question was raised:

What are the socio-technical conditions that affect the market diffusion of Solar Electric Vehicles in the Indian market?

A qualitative research approach was followed in order to gather relevant information on these socio-technical conditions namely, barriers, opportunities, strategies, and the perspectives/stakeholders involved that could potentially influence the large-scale diffusion of SEVs in India. This thesis was conducted in four different phases, with desk research and expert interviews as the main research methods.

Firstly, the current status of EVs and their similarities with SEVs were explored, and the favorable policies supporting the development and diffusion of electric vehicles. It has been identified that solar EVs have a similar base architecture as that of battery EVs, with a solar panel as an additional component, often incorporated into the roof of the vehicle. Having an additional power source (solar panel) increases the value of the vehicle as SEVs have two sources of power when compared to the traditional EVs. Although there have been multiple attempts at commercializing SEVs, globally, they are yet to be introduced into the Indian market.

Several frameworks focused on technological innovations discussed in the literature were reviewed in order to determine the conditions that influence the market diffusion of SEVs in India. The TIS framework proposed by Ortt and Kamp (2022) was used to research the socio-technical conditions surrounding a radical innovation, in the context of a developing country (India). The niche strategy framework proposed by Ortt et al. (2013) was used to identify and extend the list of strategies applicable to commercialize high-tech products. And, the Best Strategy framework proposed by Dwisatyawati (2022), was used to formulate and validate the links between the identified barriers and strategies.

By studying the characteristics of disruptive technology, it was found that SEVs could be classified under disruptive technologies. Therefore, the elements (TIS building blocks, influencing conditions) surrounding a technological innovation, proposed by Ortt & Kamp (2022), were

investigated further to understand their influence on the market diffusion of SEVs. Determining the status (completeness) of the building blocks is crucial to understand whether or not, a large-scale diffusion is possible.

The seven TIS building blocks are (1) product performance and quality, (2) product price, (3) production system, (4) complementary products and services, (5) network formation and coordination, (6) customers, and (7) innovation-specific institutions. In addition to that, the seven influencing conditions are (1) knowledge and awareness of technology (2) knowledge and awareness of application and market, (3) natural, human, and financial resources, (4) competition (5) macro-economic and strategic aspects, (6) socio-cultural aspects, and (7) accidents and events.

The barriers, their underlying influencing conditions, and the affected TIS building blocks were researched further, and linked based on the guidelines provided in the literature (Schulz (2019)). Ultimately, this resulted in the linking of the barriers with their underlying causes. Also, a certain ranking/level of threat according to experts (from high to low) was given to each barrier to understand the threat they pose to the large-scale diffusion of SEVs in India. Based on the rankings given by the experts, the status of TIS building blocks for SEVs in India was determined. Ultimately, it was found that out of 7 TIS building blocks, 2 are incomplete (product price and production system), 4 are partially complete (product performance and quality, network formation and coordination, customers, and innovation-specific institutions) and only 1 of them is fully complete (complementary products and services). The price-sensitive nature of the Indian market and the high upfront cost of the vehicle pose an immediate threat to SEV technology diffusion. Similarly, the threat level of other barriers discussed in this thesis such as 'lack of (technical) knowledge and awareness', 'lack of competition', and 'lack of collaboration among stakeholders' have been identified to be high. However, due to the availability of repair/service and maintenance, and the less reliance of SEVs on the charging infrastructure, the threat level of those barriers is considered to be low. Through such analysis, a total of 24 barriers have been identified with different levels of threat (from high to low), hindering the large-scale diffusion of SEVs in India.

According to Ortt et al. (2013), and Ortt & Kamp (2022), early niches appear when the TIS building blocks are not complete, ultimately resulting in hampered large-scale diffusion processes. However, it was also proposed that certain (niche) strategies can be implemented to circumvent those barriers. In this thesis, such strategies were investigated further and classified into the perspectives of the government, industry, and customers. After carefully analyzing their relevance to SEVs, a total of 34 strategies were proposed and validated through expert interviews. An extra layer of validation has also been provided through case studies on solar mobility companies, Aptera Motors, and Lightyear. These case studies were used to validate the identified theoretical strategies by justifying their implementation in the SEV market.

In order to overcome the identified barriers, using the identified strategies, there are several links possible between them. These links were identified by analyzing the underlying cause of those barriers and proposing several relevant strategies for every underlying influencing condition. A certain guideline was followed to link the strategies with the barriers, based on the rubrics provided by Dwisatyawati (2022). However, this guideline was primarily proposed with the perspective of the industry in consideration by Dwisatyawati (2022). Therefore, this guideline was followed to propose all the relevant links between the strategies with the barriers and has been extended to all the perspectives identified in this thesis. After framing such links it was evident that more than one strategy can be implemented to circumvent each barrier. Later, these links were validated using expert opinions on what they perceived to be the most

important strategy. Ultimately, the guideline that was followed and the opinions from the expert interviews paved the way to identify the important strategy decision per barrier.

The rankings provided for these strategies are (in the order of their priority) as follows: (1) Finance sourcing strategy, economic/financial incentives strategy; (2) Research and development (niche) strategy; (3) Partnerships niche strategy; (4) Marketing strategy, word of mouth strategy, promotion/awareness campaign strategy, geographical niche strategy, continuous user engagement strategy; (5) Product variants strategy. The important strategy decision per barrier can be made by considering the strategies that were given a highest ranking, and varying if the highly-ranked strategy is present in the list of relevant strategies linked for each individual barrier. In the case when multiple strategies are given the same ranking, the important strategy decision is made by selecting the a strategy that can benefit multiple stakeholders upon its implementation.

It was identified that the barriers and strategies associated with the financial aspects are some of the crucial socio-technical conditions having a major influence on the large-scale diffusion of SEVs. It was also evident that SEVs have a huge potential to disrupt the urban mobility market (which falls within the geographical scope of this thesis) as the purchasing power of the population living in the urban areas in India is higher than that of the rural areas. For instance, the high upfront cost of the vehicle prevents potential customers from purchasing an SEV. Therefore, SEVs with high purchase costs (>17000 EUR) are less likely to succeed in the mass market. However, introducing affordable financing schemes or offering the vehicle at a lower cost, facilitates the middle-class Indian consumer an opportunity to purchase the vehicle, thereby removing the immediate threat to the large-scale diffusion of SEVs.

By analyzing all the barriers to SEVs, a vicious cycle of barriers (pattern) was identified, where each barrier contributes to another, making it challenging to break this loop to facilitate the growth of the SEV industry in India. For instance, limited developments in the technology and limited availability of variants, affect the decision of the policy makers, ultimately, resulting in less awareness among potential end users. Due to the lack of awareness, creating a demand would be challenging, ultimately preventing the companies from taking the necessary initiatives. The list of strategies (discussed above) in their order of priority can be incorporated into the process of breaking this vicious cycle and addressing the barriers identified in this thesis. Ultimately, the recommendations originating from this key finding are provided to each of the stakeholders/perspectives identified in this thesis.

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List of Abbreviations

AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AMP	Automotive Mission Plan
BWM	Best-Worst Method
DHI	Department of Heavy Industries
EMA	Exploratory Modeling and Analysis
EVs	Electric Vehicles
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
ICEVs	Internal Combustion Engine Vehicles
IDOs	International aid and Development Organizations
ISM	Interpretive Structural Modeling
MDCM	Multi-Criteria Decision Making
NACS	North American Charging Standard
NBEM	National Board for Electric Mobility
NEMMP	National Electric Mobility Mission Plan
NGOs	Non-Governmental Organizations
RECC	Reva Electric Car Company
SETs	Sustainable Energy Technologies
SEVs	Solar Electric Vehicles
TIS	Technological Innovation Systems

1 Introduction

1.1 General background

If there is one major challenge that humanity is facing currently it is climate change. From the Northern to Southern hemispheres, and from east to west, almost every region on Earth has seen the consequences of climate change due to global warming. Although global warming was noticed during the late 19th century, it wasn't until after rapid industrialization and globalization that the consequences were realized (Bose, 2010). The rapid increase in global temperatures in the 1980s and the resulting droughts, wildfires, and watershed events led to the stark realization of climate change ("Climate", 2017). Now, the causes of climate change are manifold. However, the burning of fossil fuels such as coal, oil, and gas accounts for the highest contribution to climate change, and as a result, the emission of large amounts of greenhouse gases (Akpan, 2012).

Burning of these fuels has been essential in almost every sector to generate the required energy. However, the consequences due to that have been ignored, at least until the late 20th century (Carvalho, 2017). Now, there are several sectors that are energy (emission) intensive such as electricity, industry, transport, commercial, residential, etc. Among all these sectors, transportation has been recorded to be a significant emissions-intensive sector accounting for one-fifth of global greenhouse gas emissions (Bilgen, 2014). If we look closer into the transportation sector, emissions from road transport account for about 45% of the whole sector, while the remaining comes from aviation, rail travel, and freight (Ritchie et al., 2023). Therefore, the focus of this research has been limited to road transportation.

One of the solutions for limiting these emissions is to electrify the transportation sector by phasing out the Internal Combustion Engine Vehicles responsible for the release of greenhouse gases (Duarte Souza Alvarenga Santos, 2021). Therefore, several countries and the big players in the automobile field are transitioning toward electric mobility (Dijk et al., 2013). Although the invention of electric vehicles dates back to the early 1800s, they did not gain the importance and popularity they currently have, until the late 20th century (Simpson et al, 2014). Due to the high availability and affordability of oil and gas production in the US and the OPEC (The Organization of Petroleum Exporting Countries), during the early 20th century, the majority of the vehicles on the road ever since have been Internal Combustion Engine Vehicles (Mirchi et al, 2012). As a result, the sources of petroleum and oil have been exploited rapidly, which led to their high prices and scarcity. Therefore, to reach energy independence, technologies with a better fuel economy, and lower fuel prices were explored (Alliance, 2019). This resulted in a gradual (political and technological) shift towards hybrid and electric vehicles. General Motors (GM) was one of the pioneers in the modern electric vehicle industry. Although GM's first model EV1 did not achieve the anticipated success in reaching the mass market, it started the (modern) EV revolution (Edelstein, 2021). It wasn't until the release and the worldwide success of Toyota's hybrid electric vehicle Prius in 2000, EVs didn't gain the awareness and attention they needed (Danstrong, 2013). Toyota Prius set the benchmark for most of the EVs that originated ever since.

As batteries are an essential component within an electric vehicle, be it, Hybrid Electric Vehicles (HEVs), Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Fuel Cell Electric Vehicles (FCEVs), and also Solar Electric Vehicles (SEVs), any change in the battery market has a direct impact on the EV market (Melin et al., 2021). Therefore, an increase or decrease in battery prices affects the growth of EVs accordingly. The cost of batteries, especially Lithium-ion batteries, has proven to continuously decline, year by year, as there are more technological advancements that resulted in smaller sizes and higher capacity when compared to two to three decades ago. For instance, the cost of Lithium-ion batteries per kWh in 1991 was close to $7500, while the same costs about $150 now (Nykvist et al., 2015). With this decline, EVs are close to their tipping point in competing with ICEVs (Carrington, 2021). This rapid decline in the prices of batteries (and the overall cost of an EV) encouraged many automobile manufacturers to consider producing more EVs, and people to buy EVs over ICEVs.

Although it is anticipated that EVs will solve the problems associated with greenhouse gas emissions and soaring oil and gas prices, there are a few drawbacks to EV technology. For example, one of the barriers is the range anxiety for the EV owner due to the limited capacity of batteries (energy for propulsion) when compared to the ICEV counterpart which limits the possibility of driving long ranges on a single charge (Goel et al., 2021). In addition to that, higher charging times have also proven to be a barrier to purchasing an EV. Charging times are proportional to the size of the batteries. Hence larger batteries will require more time to charge from an empty state to a reasonably higher or full state (Goel et al., 2021). Another (external) barrier is the lack of adequate (and sustainable) grid infrastructure to charge the EVs whenever necessary, especially during peak demand hours. Therefore, researching the capability of Solar Electric Vehicles (SEVs) and their potential to eliminate some of the barriers that EVs encounter is crucial (Newman, n.d.).

SEVs, along with the most common features of an EV, also have an additional power source; solar modules over the roof/surface of the vehicle (Newman, n.d.). These solar modules convert the sunlight into useful electrical energy by charging the battery and powering electric motors to propel the vehicle forward. SEVs came to light in 1985 during the first solar car race in Switzerland (Heinrich et al. 2020). Due to the high costs and low yield of solar technology, it was almost impossible to introduce them to the market. However, the cost of solar technology decreased over time, and now, it is cheaper than ever (Barker et al., 2005). This reduction in the price and increase in the efficiency of solar technology is a great argument for the development of SEVs by companies such as Lightyear, Sono Motors, and Aptera Motors (Bringam, 2022). The well-known benefit of SEVs is that their overall carbon emissions are much lower compared to ICEVs (Newman, n.d.). What makes SEVs stand out is the additional range provided by the solar panels. Newman (n.d.) claims that the solar yield could be up to 20000 km per year just from solar energy, depending on the size and the efficiency of the solar roof. While most of the solar range is obtained during sunny days (summer), it has also been observed that the owner of the vehicle can save electricity costs from charging. This, in turn, would cut down the frequency of plug-ins to charge the vehicle by 23-40%. Overall, they are capable of reducing the burden on the electricity grid caused by EVs, and (potentially) can assist the grid by providing the energy back to the grid (Vehicle-to-grid) whenever necessary.

Although there are certain benefits of SEVs, there are a few limitations within the technology itself. The geographical location where SEVs are in use must have a considerable amount of solar irradiation for the vehicle to run on solar energy. Therefore, the market for such vehicles is predominantly limited to countries with moderate to high solar irradiation. Hence sunnier

countries such as Spain, Morocco, Australia, Indonesia, India, etc are seen as the potential market for such vehicles.

1.2 Climate change in India and EV development

Over the past three decades, the realization of climate change in India has occurred due to several abnormal conditions of living such the drastic changes in the temperature, ocean warming, sea level rise, changes in rainfall, droughts, etc (Krishnan et al., 2023). To tackle the problems associated with climate change, the Government of India (GOI) took measures by increasing the share of renewable energy (primarily the energy generated from wind and solar) and transitioning to electric mobility (Vidhi et al., 2018).

India's current CO_2 emissions are close to 2.7 billion tons, about ten times higher than the emissions in 1980, which accounts for 7.3% of annual global emissions (Ritchie et al., 2020). The burning of coal and oil is primarily responsible for these emissions. Although usage of coal is predicted to increase in the coming years, the Indian government plans to curb the overall emissions by increasing the capacity of renewable energy to 500 GW, and expanding the forests for them to absorb close to 3 billion tons of CO_2 by 2030 (Luthra, 2022). Out of all the sectors in India, power, industry, and transportation are by far the largest emitting sectors (Ritchie et al., 2020). Switching from fossil fuel-powered plants to renewables to produce power and relying on energy from renewables for industrial purposes would limit the CO_2 emissions to a greater extent in power and industry sectors. Similarly, transitioning to electric mobility will limit tailpipe emissions from the transportation sector. Due to the increased awareness and the necessity many countries, along with India, are currently striving to transition to electric mobility.

1.3 Problem definition

After establishing the importance of the transition to electric mobility in India, it is crucial to identify and address the challenges to this transition. After investigating this further, it was identified that the EV sector in India is in its nascent stage (Chaturvedi et al. 2022). Technological innovations supporting and complementing the development of the EV sector are crucial and are needed in order for the technology to mature. SEVs have the potential to address the challenges that the EV sector is encountering, and consequently, the potential to accelerate India's transition to electric mobility. Since SEVs are an up-and-coming technology, globally, the author of the current research took an interest in investigating the feasibility of SEV technology in India. Therefore, through this research, the author aims to study the market conditions and different factors that influence the adoption of SEVs in India. As SEVs are still in the early stages of technological advancement, certain challenges are likely to be anticipated in the process of their introduction and large-scale diffusion. In order to address those challenges, certain strategies that apply to commercialize SEV technology have to be researched and developed (Ertmer, 1999). Therefore, the author of the current work aims to explore the barriers and the strategies that circumvent those barriers, in this thesis.

1.4 Knowledge gap and research objective

In order to understand the success of SEVs in a particular region, it is crucial to study the technologies that are closely associated with SEVs, such as electric vehicles and solar photovoltaics (PV). Even though the EV and solar PV markets (individually) have experienced growth due to extensive research and development, backed by the policy initiatives of the Government of India, SEVs have gained little to no attention. The extent of the attention and interest in SEVs has been limited to the prototypes developed by students across various universities in India and other individual small-scale efforts (Prajapati et al., 2020).

Prajapati et al. (2020) discussed the successful (non-commercial) implementation of various solar vehicles through case studies across India. These case studies demonstrate the huge potential that SEVs have in India (Prajapati et al., 2020). In addition to that, the geographical advantage due to the high solar irradiation makes India an attractive market for SEVs. Although the introduction of SEVs into the Indian automobile market is currently pending, they have the potential to transform the automobile sector and contribute to the transition toward India's electric mobility. By the end of this thesis research, the knowledge gap in this area will be filled, and a detailed explanation of the conditions that influence the entry of SEVs into the Indian market will be provided.

The knowledge gap described above has been identified during the initial literature survey. During the literature survey, the following search query,

("Barriers OR challenges") AND/OR ("Strategies") AND ("mass adoption" OR "development" OR "market" OR "market diffusion" OR "introduction") AND ("Solar Electric Vehicles" OR "Solar cars" or "Vehicle Integrated Photovoltaics") AND India,

has been used. From the multiple combinations of such search queries, the existing literature reveals a significant gap in research pertaining to the Indian market. This knowledge gap, later, was also validated from the interviews with experts.

1.5 Research questions and sub-research questions

Based on the identified research gap in the literature, the following research question(s) are formulated to get the most out of the research and address the knowledge gap. These questions will be answered primarily through desk research, followed by expert interviews. In the case of a lack of data, valid assumptions will be extrapolated from the industries or technologies that are closely associated with SEVs, such as electric vehicles and solar PV, to draw conclusions. This resulted in framing the main research question:

"What are the socio-technical conditions that affect the market diffusion of Solar Electric Vehicles in the Indian market?"

In order to understand the strategies that are applied for market diffusion, it is crucial to study the barriers that prevent SEVs from entering the market. After identifying the barriers, the corresponding strategies will be proposed to address those barriers. This discussion will be based on the answers to the following questions.

1. Why does solar mobility present a viable option, and how can parallels between the electric vehicle (EV) sector and Solar Electric Vehicles (SEVs) be drawn to understand their applicability and potential in India?

2. What according to the existing theories in literature could be labeled as barriers that hinder and opportunities that facilitate the introduction and diffusion of SEVs in India?

3. What are the strategies available to address the barriers faced by SEVs (high-tech innovations) according to the existing literature? How can these identified strategies be used to develop and diffuse SEV technology at a large scale in India?

4. Based on existing frameworks, what are the possible links between the barriers and the strategies identified? From the established link between strategies and barriers, how can the best strategy be selected per barrier?

1.6 Research scope

In order to gather relevant data on SEV technology (through the main research methods, desk research, and expert interviews) a specific scope was established for this thesis. This section elaborates on the extent of this study.

1. **Focused perspectives**: The study concentrates on specific viewpoints, including those of government, customers, and industry stakeholders, in order to delve deeply into their roles and impact. Other stakeholders such as research, financial institutes, competitors, NGOs, and IDOs face their own barriers and can implement their own strategies, but due to targeted perspectives, those conditions are not explored in detail.

2. **Geographical focus**: The research is limited to the conditions prevalent in India and similar countries, narrowing down the context for analysis. Therefore, the findings are applicable mainly to developing countries like India and regions with ample sunlight. It may not fully encompass nations outside these criteria. In order to ensure uniformity throughout this thesis, the focus of this thesis is limited to the conditions of cities (urban areas) in India, as the conditions vary in rural areas based on the demography.

3. **Specific vehicle focus**: The research concentrates on Solar Electric Vehicles that share the foundational architecture of Battery Electric Vehicles, with the addition of solar panels, limiting its scope to this specific vehicle type. Moreover, the investigation pertains only to passenger cars and autocycles that can integrate solar technology, defining a specific category of vehicles under study.

4. **Aerodynamic aspect**: The aerodynamics of the vehicle highly influence the performance of the vehicle such as the driving speed, energy consumption, and related parameters. Therefore, such technical parameters and their influence on the socio-technical conditions of SEVs are not considered in this thesis.

5. **Current landscape (situation)**: The applicability of findings is primarily based on the current landscape and the current conditions of the market. As circumstances evolve, new barriers may emerge or fewer barriers may exist when compared to the present situation, therefore, necessitating adjustments in strategies.

1.7 Thesis structure

This section explains the structure followed throughout this thesis as shown in figure 1.1. Firstly, in Chapter 1, an introduction to this research is provided, along with the problem statement, research questions, and scope of this thesis. In Chapter 2, the research methodology is elaborated, while Chapter 3 focuses on the theoretical framework followed to conduct this thesis. Chapter 4 deals with the current status of the EV market in India, and its similarities with SEVs. In Chapter 5, theoretical barriers, and opportunities are explored, followed by the theoretical strategies from three different perspectives in Chapter 6. Expert interviews conducted during this thesis and the key findings from these interviews are discussed in Chapter 7. The results obtained from the analysis of the theoretical barriers, opportunities, and strategies including the key findings from the interviews are presented in Chapter 8. Ultimately, the conclusions obtained from this thesis are outlined in Chapter 9, along with the recommendations.

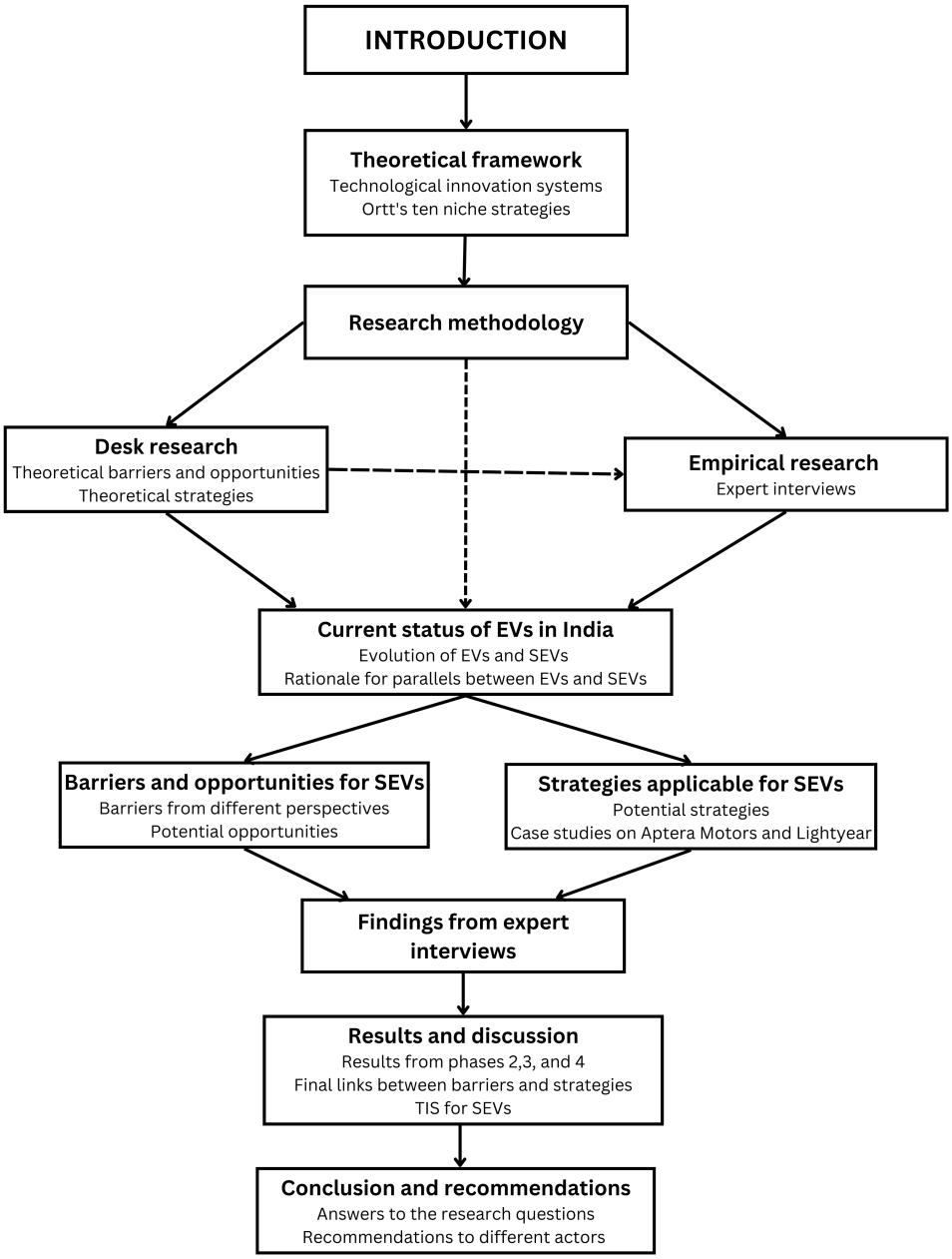

Figure 1.1: Thesis structure

2 Research Methodology

In this chapter of this thesis, the step-by-step approach followed to investigate the topic of "Barriers and Strategies for the market diffusion of Solar Electric Vehicles (SEVs) in India" is outlined. The research for this thesis is conducted throughout four phases. Due to the qualitative nature of this study, two research methods with the objective of gathering the data are identified and implemented, namely, desk research and empirical research (expert interviews). The research phases and the research methods are discussed in detail in the following sections. Section 2.1 outlines multiple phases in this thesis. Whereas in section 2.2, the literature review, and the perspectives identified from the literature are highlighted. Finally, in section 2.3, the approach followed to conduct expert interviews is highlighted.

2.1 Research Phases

In order to properly classify the information gathered during the research and to ensure a proper structure is maintained throughout the research, this thesis is conducted in four phases. The relevant literature identified is thoroughly reviewed in each phase. Expert interviews were conducted only during phases 2, 3, and 4.

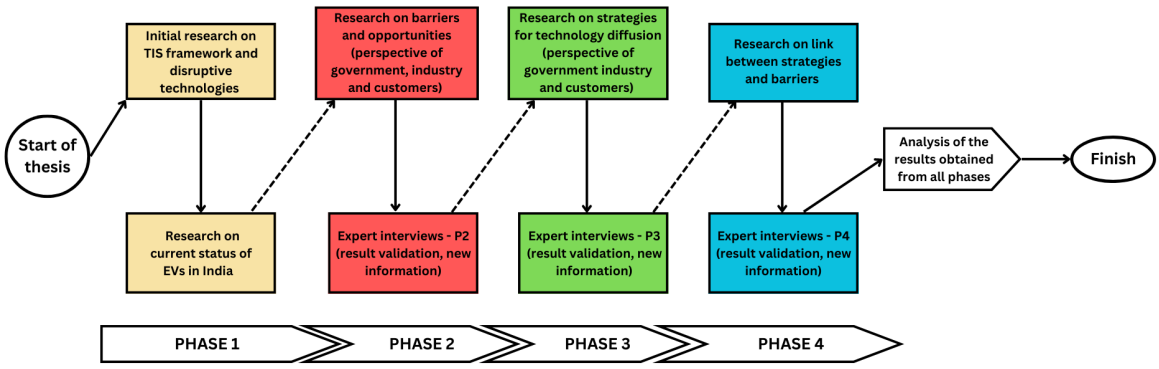

Figure 2.1: Research flow diagram

Phase One:

The research process began with a comprehensive review of the existing literature on Solar Electric Vehicles in order to gain a general understanding of the topic. It was observed that there was a scarcity of literature available, with only one notable work (Barriers and Strategies Analysis on Mass Adoption of Solar Electric Vehicles in Indonesia) by Dwisatyawati (2022).

Recognizing the need for suitable frameworks to guide the research, various frameworks that are applicable to the study were explored. Two frameworks, namely the Technological Innovation Systems (TIS) framework proposed by Ortt and Kamp, and the framework developed by Hekkert et al., were identified. Upon further research and review, it was determined that the TIS framework by Ortt and Kamp would be the most suitable for the current research.

The subsequent step involved examining master thesis documents that utilized the TIS framework to gain insights into its application. This analysis aimed to understand how the framework had been effectively employed in previous research. By leveraging the experiences and outcomes documented in these master theses, the author sought to enhance their understanding of the TIS framework's practical implementation and its relevance to the study of SEVs in India.

Phase Two:

In this phase, the author identified the barriers and opportunities of SEVs in India from various scientific literature related to SEVs, particularly electric vehicles. It was also crucial to identify the different perspectives from which the barriers can be studied. Therefore, SEV technology is studied from the perspective of companies (industry), government (policymakers), and customers. After classifying the identified literature according to the different perspectives, all the identified barriers relevant to SEVs are summarized in the chapter summary.

However, as the SEV industry is in its infancy, there is limited research and information available. Hence, the author conducted interviews with experts in the (solar) electric vehicle field to gather information and validate the results. The interviews included experts from the industry, the Ministry of Transport (policymakers), and academic researchers. The author believes that these interviews offered a valuable contribution to the literature as they provided a more in-depth understanding of the current state of SEVs in India.

The findings from the desk research and the interviews are summarized in the results section, where the completeness of the functions in the TIS framework is discussed. The TIS framework is employed to group (classify) the identified barriers, and the TIS building blocks together, using the influencing conditions that cause the barrier. Based on the level of impact of the barriers (validated from the interviews), the status of TIS building blocks for SEV technology in India is determined.

Phase Three:

The objective of this phase was to research the strategies used to diffuse a disruptive technology in the mass market. Ortt's ten niche strategies, and Dwisatyawati's (2022) Best Strategy Framework (elaborated on in section 3.4), are used as a basis for identifying the available strategies. Once all the available (and relevant) strategies are identified, a procedure is followed, similar to the steps taken during the second phase, i.e., validating the identified strategies with expert interviews. The desk research (studying various types of literature on theoretical strategies) along with expert interviews, are used as a basis to rank all the strategies identified. The author believes that this research provided a comprehensive understanding of the strategies used to diffuse disruptive technologies and how they can be applied to the SEV industry.

Phase Four:

In this phase, the author of the present work identified the link between the barriers and strategies and identified the best strategy (per barrier) based on the author's logical thinking supported by research findings and interviews. TIS framework was used as a basis to form the link between the barriers, their underlying conditions, and the affected TIS building blocks.

These links were later used to map all the applicable strategies that can circumvent a particular barrier. Also, the links proposed across multiple pieces of literature were reviewed to identify the logical strategy links that are applicable in circumventing the barriers to high-tech innovations. From the list of all the possible strategies to circumvent a barrier, the most important strategy is selected (per barrier) based on the ranking given to the identified strategies by the experts.

2.2 Desk research

In the literature review phase, several pieces of literature such as master thesis documents, and published articles related to the barriers and strategies were identified. From this research, different perspectives were identified according to various literature. Depending on the types of barriers faced, they are categorized into the barriers faced by industry (companies), government (policy makers), customers (technology users), as shown in Fig. 2.2. Firstly, the barriers that any disruptive technology encounters during the market entry phase are studied. In order to understand the barriers faced by Solar Electric Vehicles, the barriers faced by closely associated technologies (such as electric vehicles, and other renewable energy technologies) are studied in depth. From the literature search, it has been identified that various research has been conducted in line with the barriers associated with EV technology. The literature review was conducted in such a way that there is less overlap in the barriers identified from various literature, and only the articles/publications that highlight certain new barriers (different from the already identified barriers but relevant to a disruptive technology) are discussed.

The literature review on the potential strategies began by conducting a comprehensive search for strategies related to solar electric vehicles (SEVs) and sustainable energy technologies in general. Various academic literature (from TU Delft repository), research journals (Research Gate), and reputable websites (Google Scholar) were consulted to identify studies, articles, and reports relevant to strategies.

In summary, it became evident during the initial exploration that limited direct literature was available, specifically addressing the barriers and strategies for SEVs in the Indian context. Recognizing this research gap, the focus shifted towards summarizing the findings from existing literature on sustainable energy technologies and electric vehicles that were relevant to SEVs and adaptable to the Indian context. To ensure a comprehensive analysis, the findings from the existing literature were carefully evaluated. This approach facilitated the classification of strategies into three perspectives: government (policy makers), industry (companies), and customers.

2.2.1 Identification of perspectives from the literature

In this thesis, strategies and barriers for the market diffusion of Solar Electric vehicles (SEVs) have been identified from various perspectives, including industry (companies), government (policymakers), and customers (end users). Painuly (2001) acknowledges the perspective of the government and emphasizes the role of policymakers in facilitating the diffusion of Sustainable Energy Technologies (for example, SEVs). According to 't Veld (2020), the government holds the power to liberalize the markets and facilitate guaranteed markets for the actors (companies) entering the market. After realizing the importance of the role of government, it

has been identified to be a crucial perspective by the author of the present work. Therefore, the government (policymakers) perspective has been incorporated into this thesis.

Schulz (2019) highlights that the role of industry is crucial, and collaboration among multiple stakeholders is paramount in bringing in the research and development needed to support the growth of innovations such as SEVs (Dwisatyawati, 2022), ('t Veld, 2020). Acknowledging the role of various industry players in the market diffusion of SEVs, the industry (company) perspective has been incorporated into this thesis.

Krishna (2021) researched the perspective of customers on the adoption of electric vehicles. It was identified that end-user awareness and acceptance are at the heart of technology diffusion (Krishna, 2021). Therefore, the final perspective of customers (end users) has been added to this thesis. However, it was evident from the literature review that there are more perspectives that influence the mass adoption of SEVs such as the perspectives of investors, competitors, educational institutes, etc ('t Veld, 2020). While the focus of the thesis is primarily on the theories applicable to the industry, government, and customers, it is important to acknowledge the existence of other perspectives and their potential relevance to the research.

Ultimately, the thesis provides a comprehensive analysis of the diffusion of SEVs, focusing primarily on the industry, government, and customer perspectives. It is important to note that while perspectives such as investors, competitors, and educational institutes are recognized in the research, the thesis does not delve into these perspectives, in-depth. However, relevant findings from these perspectives that are deemed essential to the research objectives and contribute to the understanding of the diffusion of SEVs are incorporated and discussed within the corresponding sections.

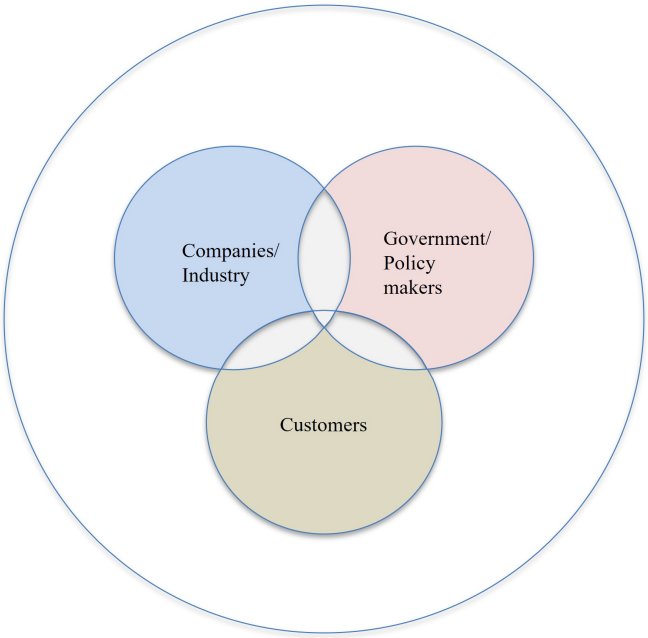

Figure 2.2: Multiple perspectives of the identified barriers and strategies

2.3 Expert interviews

This section explains the steps followed to gather information and validate the findings of this research through semi-structured qualitative interviews. According to Döringer (2020), such qualitative interviews are crucial in investigating the expertise and perspectives of the interviewees (experts) to understand the social reality of the topic in question (SEVs in this research) (Döringer, 2021). Semi-structured interviews offer the flexibility to ask open-ended questions to the interviewees, thereby allowing the interviewees to share their (in-depth) knowledge about the topic (Adams, 2015).

2.3.1 Interview structure

After selecting a particular expert for the interview, the following procedure has been followed to gather information and validation in the interviews. Firstly, the interview begins through the introduction, followed by briefing the interviewee on the thesis topic, and the structure of the interview. Once, the introduction part of the interview is done, open questions related to the (Solar) Electric Vehicles were asked. These questions were different (from interview to interview) based on the phase of the thesis, and also the expertise of the interviewee. As the interviews were conducted in phases, the questions asked during the interviews also changed, depending on the phase. For example, during phase 2 of this thesis, the research focus was primarily on the barriers and opportunities for SEVs in India. Therefore, the questions during the open discussion were also focused on the barriers and opportunities. As the experts chosen for the interviews were from different backgrounds, the questions also were focused on the area of their expertise. For example, during phase 3, in the interview with one of the experts, Co-founder and COO at Vayve Mobility, most of the questions revolved around the strategies that were applicable to SEVs, from an industry perspective. Overall, the open discussion part of the interview provided insights ranging from the policies, industry conditions, as well as the consumer's perception of SEVs.

Once the open discussion part of the interview is done, the discussion is focused on validating the theoretical findings (such as the barriers, and strategies based on the existing literature). This validation is used for analyzing the level of influence a particular strategy or barrier will have on the introduction and large-scale diffusion of SEVs. In figure 2.3, the flow of the expert interviews is shown.

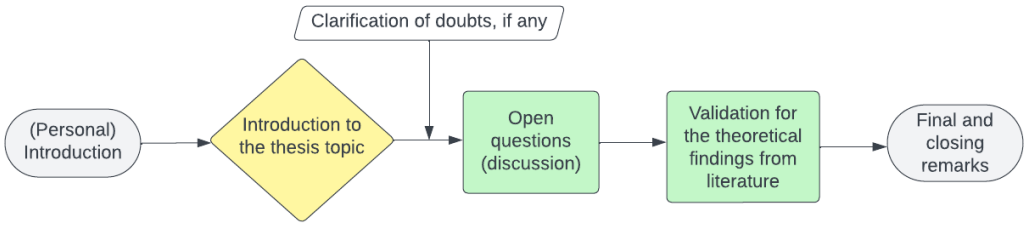

Figure 2.3: Flow of the semi-structured interview

As the discussion during the interview was based on the phase of the thesis and the expertise of the interviewee, the information and the validation received were also unique to a particular

interview. Table 2.1 provides an overview of the type and the purpose of each interview.

Table 2.1: Purpose of each interview

Interview purpose	Expert A	Expert B	Expert C	Expert D	Expert E	Expert F	Expert G (interview 1)	Expert G (Interview 2)	Expert H
(New) information on barriers	✓	✓					✓		✓
Validation of theoretical barriers from literature	✓	✓							
(New) information on strategies			✓	✓	✓	✓	✓		✓
Validation of theoretical strategies from literature			✓	✓		✓			
Recommendations for linking barriers and strategies							✓		✓
Validation of the theoretical links between barriers and strategies								✓	✓

2.3.2 Selection of experts

A certain process of selecting experts for interviews was followed to ensure a thorough exploration of Solar Electric Vehicles (SEVs). This process had three main steps.

- Firstly, experts whose knowledge was related to SEVs or other fields closely connected to them were researched using LinkedIn and also through the author's personal connections.
- Secondly, the positions and the roles of these experts in their respective organizations were considered. It was made sure that the experts selected were from different backgrounds and viewpoints, to ensure a well-rounded understanding of (Solar) Electric Vehicles from various angles.
- Most importantly, the selection was based on the availability of the experts and their willingness to participate and contribute their time and knowledge to this research.

A total of 36 experts were approached by the author of the present work. Out of all the experts approached 8 of them expressed their willingness and agreed to contribute to this research, resulting in a response success rate of 22.22%. Upon reviewing the feedback from several interviewees, it became evident that certain individuals preferred to maintain their anonymity, while others granted permission for their names to be disclosed. To ensure uniformity and coherence in the presentation of interview data within this thesis, the author of this study has opted to preserve the anonymity of all expert names. Therefore, the interviewees have been given the codes expert A, expert B, expert C, and so on, in the order (timeline) of the interviews conducted. Since all the selected experts were based outside the Netherlands, the Microsoft Teams platform was used to schedule, record, and transcribe, all the (online) interviews, after receiving consent from the interviewees. Each of these experts was given a color (consistent throughout this thesis) in order to identify their contribution to this research with ease.

Table 2.2: Background of the experts selected for the interviews

Interviewee	Role/designation	Associated organization (or) company	Interview timeline	No. of interviews
Expert A	Assistant Professor	Indian Institute of Technology (IIT), Dhanbad	May	1
Expert B	Deputy Director	Ministry of Transport, Delhi	May	1
Expert C	Consultant	Rocky Mountain Institute (RMI), Delhi	June	1
Expert D	Consultant	World Bank, Delhi	July	1
Expert E	Senior Research Associate	Evreporter, Gurugram	July	1
Expert F	Co-founder and COO	Vayve Mobility, Pune	July	1
Expert G	Associate Director - Electric Mobility	Shakti Sustainable Energy Foundation, Delhi	July/August	2
Expert H	Program Manager	Aptera Motors, Los Angeles	August	1

Expert A, an esteemed Assistant Professor at the prestigious Indian Institute of Technology, is an expert in sustainability and electric vehicle supply chain research within India. Their expertise aligns closely with the research focus of this thesis. Notably, a research article authored by expert A significantly contributed as a reference during research phase 2, underlining the relevance of their insights. This recognition of their valuable input led to the decision to select the interviewee, seeking deeper insights into the challenges and opportunities surrounding the mass adoption of (solar) electric vehicle technology.

Expert B, Deputy Director of Delhi Transport Infrastructure Development Corporation's EV cell, brings seven years of experience and a comprehensive background in electric mobility. His prior role in the Ministry of Power focused on charging policy implementation, adds a deep layer of expertise. Currently shaping Delhi's sustainable transportation policies, expert B's selection for this interview was driven by his exceptional insights from the perspective of a policymaker, which was vital for a comprehensive understanding of the role of government.

Expert C, currently serving as a Consultant at Rocky Mountains Institute (RMI) in India, possesses a unique expertise focused on policy advocacy for electric vehicles (EVs). With a distinct emphasis on international, national, and local policy evolution, particularly within India, their insights are crucial in understanding the dynamics of EV policies. Given their extensive knowledge and experience, expert C's insights into the current market conditions and strategies contributed valuable perspectives to the study.

Expert D possesses 14 years of experience in the electric vehicle (EV) and sustainability sectors. Notably, they have served as an independent consultant for reputable institutions like the World Bank and the World Resources Institute, focusing on EV-related projects. The interviewee's extensive experience in EVs, sustainability, and their recent roles with distinguished organizations such as the World Bank and the World Resources Institute made them a crucial addition to gathering insights on how the current market conditions could facilitate the adoption of SEVs.

Expert E, currently a senior research associate at EVrepoter.com, is an experienced professional with a master's degree in urban planning. Their expertise lies in researching, reporting, and quantitative analysis of electric mobility in India. With a history of working on automotive research and industry-related projects, their practical knowledge has been a great addition to this thesis.

Expert F is the Co-founder and COO of Vayve Mobility. With a proven track record spanning 15 years, Expert F is a senior global business leader who offers a wealth of expertise in marketing, cost-cutting, and risk mitigation across diverse market segments. As the Co-founder

and COO of the first SEV company in India, their insights were crucial in understanding the dynamics of the Indian EV sector from the point of view of a SEV company.

Expert G is currently working as associate director of the electric mobility program at Shakti Sustainable Energy Foundation. They have a history of working in the various verticals of the power and energy sector. With a master's degree in energy engineering, Expert G has over 10 years of experience in programs related to electric mobility and energy transition. With knowledge in both the power sector and the electric mobility sector, expert G's insights are a valuable addition in understanding the barriers the EV technology is currently facing, and strategies that are applicable in overcoming those barriers.

Expert H is currently working as a program manager at Aptera Motors. With a degree in industrial engineering, and experience working directly in the SEV industry, their insights directly contribute to understanding the barriers faced by Aptera Motors, as an SEV company, and the strategies Aptera Motors implemented to overcome those barriers.

During the interviews with all 8 experts, (hand-written) notes were taken on the important points and the new information that was highlighted by a particular expert. Upon taking such notes, after the interviews, the recordings of the interviews were carefully observed to fully comprehend the important points that were brought up by the expert. In the end, all the useful information collected from the interviews is tabulated in the tables in the chapter 7. The information from the interviews was used to identify the relevant barriers and strategies that were particularly highlighted by the experts, and later linked with the barriers and strategies identified from the literature. This consolidated the findings from the literature, and most importantly, confirmed that the findings from the literature are applicable specifically to SEVs. Additionally, these interviews were also used to validate the barriers and strategies that were not specifically discussed during the open discussion, and the experts were requested to rank the influence (of all the barriers and strategies) on the large-scale diffusion of SEVs from high to low. By doing so, the similarities and differences in the opinions of the experts were comprehended.

3 Theoretical Framework

In this chapter, the theoretical frameworks applicable to navigating the socio-technical conditions encountered by innovative technology such as SEVs are explored. Firstly, the concept of disruptive innovation is investigated in section 3.1. In section 3.2, a Technological Innovation Systems framework proposed by Ortt & Kamp (2022) is investigated further. Upon identifying the influencing conditions that are the underlying cause behind a barrier, the relationship between TIS building blocks, the influencing conditions, and the resulting barriers are explained in section 3.2.1. In the section 3.3, niche strategies proposed by Ortt et al. (2013) to commercialize high-tech products are studied. Finally, in section 3.4, the framework proposed by Dwistyawati (2022) is examined, and its relevance to this thesis is discussed.

3.1 Disruptive technologies

For any (new) technology to make an entry into the market, there are certain stages in the process, from technology ideation to product diffusion, that a product will go through. According to Peres et al. (2010), market diffusion of new and innovative products is the process of market penetration which is influenced by several factors including consumers and market players (Peres et al., 2010). In such a process, the innovation potentially faces several barriers to entering and diffusing in the market (Stringham et al., 2015). In order to overcome such barriers, certain frameworks have been proposed by researchers in the field of technological innovation. In this chapter, the frameworks which are closely associated with technology innovation are studied. The barriers and strategies identified from these frameworks will be discussed in detail in further chapters.

According to Hardman et al. (2013), if the newly introduced technology is capable of displacing the existing market leaders, by moving up the market, it can be classified as a 'disruptive technology'. Such disruptive technologies possess certain characteristics which account for their success in the market. Although these characteristics are commonly observed in successful disruptive technologies, it is not a requisite for successful technologies to exhibit such characteristics (Hardman et al., 2013). Modern automobiles were once considered a disruptive technology because, before the introduction of automobiles, horse-drawn carriages were predominantly used for transportation. Therefore, with the introduction of mass-produced automobiles, horse-drawn carriages were replaced gradually. Similarly, the potential of SEVs can be recognized by studying the seven characteristics of a disruptive technology defined by Hardman et. al (2013).

The characteristics of disruptive technology have been identified to be the (i) threat they pose to the incumbents, (ii) high initial cost, (iii) low quality, (iv) value addition to the customers, (v) gradual progression through different levels in a market, (vi) capacity to push existing market leaders into niche markets and (vii) possibility of eventually being replaced by new technology.

According to Hardman et al. (2013), these seven characteristics could be further narrowed down to three unique criteria that qualify a disruptive technology. They are:

- **Disruptive to market leaders**: Disruption can occur either if the company producing the innovative technology is different from that of the incumbent technology or due to the technology created by the same company as the existing market leaders.
- **Disruptive to end users**: Disruptive technologies also influence the change in the behavior of consumers or end users. This occurs either due to the improvement in the services offered by the technology (when compared to that of an incumbent) or the way the end users interact with the technology.
- **Disruptive to infrastructure**: Often, disruptive technologies require a new or improvement in the existing infrastructure. However, not all disruptive technologies demand new infrastructure.

A higher level of disruption could be expected depending on the more criteria a disruptive technology fulfills. However, for a technology to be truly disruptive, it must meet at least two of the three criteria mentioned above.

Firstly, the TIS framework is studied to identify where SEV technology currently stands in the market. This is done by applying TIS from multiple perspectives. Understanding the status of SEV technology is crucial in framing the strategies. In most cases, the status of a newly introduced technology in the market can be (often) compared to that of an incumbent or established competitor.

3.2 Technological Innovation System Framework

Radically new technological innovations, unlike the established incumbents, have been observed to go through a series of stages from their first introduction to the market until the large-scale diffusion. This time interval between the initial introduction and the diffusion stage can also be addressed as an adaptation phase (Ortt & Kamp, 2022). The Technological Innovation System (TIS) framework can be used to study the (niche) introduction strategies of radically new technological innovation.

According to Carlsson and Stankiewicz (1991), a technological innovation system is a dynamic network of actors involved in the generation, diffusion, and utilization of technology that are interrelated in a specific field.

The research on the relevant frameworks was conducted in order to understand the different perspectives from which the innovation can be studied. The requirement for this research was to utilize a framework that can facilitate the understanding of technology from multiple perspectives, such as companies, policymakers, and end users. Ortt and Kamp (2022) proposed the TIS framework to address a wider systems perspective, especially targeting radically new innovations. In this wider systems perspective, the market around the company is also addressed, including the network partners, customers, and supporting systems. Therefore, the perspectives of all the actors that are important in the formation of a system around technological innovation are considered. As the perspectives addressed by Ortt and Kamp (2022) align with the perspectives of this thesis research, their TIS framework is used as a basis for the present work's theoretical framework. Ortt and Kamp (2022) derived four structural

components that are present in TIS. They are (i) technology, (ii) a network of actors, (iii) supporting institutions, and (iv) demand for the technology.

Ortt and Kamp (2022) proposed seven building blocks that make up the TIS framework from the perspective of a company. The market introduction strategies are evaluated by analyzing the TIS building blocks, which are elaborated on below.

1. **Product performance and quality**: Companies aiming to introduce new technology into the market should launch the product by targeting a (sufficiently) high performance and quality in order to attract customers. The performance and the quality should be high enough for the customers to consider this a reasonable option over (alternative) competing technology.
2. **Product price**: Often when a new technology is introduced into the market the product price is initially high or expensive compared to similar (competing products). The high initial price (often) could be due to the financial and non-financial costs incurred by a company. Offering the product at a reasonable price is often necessary to achieve large-scale diffusion.
3. **Production system**: Another major building block of TIS is the ability to deliver good quality products in large quantities. It has been proven that eventually, the reduction in the price of the product will boost its competitiveness, and hence the demand. Therefore, establishing a production or manufacturing facility to keep up with the demand is a major step in large-scale diffusion.
4. **Complementary products and services**: Offering complementary products or services in various stages such as distribution, repair, maintenance, disposal, etc, will not only assist in technology diffusion but also help in aligning strategies of multiple innovations within the same firm.
5. **Network formation and coordination**: Coordination among the network of actors who share a similar vision is crucial in the successful diffusion of a product in the (mass) market. This coordination could be in terms of supplying raw materials, manufacturing or assembling the product parts, their distribution, and also providing complementary products or services.
6. **Customers**: Since a technology or product is (often) launched with the aim of solving a problem in a segment, customers associated with that segment are crucial in technology diffusion. The attractiveness of the product must be created in order for the customers to see its benefits, and to acquire and use the technology.
7. **Innovation-specific institutions**: Government policies, laws, standards, and regulations are crucial for technological innovation in order to facilitate its market introduction and diffusion. A stable innovation-specific institution with a (favorable) long-term supportive policy is essential for the market diffusion of a product.

All the seven TIS building blocks discussed above are crucial for the large-scale diffusion of radically new technology (Ortt & Kamp, 2022). On the other hand, if one or few of these building blocks or incomplete or incompatible with technological innovation, that can be regarded as a barrier. If innovation is not compatible, and in order for it to overcome these barriers, small-scale niche strategies are introduced to circumvent these barriers. Ortt and Kamp (2022) proposed a few influencing conditions that determine the type of niche-introduction strategy needed by understanding the cause of the barrier. These seven influencing conditions will be

studied in detail in the following section to understand the underlying causes of barriers to the market diffusion of SEVs in India.

3.2.1 Influencing conditions

In order to understand the cause behind a particular barrier, and to understand the reason why the barrier exists, seven influencing conditions were proposed in the TIS framework (Ortt & Kamp, 2022). Identifying such causes behind a barrier is crucial to formulate and propose suitable strategies. It is due to their "influence" on the TIS building blocks, in the framework they are referred to as influencing conditions. Schulz (2019) provides further insights into how a barrier is formed, and how these seven influencing conditions affect the TIS building blocks (also referred to as core factors), and in turn, form a barrier to large-scale diffusion. Insights from both Ortt & Kamp (2022) and Schulz (2019) are crucial to this study. Their frameworks serve as the foundational basis for elaborating the underlying causes of barriers specific to SEVs, as identified in this thesis.

Core and influencing factors proposed by Schulz (2019)

A barrier obstructing the large-scale diffusion process can be defined as a problem associated with the building blocks (core factors) of TIS which in turn is influenced by an inhibiting influencing condition (Schulz, 2019). According to Schulz (2019), a barrier consists of two elements, a core factor (B), also referred to as TIS building blocks by Ortt & Kamp (2022), and an inhibiting influencing condition (A), and the effect of such a barrier is the influence due to deficient core factor (C) as shown in fig 3.1. Each of these factors (often) consists of several smaller elements that together form the factor. For example, the factor 'product quality' can be divided into features, reliability, performance, conformance, durability, serviceability, aesthetics, and perceived quality. Each of these smaller elements influences the factor 'product quality' as a whole.

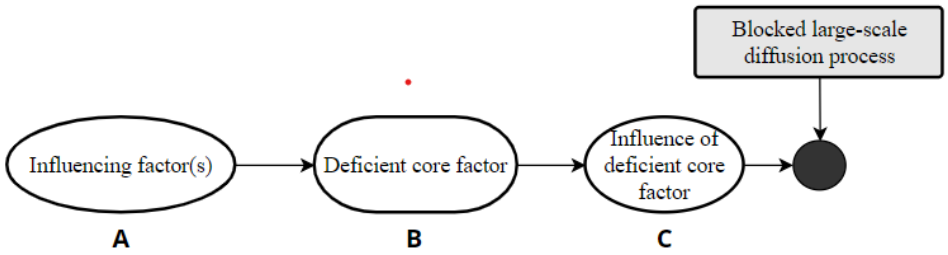

Figure 3.1: The element of a barrier (AB) and its influence (C) on the large-scale diffusion process by Schulz (2019)

The core factors, also called TIS building blocks, are elaborated in section 3.2. The influencing conditions are formed based on knowledge, resources, and macro-environmental conditions that affect the innovation system formation (Ortt & Kamp, 2022). These influencing conditions are elaborated on below in detail, and listed in the table 3.1.

1. **Knowledge and awareness of technology**: This refers to the fundamental and applied technological knowledge. The components such as product, production system, and complimentary products are the prime focus of fundamental knowledge. The factors such as developing, producing, repairing, maintaining, producing, and improving these components are applied technological knowledge. Such knowledge can be developed through experimentation and research and development, and can be transferred through education and training.
2. **Knowledge and awareness of application and market**: This factor refers to the knowledge pertaining to the application of innovation along with market structure and relevant actors involved. Learning by experimentation, learning by doing, using, and interacting with relevant actors are considered to be various elements within this factor. Lacking any of these elements among the relevant actors could hamper the large-scale diffusion of innovation.
3. **Natural, human, and financial resources**: Multiple resources are required for an innovation to be developed initially, and diffused in the market at a later stage. In order to create products, run production systems, and offer complimentary products, natural resources are crucial. Apart from natural resources, human resources with appropriate knowledge are required to develop these products. Most importantly, financial resources are essential in bringing natural and human resources together.
4. **Competition**: New innovations compete with incumbent technologies, especially while the formation of an innovation system. Another possibility for competition is the different versions of the new technology. Competition can sometimes be chaotic and hamper large-scale diffusion because of the formation of an alternative network of companies.
5. **Macro-economic and strategic aspects**: Macro-economic aspects such as economic recession and economic growth have a significant influence on the development of an innovation. Contemporary market structure and business strategies are taken into consideration while framing the strategic policies in various countries.
6. **Socio-cultural aspects**: Socio-cultural aspects are the (informal) norms and values that are essential to the customers and other relevant stakeholders within the innovation system. When compared to the laws, rules, and regulations, although socio-cultural aspects are more informal, they have a significant influence on market diffusion.
7. **Accidents and events**: Both internal (within a TIS) and external (outside a TIS) events are considered accidents. For example, accidents in a production facility or failure of the product can be considered internal accidents. On the other hand, wars and natural disasters are considered external accidents.

The insights obtained from studying all the influencing conditions in detail were used to formulate the links between the barriers, their underlying causes, and ultimately the affected TIS building blocks of SEVs in India. These links are discussed in detail in the section 8.1.

Table 3.1: TIS building blocks and influencing conditions proposed by Ortt & Kamp (2022)

Building blocks	Influencing conditions
Product performance and quality	Knowledge and awareness of technology
Product price	Knowledge and awareness of application and market
Production system	Natural, human, and financial resources
Complementary products and services	Competition
Network formation and coordination	Macro-economic and strategic aspects
Customers	Socio-cultural aspects
Specific institutional aspects	Accidents and events

3.3 Ten Niche Strategies To Commercialize New High-Tech Products

According to Ortt et al. (2013), strategies are crucial in the context of commercializing new high-tech products such as SEVs. Ortt et al. (2013) proposed niche strategies based on an assumption that these strategies come into the picture when the development, production, or large-scale diffusion and the usage of a new high-tech product are hindered. They provide a framework and direction for organizations to navigate the complexities of the market and effectively bring their products to customers. By studying the strategies proposed by Ortt et al. (2013), valuable insights, and guidance was obtained in selecting and implementing niche strategies, specifically tailored to the commercialization of high-tech products.

The lack of clarity due to the gaps in the scientific literature pertaining to different types of niche strategies and their compatibility with specific situations makes it challenging for companies to make informed decisions. Ortt's research aims to address these gaps by identifying generic actors, factors, and functions that play a role in commercialization and can hinder the large-scale diffusion of high-tech products (Ortt et al., 2013). By analyzing various market situations and historical cases, the study identifies ten generic niche strategies that can be applied in different situations. These niche strategies serve as a practical tool for companies to purposefully select the most appropriate strategy based on the specific context they are facing. These niche strategies are described in the table 3.2

Table 3.2: Ten niche strategies to commercialize new high-tech products (Ortt et al., 2013)

Generic Niche Strategies	Description
Demo, experiment and develop niche strategy	In situations where there is a limited understanding of the technology, leading to restricted product availability and limited functionality, this strategy can be employed. This approach involves showcasing the product to the public to address concerns about its limited performance quality. Experimentation facilitates ongoing product development, where enhancements can be made to improve functionality and overall quality.
Top niche strategy	A limited understanding of the technology hinders the product's availability at a reasonable cost, and also its production system. To overcome these challenges, top niche strategy can be implemented, offering customized, small-scale production for a specific high-end market segment. Alternatively, a skimming strategy can be employed to prioritize supplying a unique product to the top niche customers.
Subsidized niche strategy	Lack of knowledge and the resources required to develop the product predominantly affects the product price. This strategy can be adopted in such a way that the product can be subsidized to a particular segment of customers
Redesign niche strategy	This strategy facilitates the introduction of a simplified product version produced with available knowledge and fewer resources to achieve a more affordable price. This strategy can also be adapted in such a way that it can be explored in the areas where institutional aspects are more supportive and also the customers and the suppliers have the least resistance.
Dedicated system or standalone niche strategy	This strategy involves using a product independently or creating a specialized system of complementary products and services, such as a local network, especially when a broader infrastructure is not accessible.
Hybridization or adaptor niche strategy	This involves utilizing the new product alongside the existing product, enabling the reuse of complementary products and services. Another option is to provide an adapter or converter to ensure that the new product and existing complementary products and services are compatible with each other.
Educate niche strategy	This involves focusing on transferring knowledge to suppliers, aiming to enhance their understanding of the product. Also it emphasizes on implementing an educating and experimenting to increase customer knowledge and familiarity with the product.
Geographic niche strategy	Focusing on geographic areas where institutions, such as laws and rules, are more flexible or less stringent, allowing for easier implementation of the strategy and the resulting policies. Similar to redesign niche strategy, geographic strategy suggests moving the operations of a company to areas with availability of resources, potential suppliers and customers.
Lead user niche strategy	Identifying and engaging with innovators or lead users who are at the forefront of innovation. These individuals play a role in co-developing the product and providing valuable feedback, while innovators are often open to experimenting with the product.
Explore multiple markets niche strategy	This strategy involves the exploration of various customer applications and stimulating customers to experiment and utilize the product in novel ways. This approach encourages exploration and creates opportunities for diverse and innovative applications.

Ultimately, studying the strategies proposed by Ortt can enhance the understanding of the complexities of the market, capitalize on niche opportunities, and increase the chances of successful commercialization of high-tech products (Ortt et al., 2013). These strategies were considered as a starting point or basis to find more such strategies to commercialize high-tech products.

However, according to Dwisatyawati (2022), Ortt's niche strategies do not address all the barriers that SEVs could potentially encounter. The author of the present work agrees with Dwisatyawti (2022) and believes that most of the strategies discussed address only the lack of knowledge, resources, sociocultural aspects, and institutional aspects. Some of the other barriers identified in the chapter 5 are not addressed, and will need more (niche) strategies to circumvent them. Therefore, several scientific articles and reports (explained in chapter 6) were referred to analyze more (niche) strategies to study their relevance to the market diffusion of Solar Electric Vehicles (SEVs).

3.4 Best Strategy Framework

The Best Strategy Framework, developed by Dwisatyawati (2022), builds upon the TIS and ten niche strategies frameworks to assist users and readers in identifying the most effective strategy for overcoming the combination of barriers that hinder the widespread adoption of an innovation (Dwisatyawati, 2022). This comprehensive framework extends the application of the TIS building blocks, influencing factors, and a diverse range of strategies toward the mass adoption of SEVs in Indonesia. It establishes the links between the influencing factors and barriers and employs scoring models to evaluate their significance.

The best strategy framework provides guidelines, particularly on identifying the links between the barriers and the strategies and validating those links with expert interviews. Incorporating those guidelines by modifying the research findings pertaining to the Indian market, ultimately provides insights into the socio-technical conditions that influence the SEV market diffusion. Furthermore, countries with markets similar to Indonesia, such as India, can benefit from utilizing the Best Strategy Framework to approach strategies effectively.

Within the framework, scoring models are employed. These scoring models are incorporated into the present work by identifying the strategies that circumvent the highest number of barriers. In this thesis, such strategies are identified based on the insights gained from the expert interviews on what experts perceive as the important strategy that can circumvent a barrier. According to Dwisatyawati (2022), the strategy that circumvents most of the barriers or the highest number of barriers is considered the best strategy, also referred to as the 'important strategy' in this thesis. However, it was identified that Dwisatyawati (2022) proposed these links, with the perspective of just the high-tech companies (industry), in consideration. Therefore, in chapter 8 and section 8.3, the guidelines on extending this framework to other actors involved within the TIS of SEVs are elaborated.

4 Current Status of EVs in India

This chapter discusses the current situation of the electric vehicle market in the Indian context. Firstly, the evolution of the EV industry will be elaborated in section 4.1. Followed by that, the favorable policies that assisted the development of EVs in India will be discussed in section 4.2. In order to understand the technical differences between EVs and SEVs, a comparison with respect to their energy source is explained in section 4.3. The relevance between the research on EVs with that of SEVs is explained in the section 4.4, followed by the evolution of different SEV companies 4.5. Finally, the status of India's first solar car is discussed in section 4.6. Ultimately, this chapter answers the sub-research question "Why does solar mobility present a viable option, and how can parallels between the electric vehicle (EV) sector and Solar Electric Vehicles (SEVs) be drawn to understand their applicability and potential in India?"

4.1 Evolution of EVs in India

In order to understand the applicability of SEVs in India, it is crucial to analyze the historical events pertaining to the emergence of electric mobility in India. By analyzing the historical events, insights into the factors that influence the success of SEVs can be gained. India's transition to electric mobility started in the early 1990s, when the company Eddy Current Controls launched its first-ever electric car Lovebird (Sudarshan, 2021). Another attempt at electrification of the transportation sector was done by the company, Electromobiles India Limited, which manufactured an electric two-wheeler (Moped), Komal, about 10 years before Lovebird was introduced (Khatri, 2021). Due to the limited advancement in the EV sector such as high battery costs, limited range, limited infrastructure, and most importantly, lack of awareness, Lovebird and Komal weren't successful enough to penetrate the markets. Later, in the late 1990s, India's first electric three-wheeler, Vikram Safa was launched by Scooter's India Pvt Ltd (Sudarshan, 2021). This led to the expansion of the EV sector beyond cars (four-wheelers).

For the next two decades (although there were a lot of challenges), the EV sector in India experienced growth due to the efforts, of both, the industry, in terms of technological innovation, and the Government, in terms of introducing favorable (and attractive) policies. In order to look at the growth of the EV industry, it is imperative to understand the journey of the first electric car company, Reva Electric Car Company (RECC) which came close to being a successful mass-market EV in India. With its inception in 1994, RECC's aim was to produce (and sell) an affordable and compact electric city car. With this vision, RECC launched REVA, India's first successful EV, in 2001 (Maini, 2005), (Chandran, 2003). It was not only built for Indian roads, as RECC also launched REVA in countries like the UK, Norway, Malta, and Cyprus in Europe, and also tests were conducted in the US and Japan (Maini, 20015), (Shepard, 2005). At that point, even ICEVs in India haven't attained their tipping point yet. This led many to perceive EVs as an unnecessary innovation, as the price of REVA was relatively higher than other ICEVs in the market, and the batteries were heavier, which

needed constant replacement. In addition to that, the subsidies promised by the government were not sufficient to scale up the production of REVA. It is due to the aforementioned reasons that the success of REVA evaporated very quickly. Another automobile giant, Mahindra & Mahindra, also focusing on alternative fuel/electric vehicle technologies, acquired a part of REVA as RECC's EV technology was very advanced in 2010 (Dhote et al., 2023), (Bureau, 2010).

4.2 Favourable Policies for the Development of EVs

The 2010s marked a decade of the EV revolution in India. With Mahindra & Mahindra's acquisition of RECC, big players like TATA's investment in EVs, and new entrants such as Ather Energy and Okinawa into the market, there was a change in awareness regarding EVs. On the one hand, there were numerous technological advancements in the automobile industry. The government of India, on the other hand, introduced the National Electric Mobility Mission Plan, 2020 (NEMMP) (originally named National Mission on Electric Mobility in 2011) and set up the National Board for Electric Mobility (NBEM) (Nouni et al., 2021). With the purpose of promoting and fast-tracking the research and development of the (hybrid) electric vehicle market, by bringing in various schemes, policies, and initiatives, GOI introduced NEMMP (Raju et al., 2021). Under NEMPP, the Indian Government, specifically the Department of Heavy Industries (DHI), came up with a Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) scheme to assist the EV ecosystem in India.

The FAME scheme was introduced in two phases, FAME I and FAME II. With a focus on developing EV technology by creating demand through pilot projects and charging infrastructure development, FAME I was launched in 2015 (Raju et al., 2021). The first phase of FAME went through a series of updates and extensions due to the attractive subsidies that were provided through this scheme. Contrary to the originally intended period of 2 years (till 2017), FAME I was active until 2019 (PTI, 2018). The overall period allowed the GOI to outlay an amount of 8.95 billion Indian Rupees (102 million euros). Automobile industry leaders favored such policies that facilitated the development and accelerated the transition to electric mobility. Due to the overwhelming demand for such schemes (and subsidies) DHI planned to formulate a new phase of FAME, FAME II. Building on the original purpose of the FAME scheme to incentivize the demand for electric vehicles and improve the charging infrastructure, FAME II also facilitates public awareness campaigns by educating the public and sharing knowledge across domains (Raju et al., 2021). Through FAME II, the Indian Government plans to allocate 100 billion Indian Rupees (1.15 billion euros) over the next couple of years starting from 2019 (Livemint, 2021). Similar to the first phase, the originally intended period (until 2022) has been extended till 2024. This allows for the further electrification of the entire transportation sector, including buses, four-wheelers (cars), three-wheelers (auto rickshaws and cargo vehicles), and two-wheeler vehicles (motorcycles and mopeds).

As can be observed from the various aforementioned cases and the FAME schemes, India's transportation sector is primarily classified into (electric) two, three, four-wheelers or cars, and buses. However, the focus of this research is primarily on cars.

4.3 Comparison of EV and SEV technologies

According to Dwisatyawati (2022), the base architecture of SEVs and EVs (or BEVs) is similar, as both technologies have a battery pack and an electric motor to provide the energy for the propulsion of the vehicle. It was also evident from the research that the main difference between a SEV and an EV is that the SEVs have an additional solar panel incorporated on the roof of the vehicle (Dwisatyawati, 2022). This solar panel serves as an additional source of power, apart from the (external) electricity provided to the battery. As can be seen in figure 4.1, with an additional source of power, SEVs have an advantage, as they have the potential to provide an extended driving range. On the other hand, EVs have a pre-determined driving range which is in turn limited by the capacity of the battery.

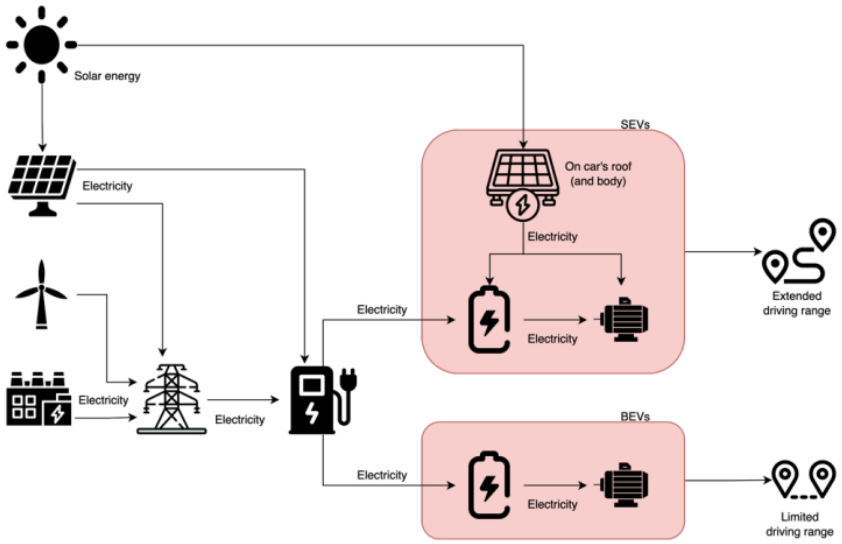

Figure 4.1: Comparing SEV and BEV technology by mapping their sources of energy, to the process of energy conversion and their end energy use (Dwisatyawati, 2022)

The following figure 4.2 shows different variations in the designs incorporated into SEVs. According to Paterson et al. (2016), the performance of a solar car is highly determined by the aerodynamics of the vehicle, as the power obtained from the solar roof is limited. Therefore, companies make a design trade-off between high efficiency, performance, and the cost of the vehicle (Paterson et al., 2016). As can be observed from the figure, the designs of Lightyear and Aptera Motors are highly aerodynamic, when compared to that of Vayve Mobility (Lightyear, 2021), (Apter Motors, 2022), (Vayve Mobility, 2023).

Figure 4.2: The difference in the design of various SEVs, Lightyear (top left), Aptera Motors (top right), and Vayve Mobility (bottom), (Lightyear, 2021), (Apter Motors, 2022), (Vayve Mobility, 2023)

4.4 Rationale for Solar Electric Vehicles: Drawing Parallels with the Electric Vehicle Sector

In order to understand and analyze the socio-technical conditions that SEVs are expected to face in India, it is crucial to understand the similarities between EVs and SEVs, and why inferences drawn from the EV sector can also be applicable to SEVs. In this section, three layers of rationale, as shown in the figure 4.3 are provided to justify the similarities between EVs and SEVs.

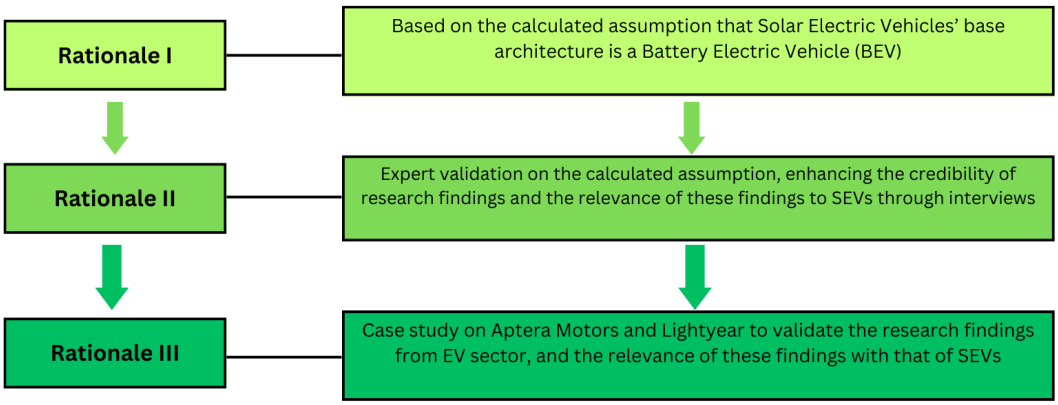

Figure 4.3: Rationale for SEVs, and justification of similarities with EVs

- **Rationale I:** As presented in the section 4.3, SEVs are basically an extension of EVs,

with an additional power source, solar panel, on the roof of the vehicle to generate (additional) power to propel the vehicle forward. Therefore, based on this reasoning, and the author's own understanding of the technology (based on the literature reviewed on barriers and strategies), the primary rationale is provided.

- **Rationale II:** The assumption made (as discussed in Rationale I) from the theoretical findings on barriers and strategies was validated by experts from the EV industry, especially experts F and G, who belonged to two solar mobility companies, Vayve Mobility in India, and Aptera Motors in the United States, respectively. Upon discussing the literature findings with the experts, the relevance of the theoretical findings on the barriers and strategies to SEVs was confirmed, thereby corroborating this argument.
- **Rationale III:** Finally, a case study was conducted (primarily, on the strategies implemented) on the two existing solar mobility companies, Aptera Motors and Lightyear, to validate the theoretical findings on the strategies, and their relevance and applicability to SEVs. These case studies are explained in detail in the section 6.5. The primary reason for selecting these two companies for the case study is because they have been working on SEV technology for longer than the other companies that were identified in this thesis. Moreover, relevant information on the strategies implemented by the companies was found through the publicly accessible reports. Upon conducting this case study, the (technical) measures taken by the SEV companies to develop and introduce the technology in the market were analyzed carefully. And, these measures were classified into the most relevant strategies that were identified from the literature, thereby supporting the argument on the relevance of findings from the literature to SEV technology.

4.5 Tracing the Evolution and Journey of Solar Electric Vehicles

Although the concept of SEVs has been there since 1985, due to the high costs and low yield from solar technology, the attempts at commercialization haven't started until the late 2010s (Heinrich et al. 2020). Therefore, it is interesting to observe how solar mobility companies have evolved over time. A total of seven companies have been identified to make an attempt at introducing the concept of SEVs. In the figure 4.4, the timeline for the evolution of SEV companies has been provided. Four out of the seven companies (Lightyear, Sono Motors, Squad Mobility, and Vayve Mobility), have been identified to be the pioneering startups within SEV industry, whereas established companies such as Hyundai and Hanergy, also attempted to introduce the concept of SEVs (Young, 2023). On the contrary, although Aptera Motors was established in 2005, their attempt at making SEVs only began in the 2010s, as there was a period when the company was bankrupt (Hunt, 2023). From the research on companies, it can be inferred that, although solar PV and EV technologies have existed for a while, there are quite a few barriers that hindered companies like Aptera and Lightyear from bringing this technology to the market.

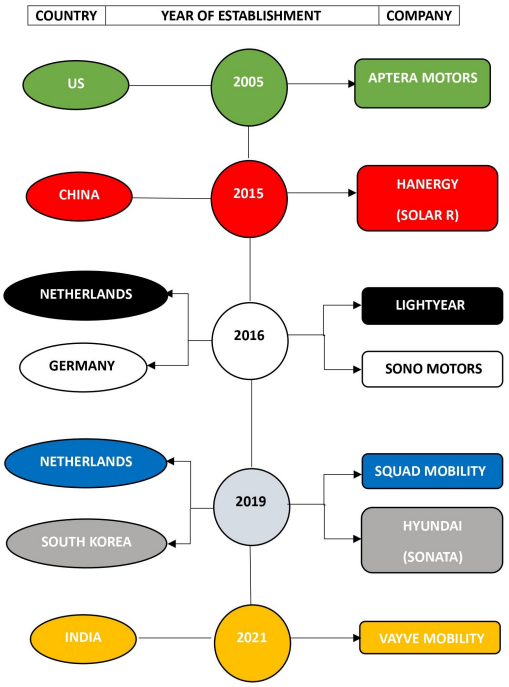

Figure 4.4: Evolution of solar mobility companies

4.6 India's First SEV

As discussed in section 1.4, so far the attempts at making Solar Electric Vehicles in India have been limited to students across various universities and the experiments by passionate individuals. However, recently, the prototype of India's first SEV, 'Eva' was launched at Auto Expo 2023, by the company Vayve Mobility (Gupta, 2023). Vayve Mobility is a startup that primarily focuses on building a solar car that is an efficient and affordable passenger car for urban mobility. Vayve Mobility claims that its SEV (Eva) has the capability to run up to 3000 km per year on solar energy alone. Along with solar energy as the power source, the car has the ability to run up to 250 km on a single charge (Pandya, 2023).

The targeted customer segment or targeted early adopters for Eva are the customers in urban areas with the daily need to travel within the city (Gupta, 2023). By targeting such a customer segment, Vayve Mobility aims to accelerate the transition to sustainable mobility, especially in urban areas. According to Vayve Mobility, 'Eva' has the capability to disrupt the market focused on urban mobility. Especially, the market segment with users whose daily travel requirements are within 20-40 km. Vayve Mobility is currently all set to start the production of 'Eva', and is expected to be introduced into the market in early 2024.

As it is India's first SEV, Vayve Mobility can be considered a pioneer or early entrant in the SEV market in India. This is a technological breakthrough for both the EV and SEV markets. However, as is the case with any new entrant (new technology) in the market, there are certain barriers to entry that SEVs are prone to face. Therefore, it is crucial to understand and analyze such barriers, specific to (Solar) Electric Vehicles, to research the strategies that

are required for this technology to diffuse in the mass market. Hence the potential barriers to market diffusion will be explored in the following chapter.

5 Potential Barriers and Opportunities for Market Diffusion

This chapter primarily focuses on the potential barriers that disruptive technology faces during large-scale diffusion, along with the opportunities the technology facilitates to solve the existing problems. Firstly, barriers discussed in multiple pieces of literature are discussed in the section 5.1. These identified barriers validated using expert interviews are presented in the section 7.1. In section 5.2, several opportunities that make SEVs a viable option in India are discussed. Finally, in section 5.3, the final list of barriers and opportunities identified in this thesis are listed.

5.1 Barriers identified from literature

As the fundamental architecture behind a SEV is an EV, the barriers pertaining to the adoption of electric vehicles in India are studied, from multiple perspectives. Therefore, several pieces of literature highlighting the barriers faced by EV technology were explored.

Literature 1: Barriers to the adoption of electric vehicles: Evidence from India

The research by Tarei et al. (2021) was explored and investigated further because of the relevance of their work on the barriers to the mass diffusion of EVs in the Indian EV market to this thesis. A comprehensive understanding of the challenges discussed by Tarei et al. (2021) is essential to address similar challenges in the context of SEVs.

Their research provided an understanding of the general barriers to adoption in the Indian market from a wider perspective. With the focus on identifying crucial barriers impeding the faster adoption of EVs in India, Tarei et al. (2021) conducted extensive research, corroborated with expert interviews to investigate the shortcomings of the EV market (Tarei et al., 2021). By identifying the barriers, Tarei et al. (2021) were able to establish relationships among several barriers. Once those relationships were established, all the identified barriers were ranked based on the outcome of a hybrid two-phased Multi-Criteria Decision Making (MCDM) method. These methods are namely, Best-Worst Method (BWM) and Interpretive Structural Modeling (ISM). By applying BWM, Tarei et al. (2021) conducted expert interviews to group the barriers with their subsequent sub-barriers. The outcome of applying this method was ranking the barriers from 'Best' to 'Worst'.

From their research, a total of 18 sub-barriers were identified. These sub-barriers were later categorized by Tarei at al. (2021) into five main barrier categories, particularly, technical, infrastructural, financial, behavioral, and external as displayed in the table 5.1.

Tarei et al. (2021) conducted expert interviews to validate their barriers by ranking them. These rankings are provided as a reference to highlight the importance of each barrier in the

following table 5.1. However, the significance of those rankings was not discussed further, as the author of the present work also conducted expert interviews to validate all the relevant barriers for this thesis, discussed in section 7.1.

Table 5.1: Barriers affecting the adoption of electric vehicles in India (Tarei et al., 2021).

Main barriers	Sub-barriers	Global ranking by Tarei et al. (2021)
Technical barriers	Performance, range and durability	8
	EV technology	12
	Unreliability of suppliers	15
	Development of alternative fuel technology	18
Infrastructural barriers	Shortage of charging stations	1
	Low availability on maintenance, service and repair	9
	Lack of EV manufacturers	5
	Unavailability of reliable electricity	3
Financial barriers	High upfront purchase price	2
	Unknown resale value	11
	Total cost of ownership	4
Behavioural barriers	Consumer perception on EVs/lack of awareness	7
	Scepticism on safety and reliability	6
	Scepticism on perceived benefits	13
	Dealer understanding/reluctance to push EVs	16
External barriers	Dependence on external sources for raw materials	14
	Wastage and recycling of battery	17
	Limited EV incentives and advertisement by government	10

Literature 2: Understanding and identifying barriers to electric vehicle adoption through thematic analysis

Understanding the importance of the perspective of the customers (end users) in the market diffusion of SEVs, the author of the present work explored literature highlighting the barriers faced by the end users. Upon investigating further, it was identified that Krishna (2021) researched the barriers from the perspective of customers. Therefore, their research was chosen to understand what customers perceive as a challenge in purchasing an (S)EV in India.

A thematic analysis was used to identify the barriers from multiple sources (Krishna, 2021). The aim of the thematic analysis is to analyze and convert the raw data into useful themes or sets of data. Through such thematic analysis, Krishna (2021) was able to identify barriers from the perspective of industry, and most importantly, from the perspective of potential consumers/customers. According to Krishna (2021), the potential customers of electric vehicles rely on the information available through traditional Word of Mouth (WOM) as well as platforms that support electronic Word of Mouth (eWOM). As there is a wide range of information available regarding the EV market on eWOM platforms, the data on the barriers pertaining to EV technology was filtered through thematic analysis and discussed.

In order to understand the credibility of the sources from which the data was collected, Krishna (2021) used techniques such as persistent observation, prolonged engagement, and peer debriefing. The author of the present work agrees with the importance of studying the barriers from the perspective of potential customers along with the barriers faced by the industry, as

customers are one of the building blocks of TIS. Therefore, the themes (barriers) identified by Krishna (2021) are studied and elaborated on in table 5.2. Krishna also identified links or relationships among multiple themes (barriers). Understanding these inter-relationships is crucial, especially for manufacturers, as the root causes for the challenges associated with the barriers are identified. In some cases, one potential solution or (proposed) strategy could address the multiple barriers at once, by establishing such relationships between various barriers.

One such inter-relationships proposed was the link between range, infrastructure, and recharge charge duration. For example, improving the range or capacity of the vehicle would mean that an EV can undergo fewer charging sessions as the battery will last longer. This, in turn, would reduce the pressure on (the public) charging stations. Another such inter-relationship is between range, infrastructure, unreliability, and lack of trust. As discussed, improving the range would put less pressure on the charging infrastructure. This will also address the problem of crowding and waiting in lines for charging points, thereby solving the problem of unreliability.

By studying the barriers and their inter-relationships, Krishna (2021) was able to achieve an understanding of the rationality behind consumers' perceptions of EV technology. Therefore, research conducted by Krishna (2021) showed an emphasis on identifying the technical difficulties, and technological barriers and also emphasize multiple intangible factors that are important to consumers while adopting an EV. As a result, the customers' (end users) perspective was incorporated in this thesis.

Table 5.2: Barriers affecting the adoption of electric vehicles from the perspective of customers (Krishna, 2021).

Barriers (Themes) identified		Description
Sales conversion ability	Supply and choice of vehicles	The higher the demand for the technology, the higher is the waiting period to obtain the technology, if the supply chain aspect can not keep up with the demand. Waiting period to obtain an EV is relatively higher than a conventional car, which highly impact the purchase decision. Also, the wide range of options targeting different audiences/customers are lacking in EVs when compared to ICEVs.
	Dealers	Vehicle dealers sometimes, can directly influence the purchase decision. Some instances observed by Krishna (2021) proved that dealers often highlight the barriers, showing reluctance to sell EVs.
Lack of trust in technology	Autonomous driving	There is a false perception among the public that EVs are always autonomous, and due to autonomy, they are vulnerable to hacking. They believe that the data they share with the car is also vulnerable to be exposed.
	Unsafe	Batteries are vulnerable to explosion as their working is associated with either heat absorption or heat dissipation, especially during an accident or an impact.
	Not environmental friendly	Although there are no tailpipe emissions associated with EVs there are emissions in the process of extraction of raw materials for batteries. Apart from emissions, there are a disputes around the fact that mining activities are in direct violation of human rights.
	Unreliability	Due to the nature of current batteries, they are prone to degradation over time. So, in the long run, EVs are believed to be unreliable as the range of the vehicles decrease with the degradation of the batteries. Also, unreliability comes from the lack of access to charging points in case of emergencies.
	Immaturity of technology	Since EV technology is not fully mature and in the stage of development, many are reluctant to be the early adopters of this technology.
Living with the technology	Cost of purchase and ownership	Expenses associated with EVs are considered to be the most sensitive topic to address. There is common perception that EVs are relatively more expensive than conventional vehicles. The expenses include high cost of purchasing, along with high repair and maintenance costs.
	Infrastructure	From the lack of enough public charging stations to the lack of space for parking and charging in the residential areas, there are many problems associated with the availability of infrastructure. Also, the rural/suburban areas are usually less equipped with the infrastructure when compared to the urban areas.
	Range	Drive range of EVs has always been a point of concern for the owners of the vehicles. The range of the battery increases with the capacity/size of the battery. However, the cost of purchase also increases with the increase in battery capacity.
	Recharge duration	The refuelling or recharging time for EVs are significantly higher than that of conventional vehicles. The larger the capacity of the battery the more time they take to charge.
Desirability	Soul and character of the vehicle	Vibration and sound are some of the characteristics that connect the car and the driver. Such characteristics which connect the driver and the car are lacking in electric vehicles.
	Repair	Some car owners find a sense of satisfaction along in repairing their own car, which also leads to saving service and repair costs. EVs are marketed with an 'anti-repair' theme and (or) complex in terms of repairing by owners themselves.
	Culture	Automobile industry is associated with culture, particularly the old school culture. This culture and lifestyle that comes with buying the car are crucial for some car owners. These car owners are not satisfied because EVs are not 'culturally' fulfilling.
	Lack of fun	The characteristic of fun is associated with the satisfaction of driving. For examples, some users lack the depth in experience because of the lack of option for manual transmission, as that influences their purchase decision.
	Bad looks and futuristic concept	The looks and the design of the car are considered highly influential while making the purchase decision. Some electric vehicles, however, are not up to the mark in the looks and the design, when compared to conventional vehicles.
	Performance	The performance factors such as top speed, acceleration and cornering play a vital role in the purchase decision. Current EVs can not completely replicate the top performance factors that are available in conventional cars.
	Sound	Sound is sometimes associated with the culture of the cars, especially among car enthusiasts. EVs, unless equipped specifically with sound enhancers by OEMs are predominantly silent.
	Emotional attachment	Due to the nature of their working EVs are considered to strip the 'freedom' that certain car owners experience with conventional vehicles.

Literature 3: Overcoming barriers to entry in an established industry: TESLA MOTORS

In order to gather the barriers from the perspective of industry, out of the scientific literature explored, research by Stringham et al. (2015) particularly stood out, as they highlighted the barriers that the EV industry was facing at the time (in 2008) when EVs were introduced in the market. Therefore, investigating the barriers faced by Tesla provided insights into what SEV (as an advancement of EV) technology will encounter once they are introduced in the market.

Tesla, being the first electric vehicle company, introduced a radically new invention (Electric Vehicle) that changed the dynamics of the automobile market. As the first company to introduce EVs (Tesla Roadster in 2008) to the market and diffuse on a large scale, Tesla encountered multiple challenges. Considering the similarities between the EV and SEV markets, the challenges faced by Tesla were studied in detail to understand the barriers to SEV technology. Stringham et al. (2015) elaborated on the barriers that Tesla had to overcome to become a leading company in the EV market from the perspective of a new entrant (Tesla) into the market. As a new entrant into the automobile market, Tesla faced multiple barriers to entry such as economies of scale, access to distribution channels, patents, unrecoverable upfront R&D expenditures, and other capital requirements (Stringham et al., 2015). These barriers, along with other barriers identified (explained in the table 5.3 can be extrapolated to the SEV market.

Some of the major barriers faced by Tesla (as a pioneer in EV technology) are elaborated upon in table 5.3. These barriers are incorporated in this research because of the close association of EV technology with that of SEVs. In order to validate these barriers to SEV technology in India, expert interviews are conducted during this thesis which is elaborated on in section 7.1.

Table 5.3: Barriers encountered by Tesla Motors (Stringham et al., 2015).

Barriers to entry	Description
High (initial) fixed costs	These are the costs faced by a company initially. Costs incurred on the infrastructure/equipment to run the operations while setting up an automobile company.
Economies of scale	New entrants lack the (financial) resources/ability to scale up the production (build higher number of vehicles). In order to produce such high number of vehicles, companies should have access to much bigger factories. Having such access is only possible if the companies raise enough capital.
Lack of access to distribution channels/networks	Having the access to distribute the product through distribution channel/network is equally important as the product itself. Because distribution channels play a crucial role in bringing the product to the customers. Lack of such distribution network poses a major challenge in bringing the products to the market.
Lack of network externalities	Network externality or network effect refers to the value of the product. The higher the number of users/customers using the product, the higher the value of the product. Therefore, success of a technology depends on the number of users. If the number of customers using any new technology (SEVs for example) are less, there is a lack of network externality.
Constantly evolving markets	The (automobile) market is constantly changing, forcing the automobile companies to constantly adapt to the change, either by constantly innovating the products, or enhancing the total product experience. Failing to do so would push the companies to bankruptcy (by pushing the non-innovating companies out of the market).

Literature 4: When and why does transition fail? A model-based identification of adoption barriers and policy vulnerabilities for transition to natural gas vehicles

Hidayatno et al. (2020) explain the barriers that are faced during the transition from older technologies to radically new innovations or technologies that have the potential to disrupt the market dynamics. They explain the barriers faced from the perspective of a policymaker or a government institution. This case study on the transition from conventional vehicles to Natural Gas Vehicles (NGV) in Indonesia clearly explains those barriers (also addressed as deep uncertainties). According to Hidayatno et al., due to several uncertainties, even seemingly successful policies and policy recommendations are prone to failure (Hidayatno et al., 2020). Even after implementing certain policies, these uncertainties hinder the growth of technology. In order to account for such deep uncertainties or barriers, Hidayatno et al. (2020) used agent-based modeling for technology diffusion called Exploratory Modeling and Analysis (EMA). EMA helps in identifying deep uncertainties or barriers that exist in the technology diffusion process. Using EMA, deep uncertainties that exist were identified and categorized into structural, economic, social, and behavioral factors. These deep uncertainties are discussed in table 5.4.

Table 5.4: Barriers encountered during the transition to natural gas vehicles (Hidayatno et al., 2020).

Barriers	Description
Structural	Structural barriers are associated with the status of the infrastructure. Lack of necessary infrastructure (Fuel supply in the case of NGVs and charging stations in the case of EVs)
Economic	Economic barrier is associated with the economic status of a particular region or a country. High upfront costs (cost of purchase or lease) and the operational/ maintenance costs, especially countries with low average income.
Social	When there is a limited awareness (or adoption) of technology among an agents' (car owners') social network, it is considered a social barrier. The tendency to adopt the technology of EVs (in this case NGVs) by an agent increases with the increase in awareness and adoption of the technology
Behavioural	Social and behavioural barriers are closely interlinked. Behavioural barrier is associated with the unavailability of relevant information pertaining to the (adoption of) technology and the agents' ignorance

Literature 5: Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management

Kemp et al. (1998) offer a new perspective on the barriers and the factors that affect the development and diffusion of sustainable (and new) transport technologies. Through this case study, Kemp et al. (1998) explain the reason for the slow transition to sustainable technologies. In order to fully develop a technology from the prototype phase to the final market-ready product phase, there is a need for overcoming the barriers or the resistance faced, both within and outside the organization producing the disruptive technology. These barriers are elaborated on in table 5.5.

Table 5.5: Barriers resulting in a slow transition to sustainable (and new) transport technologies (Kemp et al., 1998).

Barriers	Description
Technological factors	Newly introduced technologies faces the challenge to fit in the already existing technological system. For example, there is limited data from the tests conducted on new consumers that can be used to redesign and introduce the technology at a large scale. Therefore complementary products must be introduced before the final market-ready product.
Government policy and regulatory framework	Lack of investments from the manufacturers is often a consequence of poor policy implementation from the government. This is case because the existing policies or the regulations are often strict that could unintentionally hamper the development of new technologies.
Cultural and psychological factor	Sometimes the values associated with incumbent technologies may not be available in the new technology (for ex, the sound of car engine is absent in EVs).
Demand factors	The fact that sometimes the new technologies haven't proven their success and worth poses as a barrier to any (potential) consumer. As a result, there is reluctance towards adopting new technology. The new technology also have to meet certain demands and preferences of the users. According to vehicle manufacturers, although there is a change in the technology, there is little to no change in consumer demands
Production factors	Unpredictable demand for the new technology is a huge uncertainty for the manufacturers of the new technology. This uncertainty leads to risks associated with scaling up of production and subsequent investments.
Infrastructure and maintenance	Development of the new technology and the infrastructure required for the technology to function must go hand in hand. Lack of infrastructure prevents the diffusion of technology, whereas the diffusion of technology largely depends on the availability and accessibility of the infrastructure (for ex. charging stations for EVs).
Undesirable societal and environmental effects of new technologies	There is an uncertainty associated with the problems that the diffusion of the new technology may bring to the society (for ex, emissions from the production of EV batteries).

5.2 Opportunities for Market Diffusion

Due to the infant nature of the Solar Electric Vehicle industry, and the limited availability of scientific literature on this topic, their full potential is yet to be recognized. However, it has been evident that, due to the introduction of SEVs, they not only solve certain problems faced by EVs, but they also have the opportunity to solve several societal problems, which are discussed below. Some of these opportunities were identified based on the inferences drawn from the electric vehicle industry (in the cases where inferences were drawn, they were validated using expert interviews).

Increasing demand for clean and sustainable transportation:

India, like many other countries, faces significant challenges in terms of air pollution and traffic congestion, particularly in its urban centers. The detrimental effects of these issues on public health and the environment are well recognized. In response, the Indian government has set ambitious targets to combat these problems by reducing greenhouse gas emissions and promoting the use of renewable energy sources (IEA, 2021).

The focus on reducing greenhouse gas emissions aligns with global efforts to mitigate climate change and transition towards a sustainable future. India aims to increase the share of renewable energy in its energy mix, emphasizing the importance of clean and sustainable sources of power. This commitment creates a favorable environment for the adoption of SEVs, which offer the potential to reduce emissions from the transportation sector.

Abundant solar energy resources:

India is blessed with abundant solar energy resources, owing to its geographical location and favorable climate conditions. The country experiences high levels of solar irradiation, which refers to the amount of solar radiation received on the Earth's surface (Irfan et al., 2020). This abundant sunlight makes India an ideal region for harnessing solar energy. The availability of high solar irradiation throughout the country opens up vast opportunities for solar energy generation, including the integration of solar panels on Solar Electric Vehicles (SEVs).

By installing solar panels on SEVs, it becomes possible to generate significant amounts of energy directly from the sun. These solar panels, often mounted on the vehicle's roof or body, capture sunlight and convert it into electricity (Newman, n.d.). This solar-generated energy can be used to power the vehicle's propulsion system, reducing the reliance on traditional fossil fuels like gasoline or diesel. As a result, the adoption of SEVs equipped with solar panels can contribute to the diversification of India's energy sources and promote energy security.

Favorable government policies and incentives:

The Indian government has been actively promoting the adoption of electric vehicles through a range of policy and incentive measures (Raju et al., 2021). These include tax incentives, subsidies, and investments in charging infrastructure. The government has also set a target of achieving 30% electric mobility by 2030, therefore, facilitating innovations within electric mobility such as SEVs. This presents a great opportunity to introduce SEVs along with EVs (Expert B, 2023).

Growing manufacturing capabilities:

India has a growing manufacturing sector and a skilled workforce in the automotive industry. This presents an opportunity for the domestic production of SEVs and related components, which can help create jobs and promote the growth of the local economy (Chenoy et al., 2019). The 'Make in India' initiative is one among many initiatives which promote the growth and manufacturing of automobiles, locally, in India. This is also an opportunity for foreign automobile companies to invest and set up manufacturing plants in India while promoting the local automobile manufacturing companies to go global (Bhardwaj, 2021).

Rural Electrification and increased Access to Mobility:

India's rural areas are often disconnected from the electricity grid and rely on diesel generators or other fossil-fuel-based sources for power (Goyal, 2023). This leaves a lot of room for renewable energy-based innovation in rural areas. SEVs can provide an alternative solution by using solar panels to generate electricity for not only the vehicle but also for powering homes and businesses in these rural areas. This can help promote energy access and reduce dependence on fossil fuels. In addition to that, they have the potential to increase access to mobility for people in rural areas and remote regions, where access to public transportation is limited (Frank et al., 2021).

Improved Energy Security:

India's heavy reliance on imported oil and gas creates an economic burden for the nation, as the oil and gas prices are increasing (Sharma, 2023). By promoting SEVs, India can decrease its reliance on imported fossil fuels, enhancing energy security and mitigating vulnerability to global oil price fluctuations. This shift towards highly-efficient SEVs would not only reduce oil imports but also reduce the need to use external energy sources (such as charging from the electricity grid). As most of the available electricity is generated from fossil fuels, there is an opportunity for SEVs to reduce the burden on the electricity grid (and the corresponding emissions from electricity generation) (Buchholz, 2022). According to Araki et al. (2023),

having a density of about 13 SEVs per square kilometer would support temporary resilience centers such as temporary medical care centers, air conditioners for care homes, and charging stations for devices such as mobiles (Araki et al., 2023).

Innovative Business Models:

As SEVs are a relatively new (and disruptive) technology, there is ample opportunity for innovation in the business models of companies introducing this technology. For instance, ride-sharing and last-mile delivery models have proven to be successful in India. The costs incurred by companies using gasoline vehicles are high due to the increasing gasoline cost (TechSci, 2023). However, there are companies like Blu Smart, which is India's first ride-sharing company operating entirely with an EV fleet (Mahabadi, 2022). SEVs offer entrepreneurs and innovative companies like Blu Smart a chance to be sustainable and cost-efficient since they don't have any fuel expenses.

Export Opportunities:

India has the potential to become a major manufacturing and exporting hub for (solar) electric vehicles, batteries, and charging infrastructure (Chenoy et al., 2019). With the 'Make in India' initiative, the country can focus on producing these vehicles locally, which would not only drive growth and development in the Indian EV industry but also create opportunities for exports. By leveraging its manufacturing capabilities and competitive advantages, India can produce high-quality SEVs at a competitive price, making them attractive to international markets.

Job Creation:

According to Chenoy et al. (2019), India is targeting to become the top three automobile manufacturers in the world. Through Automotive Mission Plan 2016-26 (AMP 2026), an estimated 65 million jobs will be created, in order to facilitate the growing demand in the automobile sector, especially facilitating India's transition to electric mobility. Therefore, both skilled and semi-skilled labor are required in order to facilitate the growing manufacturing capabilities and also demand (Chenoy et al., 2019). SEVs have the opportunity to tap into the growth potential of India's manufacturing capability by creating jobs required within the SEV industry.

Integration with existing renewable energy systems and electricity grid:

According to Lopes et al. (2011), EVs have the capability to deliver energy back to the electricity grid, when the vehicles are idle and parked. This way EVs have the ability to provide ancillary services to the electricity grid, especially during the peak hours of electricity usage (Lopes et al., 2011). EVs are also able to store excess energy generated by renewable energy sources, to avoid wastage of excess energy produced by solar and wind parks (and other renewable sources), and inject the same back into the grid, whenever required. SEV, having the base architecture of EVs, both have the ability to generate clean electricity (by themselves) and can also be incorporated into the electricity grid whenever there is a need for additional energy (Newman, n.d.).

5.3 Chapter summary

In this chapter, the barriers specific to technologies close to SEVs, such as EVs were explored, and the theoretical findings from each of the literature are highlighted, and the final list of barriers is presented in this chapter (also in the table 5.6). As discussed in section 3.2.1,

multiple sets of links are possible between the main barriers, their underlying influencing conditions, and the affected building blocks. These links are explained in detail in the section 8.1, and are shown in the table 8.1.

In order to see the potential for SEVs in India, and whether SEVs present a viable option, a few opportunities were discovered from the literature, compiled in the table 5.6.

Table 5.6: Final list of barriers and opportunities obtained from literature

No.	Barriers	Opportunities
1	Lack of (technical) knowledge	Increasing demand for clean and sustainable transportation
2	Lack of awareness	Abundant solar energy resources
3	Supply and choice of vehicles/lack of competition	Favourable government policies and initiatives
4	Safety (due to the nature of batteries)	Growing manufacturing capabilities
5	Environmental impact	Rural electrification and increased access to mobility
6	Reliability (depletion, wear and tear of the components such as batteries)	Improved energy security
7	Maturity of technology	Innovative business models
8	Cost of purchase and ownership	Export opportunities
9	Limited infrastructure (Charging stations)	Job creation
10	Range anxiety/driving range	Integration with existing renewable energy systems and electricity grid
11	Long recharge duration	
12	Soul and character of the vehicle (Sound)	
13	Availability of repair/service and maintenance	
14	Cultural and psychological factors	
15	Lack of product satisfaction (fun)	
16	Performance	
17	Government policy and regulatory framework	
18	Demand factors	
19	Production factors/Economies of Scale	
20	Lack of access to distribution channels/networks	
21	Lack of network externalities	
22	Constantly evolving markets	
23	Low resale value (value depreciation)	
24	Lack of collaboration among stakeholders	

According to Ortt et al. (2013), there is a need for formulating and proposing (niche) strategies in order to circumvent or overcome the barriers faced by a high-tech innovation during large-scale diffusion. Therefore, in the following chapter, such strategies are explored.

6 Potential Strategies for Market Diffusion

This chapter highlights the strategies applicable to disruptive technologies like SEVs. It has been identified that SEVs are a relatively new and disruptive technology. As discussed by Hardman et al., these disruptive technologies in the initial phase require (niche) strategies to diffuse in the market (Hardman et al., 2013). Therefore, in this chapter, such (niche) strategies applicable to high-tech innovations are studied. Also, the observations made during the literature review, that are crucial for this research are discussed in section 6.1. After the important observations are explained, the strategies from individual perspectives are analyzed in sections 6.2, 6.3, 6.4. A case study analysis was conducted to research the strategies implemented by existing SEV companies, Aptera Motors and Lightyear. This case study is presented in the section 6.5. In order to validate the results obtained from the literature analysis, interviews are conducted and the findings from the interviews are discussed in the interviews chapter, section 7.2. Finally, the chapter summary on potential strategies is provided in section 6.6.

6.1 Important observations on theoretical strategies

In this section, important observations made in the literature are presented, which have significantly contributed to the research on strategies. It is crucial to explore the relevant strategies discussed in the literature in order to address the barriers faced during the mass adoption of SEVs. Several research literature have been thoroughly reviewed, enabling the identification of various strategies and an in-depth examination of the methodologies discussed in the literature. This comprehensive analysis allows for relevant links between the strategies and the barriers they aim to address, enhancing the overall depth of the analysis.

The literature specifically discussed in this section serves as the foundation for the strategies identified in this research. The examination of the findings and insights presented in each paper offers a deeper understanding of the strategies' relevance and potential effectiveness.

In the subsequent sub-sections, each selected literature will be explored in detail, examining key findings, methodologies, and contributions to the overall understanding of strategies. The following are the key observations (elaborated in the following sections) made during the research:

1. Multiple individual strategies can be combined to form one main strategy. These sub-strategies with the same focus or purpose are grouped together, ultimately completing the main strategy. Classification of sub-strategies into the main strategy has been discussed in detail in section 6.6.
2. The strategies identified from the literature are predominantly focused on the industry perspective (and the actors associated with the industry), followed by the government and customers. Through this observation, it was also evident that the industry (and the

actors associated with it) has a higher responsibility to prove the potential of SEVs to the government and other stakeholders, in order for SEVs to attain large-scale diffusion.

3. Some strategies can be applicable to all the stakeholders (government, industry, and customers). So, there is a potential overlap in the proposed strategies among the three different perspectives. Therefore, those strategies that can be implemented by multiple stakeholders have been highlighted in the section 6.6.

Ultimately, all the identified strategies have been discussed, and are classified into strategies applicable to the industry (in section 6.2), the government (in section 6.3), and the customers (in section 6.4). A detailed description of the main strategies identified are provided in the appendix section 2.

6.1.1 Literature 1: Strategies for the diffusion of sustainable energy technologies in developing countries

'T Veld (2020) provides a comprehensive understanding of the different types of strategies that enable the large-scale diffusion of sustainable energy technologies (SETs). These different drivers were formulated by improving and extending the niche strategy framework by Ortt et al. (2013) to address the diffusion of SETs in developing countries specifically. After a thorough review, it was identified that the framework developed by 't Veld (2020) is applicable to the market diffusion of SEVs in India, as it is a subset of SETs in developing countries.

It was also identified that there are many other stakeholders including the focal actor (the company or entrepreneur associated with the technology) that influence the large-scale diffusion of SETs. They are entrepreneurs (the focal actor), competitors, the government, private investors, financial and educational institutes, Non-governmental organizations (NGOs), International aid and development organizations (IDOs), and customers ('t Veld, 2020). This observation was crucial for the present work as it serves as a basis for studying the strategies from different perspectives (government, industry, and customers).

A few counteracting strategies were also proposed by 't Veld (2020) that are applicable to actors such as competitors, private investors, and incumbent firms. While the author of the present work agrees that the influence of individual actors on large-scale diffusion must be studied, but disagrees with the counteracting strategies because they serve as strategies that work against large-scale diffusion. For example, a counteracting strategy 'provide false or misleading information to institutional actors' was discussed by 't Veld (2020) as a counteracting strategy that is applicable to incumbent firms (Smink et al., 2015). Similarly 'delaying the transition process' and 'spreading negative information about the focal actor' were also proposed as counteracting strategies to incumbent firms and customers respectively (Urmee et al., 2016), (Smink, 2015).

Therefore, these counteracting strategies are not discussed in the present work. Other strategies such as the ones applicable to sustainable energy technologies (SETs) in general but not specific to solar electric vehicles are also excluded. For example, 'issuing feed-in tariffs' is discussed as a financial incentive that can be provided to renewable energy plants (Zafar et al., 2018). Although feed-in tariffs are applicable to SETs, they are not directly applicable to SEVs. Therefore, feed-in tariffs are not included. The strategies specifically described by 't Veld (2020) are elaborated in the appendix section 1.

6.1.2 Literature 2: Developing a conceptual model on strategies overcoming barriers for the introduction of radical innovations in niches

In order to address the barriers faced during the development process of radical innovation, Schulz (2019) proposed a set of (niche) strategies. Schulz (2019) classified those (niche) strategies into three types. Type 1 focuses on overcoming the barriers faced during the market diffusion process (Schulz, 2019). Type 2 highlights those that influence the influencing factor, while type 3 focuses on addressing the limitations within the core factors. After a thorough review of the strategies, only the ones applicable to the context of large-scale diffusion of SEVs are discussed in the present work. Although these strategies are classified based on the type of problem they solve, they do not clearly define which actor or perspective can be benefited from the application of such (niche) strategies.

Therefore, by the logical reasoning of the author of the present work (backed by validation from the expert interviews), strategies proposed by Schulz (2019) are further classified into those applicable to the government, industry, and customers. This is included in the appendix section 1.

6.1.3 Literature 3: Barriers and strategies analysis on mass adoption of solar electric vehicles in Indonesia

Dwisatyawati (2022) proposed 17 unique strategies, pertaining to the mass adoption of Solar Electric Vehicles in Indonesia. It was also identified that the research findings (barriers and strategies) by Dwisatyawati (2022) are applicable to developing countries (economies) with similar characteristics and conditions as Indonesia. Therefore, these strategies have been identified to be applicable to the context of large-scale diffusion of SEVs in India. These strategies are elaborated on in the section 1.

Out of the total strategies proposed by Dwisatyawati (2022), a few strategies, such as the "turnkey product strategy", "aggressive penetration strategy", "market positioning strategy" and "get specified strategy" were excluded in the present work. The feasibility of applying these strategies in the context of SEVs has been analyzed by the author of the present work through scientific literature analysis, and expert interviews have been determined to be limited.

6.2 Strategies applicable to industry

The development and diffusion of the SEV sector require a comprehensive approach and initiative from the industry. Therefore, the industry perspective has been identified to be crucial among the stakeholders involved in the large-scale diffusion of SEVS. The transition to sustainable transportation systems, coupled with the increasing demand for green and renewable energy solutions, presents a unique opportunity for the industry to implement innovative strategies. Industrial strategies play a crucial role in facilitating growth and competitiveness in the SEV sector. By implementing these strategies, industry stakeholders can overcome challenges, take advantage of the market opportunities, and contribute to the overall success of the SEV industry.

In the context of the SEV sector, various strategies can be explored to facilitate its development and diffusion. These strategies include different aspects such as technological advancements, market positioning, collaboration, etc. Technological research and development (R&D) initiatives focused on improving solar energy conversion efficiency, battery technology, and electric drivetrain systems are key to enhancing the performance and viability of SEVs (Waseem et al., 2019). Additionally, strategic partnerships and collaborations among various actors, research (educational) institutions, and government agencies can facilitate knowledge sharing, and ultimately, the success of the innovation ('t Veld, 2020).

Industrial strategies in the SEV sector offer numerous benefits from an industry perspective. Firstly, they create a favorable environment for innovation, research, and development, facilitating the industry players, especially high-tech firms, to stay at the forefront of technological advancements (Fromhold et al., 2013). This positions them as pioneers in the SEV market, attracting investments, partnerships, and skilled talent. Moreover, these strategies facilitate collaboration and knowledge sharing, which can lead to faster and more efficient problem-solving, reducing barriers to entry (Tuchman, 2015).

In addition to primary industry stakeholders, the successful development and diffusion of the Solar Electric Vehicle (SEV) sector rely on the active involvement and support of various other actors within the industry ecosystem ('t Veld, 2020). These actors, including investors, educational institutes, non-governmental organizations (NGOs) and International Development Organizations (IDOs), competitors, and many more, play crucial roles in shaping the trajectory and impact of the SEV industry. Recognizing the significance of each of the individual actors, and the barriers that can be circumvented by their individual measures, the author of the present work acknowledges the strategies applicable to each individual actor from the industry perspective. However, the role and the influence of these individual actors are not discussed in detail in this thesis, in order to discuss the strategies relevant to the perspectives identified in this thesis in depth. The strategies tailored for the industry perspective are elaborated on in the table 6.1.

Table 6.1: Strategies tailored for industry perspective

No.	Main strategies	Sub-strategies	Adapted from/Source
1	Research & develop (niche) strategy	Commercialize scientific research outputs	Dwisatyawati (2022), 't Veld (2020), Schulz (2019), Olsthoorn (2017), Fromhold-Eisebith & Werker (2013)
		Technology transfer through collaborative R&D	
		Pilot research and development through multiple experiments on the product	
		Pilot projects involving public (end users)	
		Market research on the diffusion of technology	
2	Human resource management strategy	Hiring skilled employees	Dwisatyawati (2022), 't Veld (2020), Schulz (2019), Davey et al. (2018), Fromhold-Eisebith & Werker (2013), Expert F (2023), Expert H (2023)
		Optimizing workforce allocation for strategic focus	
		Appointing financial and strategic advisors	
		Generating human capital and entrepreneurs by educational institutes	
		Provide human resources	
3	Education niche strategy	Provide education and training	Dwisatyawati (2022), 't Veld (2020), Schulz (2019), Zafar et al. (2018), Fromhold-Eisebith & Werker (2013)
		Internal knowledge sharing	
		Improved accessibility to (technical) information	
4	Lead-user niche strategy	Focusing on lead-users with specific needs	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
5	Finance sourcing strategy	Seeking loan (from different lenders)	Schulz (2019), Dwisatyawati (2022), 't Veld (2020),
		Crowd funding campaigns	
		Seeking investments from financial institutes	
6	Subsidized niche strategy	Implementing product subsidies	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
		Implementing tax subsidies	
7	Redesign niche strategy	Redesigning the application of the product	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
		Redesigning to a simpler and/or cheaper version	
8	Dedicated system or Stand-alone niche strategy	Alter the physical aspects of the product (and its system)	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
		Adapt to eliminate the requirement of complementary products and services	
9	Hybridization or Adaptor niche strategy	Combining new product with the old product	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
		Improving compatibility between the product and existing complementary services by providing adaptor or converter	
10	Lobbying strategy (Advocacy strategy)	Directly influencing the policy makers through direct contact	Dwisatyawati (2022), Schulz (2019), Hardman et al. (2013), Expert D (2023)
		Indirectly influencing the policy makers through NGO's, public and media	
		Lobbying through contributions to campaigns	
		Company representative joining regulatory agencies	
11	Collaborative product utilization strategy	Consumers owns the product while the company maintains juridical ownership	Dwisatyawati (2022), Schulz (2019), Strupeit & Palm (2015), Bloem (2018)
		Company retains the ownership throughout the lease contract	
		Open up opportunities for economies of scale	
		Enabling shared utilization, access and ownership of the offered product	
		Offer subscription option to spread out the cost of purchase over a period of time	
12	Buy-one, give one niche strategy	Selling product to top-end customers and donating the same product to poor target market	Dwisatyawati (2022), Schulz (2019)
13	Geographical niche strategy	Selling the product at a particular (high demand) geographical area	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
		Moving the company to another geographical area	
		Seek support from relevant stakeholder from other locations	
14	Top-end niche strategy	Producing high quality products on a small scale	Ortt (2013), Schulz (2019), Dwisatyawati (2022), Sonali (2016)
		Selling the product to a targeted (wealthy) market segment/customers	
15	Partnerships niche strategy	Working together with partners/other stakeholders to remove (common) barriers collectively	Dwisatyawati (2022), Schulz (2019), Strupeit & Palm (2015), Hardman et al. (2013), 't Veld (2020), Expert D (2023)
		Buying bulk natural resources by partnering with other parties with similar needs	
		Collaborating with companies multilaterally and internationally	
		Collaborative talent (human resources) pooling with other partners	
		Establish collaborations and alliances with focal actor to reduce power position of incumbent firms	
16	Integrated network strategy	Building and expanding network outside the organization to accelerate the market diffusion process	Dwisatyawati (2022), Hardman et al. (2013)
		Utilizing inhouse network to support the market diffusion (sales) of the product	
		Utilizing the existing network of stakeholders to develop and sell the product	
17	Marketing strategy	Bringing in influencers to raise awareness on the technology, company and/or the product	Dwisatyawati (2022), Schulz (2019)
		Preannouncing strategy	
18	Stepping stone strategy	Targeting other culturally and geographically closer markets to gain validation	Dwisatyawati (2022), Olsthoorn (2017)
		Launching products in the market more familiar to the company/firm	
		Expanding or diversifying the product portfolio to serve a bigger (target) market	

19	Product variants strategy	Offering products with different designs, specifications or features addressing diverse range of the needs of end users	Dwisatyawati (2022), Sonali (2016)
20	Cross-selling strategy	Offering other features to make the product attractive Offering the product in combination with other related products	Dwisatyawati (2022), Stupeit & Palm (2016), Expert E (2023)
21	Result-oriented contracting strategy	Focusing on consumer needs, and consumer satisfaction Promising guaranteed (desired) results from the use of the product such as good performance, durability, etc Informing end users of the guaranteed results (return on investment)/Mobility as a service	Dwisatyawati (2022), Strupeit & Palm (2015), Expert E (2023)
22	Blue ocean strategy	Creating new market spaces or industries, rather than competing within existing ones Focus on a different market/sector first (ex: marine sector)	Dwisatyawati (2022), Sharma (2016), Kim & Mauborgne (2004)
23	Explore multiple markets strategy	Understanding current trend, demand and competition in a different (or new) market Exploring different (or new) markets with other stakeholders (for ex: competitors) to eliminate certain barriers	Ortt et al. (2013), 't Veld (2020), Bloem (2018)

6.3 Strategies applicable to government

Government intervention is crucial in facilitating the diffusion of new and innovative technologies such as SEVs (Painuly, 2001). It is due to their role in promoting electric mobility and reducing reliance on ICEVs, that strategies from the perspective of the government are explored further. The government's involvement is necessary to address various aspects such as facilitating favorable market conditions for the technology through necessary regulations, social acceptance, and the development of supportive policies. Ultimately, supporting the development of the technology by removing barriers, building capacity, promoting research and development, creating an investment-friendly environment, and providing information to promote the adoption of SEVs (Painuly, 2001).

't Veld (2020) claims that to facilitate government intervention in the large-scale diffusion of sustainable energy technologies, several strategies can be employed. These strategies include establishing collaborations and alliances with the industry stakeholders, facilitating skills and knowledge-sharing mediums, exploring new markets, and innovating collaboratively to reduce the upfront cost of the product (Ang, 2008), (Gabriel et al., 2016), (Gabriel, 2016). These strategies are discussed in table 6.2.

Table 6.2: Strategies tailored for government perspective

No.	Mian strategies	Sub-strategies	Adapted from/Source
1	Liberalizing the market strategy	Restructuring the sector/Privatization Facilitating competition Removing other controls Public sector participation Setting up independent regulatory bodies	't Veld (2020), Painuly (2001), Zafar et al. (2018)
2	Guaranteed markets strategy	Provide standards and regulations Ensuring a secure and stable market	't Veld (2020), Painuly (2001), Pratiwi (2016)
3	Economic/financial incentives strategy	Providing subsidies Providing scrapping (end of life) incentives Tax exemption/reduction	Dwisatyawati (2022), 't Veld (2020), Painuly (2001), Schulz (2019), Ortt (2013), Expert G (2023)
4	Investment strategy	Government investment Promote external (private) investments	't Veld (2020), Fromhold-Eisebith & Werker (2013), Painuly (2001)
5	Promotion/awareness campaign strategy	Educating stakeholders Educational seminars and webinars	't Veld (2020), Balachandra et al. (2010), Painuly (2001), Pratiwi (2016)
6	Research & development (niche) strategy	Pilot research and development Providing funding and grants Establishing research centres Facilitate external R&D investments	Dwisatyawati (2022), 't Veld (2020), Painuly (2001), Schulz (2019), Fromhold-Eisebith & Werker (2013)
7	Supportive demonstration and cost-reduction strategy	Providing testing/demonstration facilities	't Veld (2020), Reddy & Painuly (2004)
8	Initiate (technical) training strategy	Improve accessibility to (technical) information Create jobs aligning with the roles associated with the development and diffusion of the technology Promoting/conducting training workshops	't Veld (2020), Zafar et al. (2018)

In practice, governments can adopt supportive policies and measures to encourage the diffusion of SEVs. According to Painuly (2001), these include liberalizing the SEV sector, providing guaranteed markets for SEV developers, offering financial incentives such as subsidies and tax exemptions, initiating information and awareness campaigns, establishing standards and regulations, setting up R&D programs, supporting demonstrations and cost-reduction strategies (Painuly, 2001), (Sen & Ganguly, 2017). Due to the power that the government holds, strategies like liberalizing the sector, providing guaranteed markets, and financial incentives can only be employed by government entities.

Applying these strategies can yield fruitful outcomes for the government and other stakeholders. Governments can stimulate the uptake of SEVs by improving the competitiveness among manufacturers, promoting electric mobility, achieving social and environmental benefits, attracting investments, creating jobs, enhancing energy security, and contributing to the reduction of greenhouse gas emissions (Zafar et al., 2018). Additionally, the diffusion of SEVs can lead to technological advancements, cost reductions, improved accessibility to SEV-related information, and the development of skilled human resources (Painuly, 2001).

It is important to note that government approaches to promoting SEVs may vary across regions and countries, with some governments taking neutral or opposing positions due to the implications of substituting established fossil fuel industries. Institutional capacity and integrity issues sometimes could also hinder government interventions in certain developing countries such as India (Balachandra et al., 2010).

6.4 Strategies applicable to customers

Customers play a crucial role in the large-scale diffusion of any technology, including Solar Electric Vehicles (SEVs). Their adoption and acceptance of SEVs directly impact the market demand and growth of the industry (Krishna, 2021). Customers' preferences, needs, and feedback shape the development of SEVs, influencing manufacturers, policymakers, and other stakeholders. Therefore, understanding and engaging customers in the SEV ecosystem is essential for its success.

A major factor that influences the engagement of customers in the large-scale diffusion of technology, is their trust in the high-tech companies developing the technology (Wüstenhagen et al., 2007). Pesch (2014) claims that maintaining the trust of customers is a crucial aspect of the successful large-scale diffusion of technology (Pesch, 2014). One of the ways to gain trust and acceptance is to adhere to the customer/end-user requirements (Chaurey & Kandpal., 2010). Customers could clearly formulate their requirements and expectations from the technology while adhering to the safety standards and other regulations set by the government. This allows the focal actors (high-tech companies developing the technology) to gain their trust by satisfying the customers' needs (Pesch, 2014).

Another (indirect) way to gain the users' trust is to gain the trust of an influential member (for example, the head of a community or a village) of a community first (Uremee et al., 2016). In modern urban and rural communities, the general members of the community (potential users), accept the beliefs of influential community members. This way, influential community members can promote and spread awareness regarding the technology. They not only influence the decisions of other potential users but also can engage in (active) word-of-mouth (WOM) advertising of the technology (Krishna, 2021). In addition to that, active customers and influential community members can also use electronic Word of Mouth (eWOM) platforms to spread information and awareness of a particular technology (Krishna, 2021).

Although, the customers' role is undermined, from the literature it was identified that the measures discussed above can be taken by the customers, to support the large-scale diffusion. Recognizing the importance of the role of customers in large-scale diffusion, these strategies have been highlighted in the table 6.3.

Table 6.3: Strategies tailored for customer perspective

No.	Main strategies	Sub-strategies	Adapted from/Source
1	Formulate requirements strategy	Articulating the specifications and requirements for the technology	't Veld (2020), Chaurey & Kandpal (2010)
2	Influential community member strategy	Creating a trend by incorporating the technology at an early stage	't Veld (2020), Urmee & Md (2016), Expert E (2023)
		Spreading awareness among communities	
3	Word of mouth strategy	Usage of electronic Word of Mouth (eWOM) platforms	't Veld (2020), Kenton (2016), Krishna (2021)
		Word of Mouth (WOM) advertising	
4	Continuous user engagement strategy	Organize feedback sessions, surveys, user forums, and social media engagement with companies developing the technology	't Veld (2020), Urmee & Md (2016)

6.5 Case study on strategies: Aptera Motors and Lightyear

A case study is conducted on Apetra Motors, and Lightyear to investigate the measures they've taken to launch and introduce their SEVs in the market. According to Shakir (2002), when the research topic in question addresses a contemporary phenomenon (in this case, the measures taken by existing SEV companies), case studies are a suitable research method to gather data.

Hence case studies are done to gather insights from the public reports made available by Aptera Motors and Lightyear. This case study on Lightyear and Aptera Motors was crucial to understanding the strategies that are being implemented by the pioneers of SEV technology. In addition to that, this case study provided an additional layer of rationale for the applicability of the strategies obtained from the literature to the context of SEVs. In order to obtain the data on the strategies from these companies, firstly, the available scientific literature was explored. Since this case study was based particularly on the measures taken by Lightyear and Aptera, publicly available reports were used to gather information on the strategies as there was limited (direct) scientific literature available.

6.5.1 Aptera Motors

The following strategies are implemented by Aptera Motors. The particular (technical) measures taken by Aptera Motors are discussed below in relation to the most relevant strategies identified from the literature.

1. Technological research & development (niche) strategy
    - Employing the usage of the additive manufacturing process (alternative to steel stamping) as it is more efficient to launch new models quickly to manufacture body parts (Aptera, 2022).
    - Incorporating Artificial Intelligence (AI) to optimize part designs for strength and material efficiency, ultimately making the vehicle more rigid.
    - The use of resin-infused sandwich-core construction creates lightweight composite structures, ultimately facilitating advancement in vehicle design.
    - Usage of Automated Guided Vehicles (AGV) to simplify and automate the production process, thereby reducing manufacturing expenses.
2. Marketing strategy
    - Hybrid marketing/promotion of the company and the vehicle by scheduling test-drive opportunities with the enthusiasts and organizing events in the markets with potential demand (Aptera, 2022).
    - Through the Summer of Solar Mobility campaign, the active promotion of the technology is done by social media advertising and touring the United States in Apetra's SEV (Aptera, 2023).
3. Geographic niche strategy
    - Rolling out the vehicles from the first line of production in Southern California (Aptera, 2022).
    - After Southern California, other major metropolitan cities are targeted.
4. Finance sourcing strategy
    - Through Aptera's accelerator program, they encourage crowdfunding by allowing investments from accredited investors.
    - Aptera successfully raised over $8 million from 553 investors worldwide (Aptera, 2023).

5. Partnerships niche strategy, blue ocean strategy
    - Aptera partnered with eco-accelerator SustainabilitySooner to provide a 101 SEV fleet promoting solar mobility among fleet operators.
    - By targeting fleet operators like SustainabilitySooner, Aptera is venturing into a new market space where there is limited competition (Blue Ocean Strategy) (Aptera, 2023).
    - Aptera has formed a strategic partnership with the C.P.C. Group, an experienced and renowned company in the automotive industry that specializes in composite solutions.
6. Lead user niche strategy
    - Aptera targeted the first 2000 (lead) users/pioneers of SEV technology to accelerate the first line of production (Aptera, 2023).
7. Hybridization or adaptor niche strategy
    - Aptera is adapting to the existing charging infrastructure in the market by integrating the North American Charging Standard (NACS), which was formerly known as the Tesla connector (Aptera, 2022).
8. Integrated network strategy
    - By partnering with Maxeon, Aptera is tapping into the expertise of an industry leader in solar innovation, allowing them to leverage high-quality and efficient solar cells for their solar electric vehicles (Aptera, 2022).
    - Aptera motors utilize the highly-efficient 21700 NMC 811 cells by relying on and partnering with EVE Energy Co, Ltd to produce lightweight batteries.
    - Aptera is strategically collaborating with Elaphe, a specialized company with expertise in in-wheel motor technology by developing cutting-edge vehicles at a rapid pace.
    - Aptera's partnership with RedViking enables to optimize its final vehicle assembly, increase production efficiency, and meet its pre-production and production timelines with confidence.
9. Human resource management strategy, finance sourcing strategy
    - Aptera appointed a corporate veteran and venture capital partner to be a strategic advisor due to their expertise as an investor and knowledge of the industry. Similarly, the Managing General Partner of Impala Ventures was also appointed as another strategic advisor & investor (Aptera, 2022).

6.5.2 Lightyear

The following strategies are implemented by Lightyear. The particular (technical) measures taken by Lightyear are discussed below in relation to the most relevant strategies identified from the literature.

1. Human Resource Management Strategy

- The appointment of Bart Welten and Floris van de Klashorst as the new Chief Financial Officer (CFO), and the Chief Transformation Officer (CTFO), respectively, indicates that Lightyear has incorporated a strategic approach to managing human resources within the company (Lightyear, 2023).

2. Redesign Niche Strategy
    - Lightyear has made the strategic decision to suspend the production of Lightyear 0 (the expensive version of the car) and redirect its focus and resources completely towards Lightyear 2 (the cheaper version of the car), a more affordable solar electric vehicle aimed at a wider audience (Lightyear, 2023).
    - R&D conducted for Lightyear 0 and the learning obtained through its market introduction will be utilized as a basis for the development of Lightyear 2.
3. Partnerships Niche Strategy
    - By forming partnerships with leasing and car-sharing companies like Arval, Athlon, LeasePlan, and MyWheels, Lightyear is expanding its market reach and making its Lightyear 2 solar car accessible to a broader audience.
    - Lightyear partnered with the supercar manufacturer, Koenigsegg, which allowed them to tap into Koeningsegg's resources and experience in building high-performance sports cars to ultimately develop cutting-edge innovations (Lightyear, 2022).
4. Collaborative Product Utilization Strategy
    - By partnering with companies like Arval, Athlon, LeasePlan, and MyWheels, Lightyear is facilitating the option of leasing and car sharing for the end users. This enables the end users to use the product (SEV) without the need to purchase the vehicle.
5. Marketing strategy (preannouncing strategy specifically)
    - Lightyear by participating in CES 2023 (Las Vegas), a tech event, is promoting their product by spreading awareness regarding solar mobility. They showcased not only Lightyear 0 (their existing model), but also (pre-) announced Lightyear 2 (affordable mass market model) by reaching a global audience.
    - Announced waitlist for Lightyear 2 by building anticipation of the product.
    - Lightyear promoted Lightyear 0 by letting the (potential) customers/end users experience the driving of Lightyear 0 through the Destination Daylight campaign (Lightyear, 2022).

6.6 Chapter summary

In this chapter firstly, the strategies identified from the literature are discussed from the perspectives of industry, government, and customers. In addition to that, the strategies implemented by the solar mobility companies, Lightyear and Aptera Motors were discussed, emphasizing the relevance of the findings from the literature to SEV technology. After thoroughly reviewing the literature, it was identified that some of the strategies that were proposed could be classified as sub-strategies and combined into a main strategy. Therefore, such strategies were identified and grouped as sub-strategies in the present work. For example, several

strategies from the literature such as setting up independent regulatory bodies, promoting competition or privatization, and restructuring the sector were discussed individually by Painuly (2001) and 't Veld (2020). However, it was identified that these strategies serve the same purpose of liberalizing the targeted sector. Therefore, a new main strategy (combining the sub-strategies) named "Liberalizing the market strategy" was formed. Such modified strategies (after combining the sub-strategies) are highlighted in red color. This color code (red) has been used to clearly differentiate the main strategies that were modified (combined), from the main strategies which were directly adapted from literature without any modification.

In addition to that, it is also important to acknowledge the strategies with the same name and purpose, that can be implemented by different stakeholders from different perspectives. One such strategy is the Research and Development (niche) strategy. Both the government and industry, have different roles in facilitating research and development. However, it allows for them to work towards the (common) goal of improving the R&D of SEV technology, which in the long term accelerates large-scale diffusion of SEVs. On one hand, the government can provide research funding and grants, while the industry can commercialize the scientific research outputs, on the other hand. However, there are some measures under research and development strategy such as testing the technology through pilot projects, which can be taken by both the government and industry together. Similarly, all the stakeholders involved (government, industry and customers) have different roles in promoting and spreading awareness regarding the technology.

A brief overview of those modified main strategies under individual perspectives is provided below

1. Government
    - Liberalizing market strategy
    - Research and development (niche) strategy
    - Initiate (technical) training strategy
2. Industry
    - Research and development (niche) strategy
    - Human resource management strategy
    - Finance sourcing strategy
    - Lobbying strategy
    - Collaborative product utilization strategy
    - Partnerships niche strategy
    - Integrated network strategy
    - Marketing strategy
    - Explore multiple markets strategy
3. Customers
    - Word of mouth strategy

Table 6.4: Final list of main strategies

No.	Main strategies	Adapted from/Source
1	Liberalizing the market strategy	't Veld (2020), Painuly (2001), Zafar et al. (2018)
2	Guaranteed markets strategy	't Veld (2020), Painuly (2001), Pratiwi (2016)
3	Economic/financial incentives strategy	Dwisatyawati (2022), 't Veld (2020), Painuly (2001), Schulz (2019), Ortt (2013), Expert G (2023)
4	Investment strategy	't Veld (2020), Fromhold-Eisebith & Werker (2013), Painuly (2001)
5	Promotion/awareness campaign strategy	't Veld (2020), Balachandra et al. (2010), Painuly (2001), Pratiwi (2016)
6	Supportive demonstration and cost-reduction strategy	't Veld (2020), Reddy & Painuly (2004)
7	Initiate (technical) training strategy	't Veld (2020), Zafar et al. (2018)
8	Research & development (niche) strategy	Dwisatyawati (2022), 't Veld (2020), Schulz (2019), Olsthoorn (2017), Fromhold-Eisebith & Werker (2013), Painuly (2001),
9	Human resource management strategy	Dwisatyawati (2022), 't Veld (2020), Schulz (2019), Davey et al. (2018), Fromhold-Eisebith & Werker (2013), Expert F (2023), Expert H (2023)
10	Education niche strategy	Dwisatyawati (2022), 't Veld (2020), Schulz (2019), Zafar et al. (2018), Fromhold-Eisebith & Werker (2013)
11	Lead-user niche strategy	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
12	Finance sourcing strategy	Schulz (2019), Dwisatyawati (2022), 't Veld (2020),
13	Subsidized niche strategy	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
14	Redesign niche strategy	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
15	Dedicated system or Stand-alone niche strategy	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
16	Hybridization or Adaptor niche strategy	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
17	Lobbying strategy (Advocacy strategy)	Dwisatyawati (2022), Schulz (2019), Hardman et al. (2013), Expert D (2023)
18	Collaborative product utilization strategy	Dwisatyawati (2022), Schulz (2019), Strupeit & Palm (2015), Bloem (2018)
19	Buy-one, give one niche strategy	Dwisatyawati (2022), Schulz (2019)
20	Geographical niche strategy	Ortt (2013), Schulz (2019), Dwisatyawati (2022)
21	Top-end niche strategy	Ortt (2013), Schulz (2019), Dwisatyawati (2022), Sharma (2016)
22	Partnerships niche strategy	Dwisatyawati (2022), Schulz (2019), Strupeit & Palm (2015), Hardman et al. (2013), 't Veld (2020), Expert D (2023)
23	Integrated network strategy	Dwisatyawati (2022), Hardman et al. (2013)
24	Marketing strategy	Dwisatyawati (2022), Schulz (2019)
25	Stepping stone strategy	Dwisatyawati (2022), Olsthoorn (2017)
26	Product variants strategy	Dwisatyawati (2022), Sharma (2016)
27	Cross-selling strategy	Dwisatyawati (2022), Stupeit & Palm (2016), Expert E (2023)
28	Result-oriented contracting strategy	Dwisatyawati (2022), Strupeit & Palm (2015), Expert E (2023)
29	Blue ocean strategy	Dwisatyawati (2022), Sharma (2016), Kim & Mauborgne (2004)
30	Explore multiple markets strategy	Ortt et al. (2013), 't Veld (2020), Bloem (2018)
31	Formulate requirements strategy	't Veld (2020), Chaurey & Kandpal (2010)
32	Influential community member strategy	't Veld (2020), Urmee & Md (2016), Expert E (2023)
33	Word of mouth strategy	't Veld (2020), Kenton (2016), Krishna (2021)
34	Continuous user engagement strategy	't Veld (2020), Urmee & Md (2016)

7 Expert Interviews

Expert interviews conducted during this thesis are discussed in this chapter. Since interviews were only conducted during phases 2, 3, and 4, the chapter is also organized into the interviews conducted from phases 2, 3, and 4 respectively, as shown in the figure 7.1. Firstly, interviews conducted with experts A, and B, and the validation received from them on the barriers identified in this thesis are discussed in section 7.1. In addition to that, the interviews with experts C, D, E, and F, and the validation received from them on the strategies are also reviewed in section 7.2. Ultimately, interviews conducted in phase 4 with experts G and H were used to identify the most important strategies that could be implemented per barrier, discussed in the section 7.3. All the experts were interviewed once whereas Expert G expressed his willingness to participate in a second interview where some additional insights were gained.

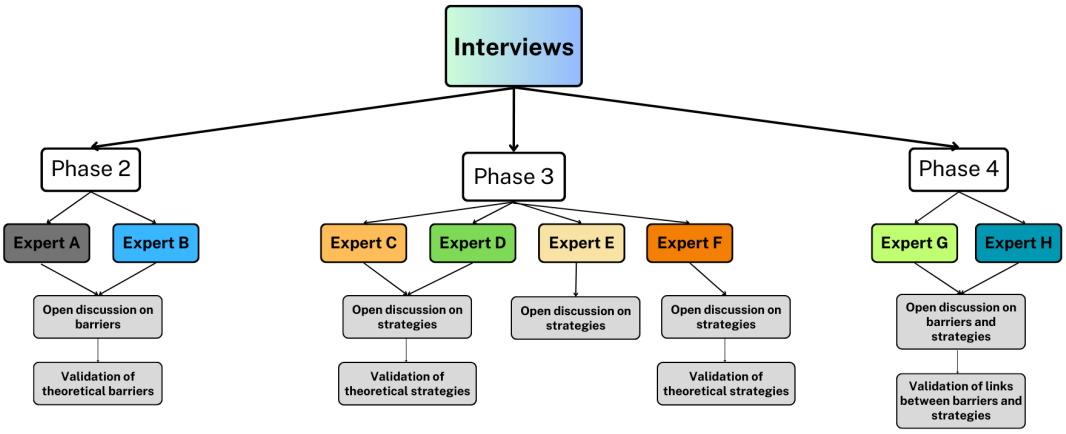

Figure 7.1: Classification of interviews into different phases of this thesis

7.1 Interviews - Phase 2

This section highlights the key findings (new information) from the interviews conducted in phase 2. In addition to that, the key findings from the interviews have been linked to the barriers identified from the literature, and the method used to link the findings is presented in figure 7.2.

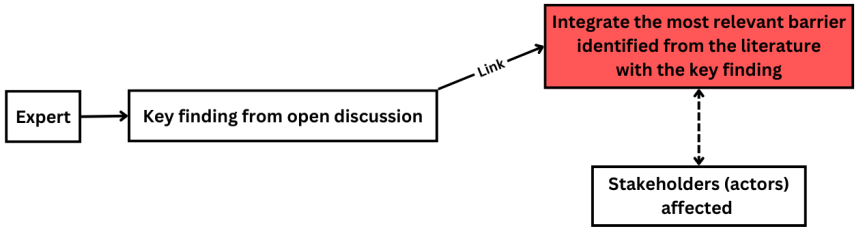

Figure 7.2: Method used to link the key findings from the interview with the barriers from literature

Interviews conducted during phase two focused on finding new information on the barriers that the EV industry is facing in India and validating those barriers for SEV technology, along with the potential opportunities from the expert's perspective. Experts A and B were primarily interviewed based on their areas of expertise, and the findings from these interviews are presented in table 7.1.

According to expert A (2023), SEVs present opportunities for foreign companies to tap into the potential of the Indian market, by tapping into the potential of existing distribution networks. Such collaborations are also possible in academia, within Indian universities, and renowned global research institutes. However, it was also highlighted that currently there is limited collaboration between academia and industry, as a consequence, knowledge development and diffusion are hindered. Lack of knowledge development and diffusion in turn affects the competition within the SEV market, as OEMs are hesitant to invest in this technology. The author of the present work agrees with the insights provided by expert A (2023), as the lack of collaboration between industry and academia (and the resulting consequences) has been found to be a barrier in the literature, and also confirmed by expert F (2023).

According to expert B (2023), due to the discovery of lithium reserves in India, there is a huge potential for the cost of batteries to go down. In addition to that, adding a solar panel over the roof of the vehicle reduces the burden on the battery, as the vehicle will have two sources of power. Ultimately, reducing the need for a battery with high capacity, and as a result, the cost of the vehicle can be reduced. However, currently, this is not the case, as EV technology itself is quite new in India, therefore, the cost of ownership is relatively higher than an ICEV. Due to this, there are a limited number of EV models available. Additionally, detailed findings from the interviews with experts A and B are outlined in the table 7.1

Table 7.1: Key findings from interviews with experts A and B and their relevance with barriers from literature

Interviewee	Stakeholders affected (Perspectives)	Information gathered on a particular barrier during open discussion	Interview-based barriers aligned with barriers from literature
Expert A	Industry (OEMs)	Solar PV technology in India is still developing, and innovation is needed in order to incorporate the solar panel (if they are curved) on the solar cars, as a result, it presents design challenges as well	Lack of (technical) knowledge, Maturity of technology
		Availability of materials for solar panels is a challenge as with the increase in demand for SEVs the demand for producing solar panels will also increase	Production factors/Economies of scale, Maturity of technology
	Customers (end users)	As majority of the population in India belongs to the middle-class, bearing the high-upfront cost of the vehicle is also a challenge if the vehicle is expensive, although middle-class consumers are target class of consumers.	
	Industry (financial institutes), Customers (end users)	Some of the (potential) middle class consumers rely on bank loans to support their (S)EV purchase but banks are reluctant to provide loans due to the high-upfront costs when compared to traditional vehicles, ultimately affecting the decision of customers	Cost of purchase and ownership, Demand factors
	Industry (OEMs)	Limited number of companies (only Vayve Mobility) are working on SEV technology in India, and as a result (according to expert A), there is no competition among SEV manufacturers	Supply and choice of vehicles/lack of competition,
	Government, Industry (financial institutes)	Lack of funding from the government and private sector (towards research institutes) to research, develop and diffuse the knowledge pertaining to SEVs	Government policy and regulatory framework, Lack of (technical) knowledge
	Industry (OEMs and financial institutes)	Although there are collaborations within research institutes, no knowledge sharing platforms between research institutes and high-tech companies.	Lack of collaboration among stakeholders
Expert B	Customers (end users)	Cost of (Battery) Electric Vehicles is significantly higher than conventional vehicles in the Indian market	Cost of purchase and ownership
	Industry (OEMs), Government (policy makers)	Limited number of (Solar) Electric Vehicle product variants are available, as a result there are less models for end users to choose from	Supply and choice of vehicles/lack of competition, Demand factors
	Customers (end users)	Limited financing capability of potential end users with middle and low income, resulting in less demand for expensive vehicles	Cost of purchase and ownership, Demand factors
	Customers (end users)	Range anxiety is another barrier for the use cases when long distance (outside the city) travelling is required	Range anxiety, long recharge duration
	Industry (OEMs)	Shortage in SEV components such as solar cells, and semi-conductors resulting in limited supply towards SEVs	Production factors/Economies of scale
	Customers (end users), Industry (OEMs)	Limited number of OEMs are focusing on (Solar) Electric Vehicle technology	Lack of collaboration among stakeholders, Supply and choice of vehicles/Lack of competition
	Industry (OEMs), Customers (end users)	Since the cost of EVs are really high, only high end customers are targeted by some companies	Lack of network externalities, Demand factors, Cost of purchase and ownership
	Industry (OEMs), Customers (end users)	High import taxes on (Solar) Electric Vehicles manufactured outside India, eventually restricting all (S)EV companies with manufacturing facilities outside India, in order to encourage manufacturing locally, in India.	Government policy and regulatory framework
	Industry (OEMs), Government (policy makers)	Investment in alternative technologies like Hydrogen vehicles could potentially disrupt EV sector	Constantly evolving markets

An important observation made during the research on barriers is that the barrier 'environmental impact' was highlighted in the literature as a barrier to the adoption of EV technology. However, from the interviews, it was found that the threat of the barrier 'environmental impact' from the perspective of solar EVs is low. This ranking was primarily given based on an assumption that the environmental emissions considered by the usage of solar EVs are lower compared to the traditional EVs, as SEVs make use of clean energy to charge the battery and propel the vehicle forward. The environmental emissions involved in the production of the vehicle and its components such as batteries, and solar PVs are not considered. This resulted in the limitation that environmental emissions associated with solar EVs have been excluded from this thesis, as the socio-technical conditions that affect the environmental impact and the emissions resulting from the production of the vehicle are not discussed in this thesis. Therefore, by listing the barrier 'environmental impact', the author acknowledges the barrier but it is not investigated further in this thesis.

7.2 Interviews - Phase 3

This section highlights the key findings (new information) from the interviews conducted in phase 3. In addition to that, the key findings from the interviews have been linked to the strategies identified from the literature and are presented in figure 7.3. These key findings from the interviews are predominantly related to the measures that are taken currently and also measures that are applicable in the future in the Indian (solar) electric vehicle market.

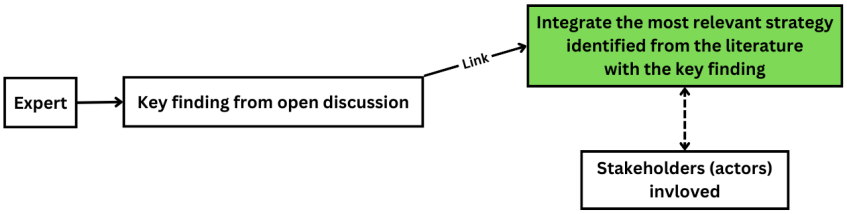

Figure 7.3: Method used to link the key findings from the interview with the strategies from literature

During phase 3, firstly, experts C and D were interviewed to understand the current market conditions and the strategies that were being implemented in the EV sector. By interviewing them on the current market conditions of the EV sector, some insights were gained on how well the current market conditions can accommodate a disruptive technology like SEVs. Therefore, the information and validation received from experts C and D were crucial, in order to extend and study the applicability of the strategies found in the literature, to the Indian market. In addition to that, experts E and F were interviewed to understand what could be done in the future to accommodate SEVs in the Indian market. Therefore, the information received from experts E and F is primarily based on the type of strategies that are both, applicable now and also in the future.

According to Expert F (2023), Vayve Mobility is targeting a market where there is a possibility to offer the vehicle with the option of a solar roof, instead of offering a solar-only vehicle. This presents the customers with an option to choose from, as they have a choice to buy the vehicle with or without the additional solar roof. This way, Vayve Mobility expands its presence into the traditional EV market along with the SEV market. According to Expert F (2023), due to the price-sensitive nature of the Indian market, offering the product at an affordable price is the best way to introduce SEVs in the market. Vayve Mobility aims to provide solar electric vehicles at an affordable price of 6000$, by making the vehicle smaller and compact, and more suitable for an urban setting. Due to the road and traffic conditions in urban areas in India, there is a huge potential for such small and compact cars.

On the other hand, Expert F claims that, for a SEV company to be successful in India, the purchasing price must be affordable to the end users in the middle-class income range. Therefore, it was inferred that any vehicle with a high purchasing cost of over 15 lakh Indian Rupees (about 17000 EUR) is likely to not succeed in the mass market. Currently, from the perspective of an average Indian customer, the available SEV models from Lightyear and Aptera Motors are highly priced (>25000 EUR), therefore, such models are highly unlikely to succeed in the mass market. In addition to the economic conditions in India, the SEVs must also meet and adapt to the conditions of the Indian roads. Therefore, according to expert F (2023), it is crucial for companies introducing SEVs in the Indian market to meet the economic and geographical (road) conditions in India, which are often different when compared to developed countries. The author of the present work agrees with the above points raised by expert F, as the economic and geographical conditions in India must be taken into consideration before introducing SEVs into the Indian market. This was also confirmed by other experts (particularly expert G) who claimed that for a SEV to be able to diffuse in the mass market, it must make sense for the customers to be able to afford it (from a financial point of view), and the vehicles must be designed to be able to withstand the road conditions in India (from a design point of view).

Table 7.2: Key findings from interviews with experts C and D and their relevance with strategies from literature

Interviewee	Stakeholders involved/Perspectives	Information gathered on a particular strategy during open discussion	Strategy applied
Expert C	Central government	Through Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) I and II policy implementation, the feasibility of EVs are tested and later incentivized	Economic/financial incentives strategy
		Reduction in the upfront cost of the vehicle through subsidies	Subsidized niche strategy
	State government	State governments (of around 20 Indian states) introduced their own sub-national policies in addition to FAME I and II	Economic/financial incentives strategy
		Land, water, electricity, and other resources required for manufacturing are incentivized	
		Initiatives are introduced both on the supply and demand sides of the vehicles	
	Local municipalities	Local municipal corporations and local companies (For ex: Delhi, Bangalore, and Mumbai) formulated their own initiatives targeting a particular city/region	Geographical niche strategy
	Central government	Ministry of Power came up with guidelines and regulations for the charging stations	Research and develop (niche) strategy
		Improving the density of the charging stations within urban and rural areas with pilot projects	
	Industry (OEMS)	Collaboration among multiple industry players, for ex: Gogoro and Zypp Electric to collaborate and produce EVs, and between TATA and BluSmart to improve charging infrastructure	Partnerships niche strategy/ integrated network strategy
	Industry (High-tech companies)	50-60% of the sales in EVs originated from high-tech startups led by up and coming (skilled) entrepreneurs	Education niche strategy
			Research and develop (niche) strategy
			Human resource management strategy
	Government and industry	Shoonya Platform initiated by the government for collaboration among 100+ companies	Integrated network strategy
			Partnerships niche strategy
		No road and registration tax for new (S)EVs in Delhi	Economic/financial incentives strategy
		Switch Delhi campaign for switching to electric mobility, by spreading awareness	Promotion/awareness campaign strategy
	Customers/end users	E-Amrit portal for comparison of different models EVs (for end users)	Promotion/awareness campaign strategy
			Product variants strategy
		Sales of EVs are improving due to increased awareness and curiosity among customers	Influential community member strategy
			Word of mouth strategy
			Result oriented contracting strategy
Expert D	Central government	Government's FAME scheme allocated a separate budget to support R&D activities within (solar) EV industry	Economic/financial incentives strategy, Research & develop (niche) strategy
		Government is supporting the general public (end users with average income level), and not the rich users (so for a costly high end SEVs these policies may not be applicable)	Subsidized niche strategy, Economic/financial incentives strategy
	State government	Individual state governments (of around 20 Indian states) have their own policies and schemes for state-wise technology development	
	Central and state governments	Incentives are provided in the form of demand incentives (subsidies), manufacturing incentives, waiving permits and road taxes	
	Central government	Production Linked Incentive (PLI) schemes are implemented by the central govt to promote Advanced Chemistry Cell (for battery technologies), and different solar EV components	Investment strategy
		Separate PLI scheme is implemented for Solar PV cells to promote the local production of cells	
		Active participation of Indian government in G20 summit to promote and develop climate tech and clean technology like (solar) EVs	Partnerships niche strategy
		Indian government is commercializing the advanced solutions with the EV sector through multilateral collaboration	
	Industry (OEMs)	Companies are identifying the need to target urban areas and regions with high demand for the successful large-scale diffusion of (solar) EVs	Geographical niche strategy
	Industry (OEMs and research institutes)	Companies are collaborating to develop the product from individual component (battery) level to the entire vehicle	Partnerships niche strategy, Research & develop (niche) strategy, Integrated network strategy
		Department of Science and Technology is initiating partnerships among multiple Indian universities and foreign universities for knowledge transfer and technology development	
		Department of Science and Technology developed a platform Science India Forum (SIF) to promote collaboration among academic institutes	
	Industry (OEMs)	Log 9 materials (a high tech company) came up with a new battery technology that can help charge EV batteries at a much faster rate than an average battery	Research & develop (niche) strategy
	Customers (end users)	Having low or no operational costs of (solar) EVs enables customers to prefer EVs over ICEVs, and companies have the ability to ensure such guarantees	Result oriented contracting strategy
		Consumers awareness regarding (solar) EVs is happening at a faster rate and at all levels of the sector including rural areas	Marketing strategy, Word of mouth strategy, Promotion/awareness campaign strategy
	Government, industry, and customers	Media, news papers, news channels are the primary source of information and awareness regarding (solar) EVs	
	Industry (OEMs)	Automakers in industry (who produce both EVs and ICEVs) are advertising their (solar) EV products over ICEVs, by promising good performance and other related benefits	Marketing strategy, Result-oriented contracting strategy
	Customers (end users)	Consumers prefer investment in a (solar) EV compared to ICEVs after realizing performance related benefits of EVs	Formulate requirements strategy, Promotion/awareness campaign strategy
	Industry	Having a brand ambassador (champions) such movie stars, sports stars, influencers, etc to advertise and promote new (solar) EVs	Marketing strategy
	Industry (NGOs, IDOs)	Non Profit Organizations are lobbying for high-tech companies to bring in effective and helpful policies	Lobbying strategy

Table 7.3: Key findings from interviews with experts E and F and their relevance with strategies from literature

Interviewee	Stakeholders involved	Information gathered on a particular strategy during open discussion	Strategy applicable
Expert E	Industry (OEMs)	Making Solar EVs future proof by incorporating additional features such as autonomous driving, advanced digital systems and connectivity with other vehicles will make them an attractive choice to end users	Cross-selling strategy
		Targeting pre-orders or consumer reservation before the release of the vehicle by making it future proof will attract potential investors	Marketing strategy, Promotion/awareness campaign strategy
		Use case must stand out from conventional vehicles and traditional EVs. Companies should focus on selling the vehicles to service and delivery fleet operators	Blue ocean strategy, Explore multiple markets strategy, Collaborative product utilization strategy
	Industry (OEMs), Customers (end users)	Solar EVs could be used as backup generators, and a technology with complements the electricity grid, instead of relying on the grid for power. In addition to that it can generate income, by selling additional power (if applicable)	Result oriented contracting strategy
	Industry, government	Setting up a manufacturing plant in India (if it is a foreign company) would entitle the company to receive government support for the production of SEVs	Geographical niche strategy, Lobbying strategy, Finance sourcing strategy
	Industry (OEMs and research institutes)	Industry and academia have an opportunity to come together and form a unified body to share knowledge and development, and complement each other to develop SEVs together	Partnerships niche strategy, Integrated network strategy, Research and development (niche) strategy
	Industry (OEMs)	Industry wide collaborations could be enhanced through Society of Automotive Manufacturers (SIAM) to set up a benchmark and regulations for companies working towards the development of SEVs	Partnerships niche strategy
		Utilize existing 'Vaahan' portal to be aware of the recent developments and establishments with SEVs	Promotion/awareness campaign strategy
	Industry, customers (end users)	In order to reach the end users, companies building SEVs have to tap into the consumer passion and emotional attachment to the vehicle, and satisfy those needs	Marketing strategy, Result oriented contracting strategy, Formulate requirements strategy
		Creating a spark and establishing a trend for SEVs through community participation and spreading awareness will create curiosity among general public	Influential community member strategy, Word of mouth strategy
Expert F (Perspective of Vayve Mobility)	Industry (OEMs), customers (end users)	Targeting a particular class of end users (use case: short commute within the city), and building a car that is flexible to navigate through the city traffic	Explore multiple markets strategy
	Industry	Creating a new category (small and compact) of electric vehicle with additional solar roof. This allows the vehicle and company to be flexible, and not just a solar-only vehicle, attracting both EV and SEV enthusiasts	Blue ocean strategy, Explore multiple markets strategy, Cross-selling strategy
		Making the SEV small makes it efficient in terms of energy usage (20 km/kWh)	Redesign niche strategy
	Industry (OEMs), customers (end users)	Selling the SEV at cheaper price (about $6000) than the existing EVs will make sense from financial point of view to (potential) end users, without relying on government incentives and subsidies	Redesign niche strategy
		Tier 2 and tier 3 cities, along with major cities are also being targeted to attract a wide range of potential end users	Geographical niche strategy, Stepping stone strategy
		Ample focus on serving the needs of the customers, and their requirements must be carefully evaluated with that of what is feasible, from the point of view of the design of the vehicle. At the same time, it is crucial that those requirements align with the vehicles standards and regulations	Formulate requirements strategy
		Incorporating hybrid mode of marketing/promoting the vehicle both by offering a virtual experience online and physical test drives through experience centres in various markets.	Marketing strategy, Promotion/awareness campaign strategy
	Industry (OEMs and research institutes)	Best way for the industry and academia to collaborate is to conduct the research and demonstration projects jointly	Research and development niche strategy, Partnerships niche strategy
	Industry	Utilizing the existing supply chains that are already mature and certified helps the company in building their product	Integrated network strategy
		Optimizing the human resources (workforce reduction) is a strategy that companies (such as Lightyear, and Aptera Motors) use to direct the (financial) resources towards the right areas, and the departments where it is needed	Human resource management strategy
	Industry (OEMs), customers (end users)	Vayve Mobility is planning to introduce another model of the car (taxi), in the future, which potentially could bean opportunity for ride-sharing and ride-hailing companies to incorporate SEVs	Blue ocean strategy, Explore multiple markets strategy, Product variants strategy

7.3 Interviews - Phase 4

Experts G & H (2023), also highlighted some of the barriers that could potentially influence the market diffusion of SEVs in India. The key findings on the barriers are provided in table 7.4. During phase 4, Expert G was interviewed in two separate interviews. During the first interview, the barriers from the perspective of Expert G (2023) were discussed.

Table 7.4: Key findings from interviews with experts G and H and their relevance with barriers from literature

Interviewee	Actors affected	Information gathered on a particular barrier during open discussion	Interview-based barriers aligned with barriers from literature
Expert G	Industry (OEMs), Customers (end users)	Due to the price-sensitive nature of the Indian market, the capital costs for the companies, and the upfront cost for the end users in this industry are relatively higher	Cost of purchase and ownership, Production factors/Economies of Scale
		Limited EV models are available, and no SEVs are commercial yet in India	Supply and choice of vehicles/lack of competition, Demand factors
		OEMs are reluctant to produce more vehicles, as there is a limited demand for (S)EVs	Demand factors, Supply and choice of vehicles/lack of competition
		In the use case of long drives it will be inconvenient to go long distances without stopping multiple times for charging with the existing models in the market	Lack of infrastructure (charging stations), Range anxiety/driving range Long recharge duration
	Government, Industry, Customers (end users)	If EVs are towards the end of their life there are no regulations on sustainably scrapping the vehicle or even in the resale market	Low resale value (value depreciation), Reliability (wear and tear of components such as batteries)
	Industry (financial institutes), Customers (end users)	Due to lack of enough (S)EVs banks are reluctant to provide loans when compared to traditional vehicles	Lack of network externalities
Expert H	Industry (OEMs)	Solar engineering team needs significantly more (financial) resources when compared to the teams developing other parts of the vehicle, as the other parts such as batteries are significantly advanced in innovation when compared to the curved solar panels incorporated in SEVs.	Constantly evolving markets
		Although there are developments in the solar technology suitable for SEVs, manufacturing them at a large scale for lower costs is another challenge	Production factors/Economies of scale
		(Curved) solar panel suppliers specific to SEVs are very limited compared to suppliers for parts such as batteries	Production factors/Economies of scale, Lack of access to distribution channels/networks
		SEVs are not yet competitive as there are limited no of companies that are working on this technology, and hardly any companies are commercial till date	Supply and choice of vehicles/lack of competition

Additionally, the validation of the linkage between the barriers and strategies was received by asking the experts to highlight the strategies which they think are important in circumventing the barriers. All the barriers were linked with the corresponding strategies. Expert H (2023), highlighted certain strategies identified in this thesis to be the most important ones, as they address the majority of the underlying conditions behind the identified barriers.

According to Expert H (2023), from the perspective of a startup/high-tech company, (external) investment in resources is the most crucial strategy among all the discussed strategies. The development of the first SEV product, launching it in the market, and surviving in the market require a significant amount of financial resources. Therefore, sourcing the necessary financial resources ('Finance sourcing strategy') is required for all the activities carried out within the industry. Similarly, the financial burden on the end users can also be reduced by implementing subsidies and incentives ('Economic/financial incentives strategy') on SEV technology. From the interview with Expert H (2023), it could be inferred that the strategies pertaining to the financial aspects, discussed in this thesis, can be combined. For example, 'Finance sourcing strategy', 'Investment strategy', and 'Economic/financial incentives strategy'. Although these strategies primarily focus on the financial aspects (and solving the financial problems) of the technology, the stakeholders who are able to implement these strategies are different. Therefore, the stakeholders who are involved in implementing the strategy, and also those who benefit from implementing the strategy are highlighted in the table 8.5.

According to Expert H (2023), 'Research and Development (niche) strategy' is equally important but strategies associated with the financial aspects take precedence because sufficient financial resources are essential for activities such as investment in R&D, building the first prototype or the market ready product, reducing the upfront cost of the vehicle by providing incentives. Therefore, the 'Research and Development (niche) strategy' is also considered an important strategy, and given the second priority (ranking). Similarly, 'Partnerships niche strategy', 'Marketing strategy', 'Advertising strategy', and 'Geographical niche strategy' are also discussed. The justification for their importance and their ranking is provided in the table 7.5.

Table 7.5: Justification of the importance of the strategies discussed in the interview with Expert G & H (2023)

Important strategies according to expert's opinion	Ranking based on their importance	Justification
Finance sourcing strategy Economic/financial incentives strategy Investment strategy	1	These strategies emphasize on the financial aspects of the TIS of SEVs, and by implementing these strategies the barriers that arise due to financial problems can be circumvented
Research and development (niche) strategy	2	In order to come up with an SEV, research and development is crucial in having a prototype/functional product (SEV). R&D is crucial in bringing the technology from the concept phase to the design phase, and ultimately in to the market
Partnerships niche strategy	3	For startups/high-tech companies, it is crucial to engage with large companies and other stakeholders to take the product (SEV) to the market. This can be done by utilizing the resources and the expertise of the partner company, thereby mitigating the risks and facilitating the market reach
Marketing strategy Word of mouth strategy Promotion/awareness campaign strategy Geographical niche strategy Continuous user engagement strategy	4	These strategies emphasize on the promotional activities that are needed to educate the market and attract attention among the stakeholders, especially the end users involved to bring the product to the market
Product variants strategy	5	Variation in the products are needed in order to attract potential customers. And, this is linked with Research and development strategy because, without the first functioning product, the variations in products are not possible.

In the second interview with Expert G (2023), the key finding was that, in order for SEVs to be successful in the market, there should be some affordable finance schemes. This can be in the form of incentives that government provides, or bank loans provided specifically for purchasing SEVs. Moreover, this corroborates what was discussed during the interview with Expert H, especially when it comes to the financial aspect. Therefore, from both these interviews, it has been inferred that the most important socio-technical conditions affecting the large-scale diffusion of SEVs in India are associated with the financial aspects. Financial aspects can be in the form of barriers and/or strategies. High 'cost of purchase and ownership', and lack of funds for scaling up the production ('economies of scale') are considered one of the main barriers because of this aspect. However, on the other hand, offering the product at a cheaper price by providing 'Economic/financial incentives' or providing bank loans for the purchase of the SEVs is considered one of the important strategies. According to Expert G (2023), such options can be classified as 'affordable financing'.

It was evident from the interviews that the majority of the barriers associated with SEV technology can be circumvented by the strategies discussed in table 7.5. Firstly, all the possible strategies that can circumvent a barrier are listed in the table 8.5 against that particular barrier. Secondly, the most important strategy (that can circumvent a particular barrier) can be selected from the table 7.5 based on all the possible strategies that can circumvent that particular barrier in the order of ranking provided.

7.4 Chapter summary

This section reiterates the findings from expert interviews, and the most important findings from all the interviews are highlighted.

Firstly, two interviews (Expert A, Expert B) were conducted with the primary focus on identifying and validating the barriers that hinder, and opportunities that facilitate the large-scale diffusion of SEVs. In phase 3, four interviews (Expert C, Expert D, Expert E, and Expert F) were conducted to validate the theoretical strategies identified in this thesis. Finally, Expert G and Expert H were interviewed to gather opinions on the most important strategies that can be applied out of the 34 strategies identified. Based on the opinions of experts G and H, the links between strategies and barriers were formed and validated.

Although, only two interviews were specifically focused on validating the barriers (presented in the section 8.1, all the experts were asked for their opinions on what they think the biggest barrier to SEV technology is, as the first question during the interviews. As a result, it was found that 6 out of 8 experts confirmed (during the open discussion part of the interview) that the upfront cost of the vehicles (**'cost of purchase and ownership'**) in India is the biggest and an immediate threat to SEVs, due to the price-sensitive nature of the Indian market. In addition to that, some of the other barriers such as the 'lack of (technical) knowledge and awareness', 'lack of competition', and 'lack of collaboration among stakeholders' have been identified to pose a high threat to the market diffusion of SEVs. In order to overcome those barriers, some of the strategies emphasized particularly by the experts are 'Economic/financial incentives strategy', 'Partnerships niche strategy', 'Promotion and awareness campaign strategy', 'Geographical niche strategy', and 'Research and development niche strategy'. Ultimately, it was found that the strategies eliminating or circumventing the barriers associated with the financial aspects are considered the most important by the experts.

8 Results and Discussion

In this chapter, the results obtained from each phase of this thesis are outlined. These results are obtained by extending the original TIS framework considering the application of solar electric vehicle technology with a geographical focus on India as depicted in the figure 8.1.

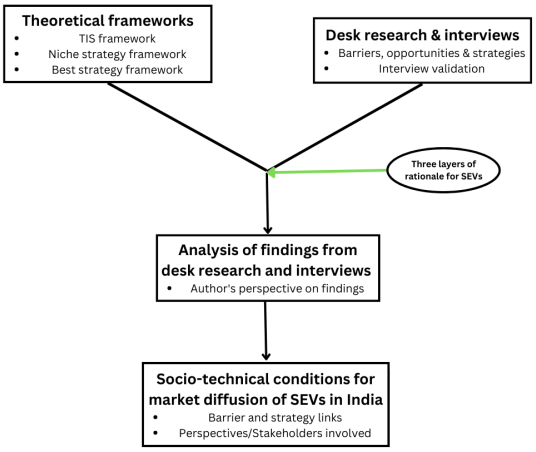

Figure 8.1: Extension of original TIS framework to SEVs in India

8.1 Results from phase 2

This section outlines the results obtained from phase 2 of this thesis. Firstly, the results obtained from the analysis of the barriers from the literature are highlighted. Then, the validation received from the experts on these barriers is discussed. Ultimately, the outcome from the results obtained from phase 2 is the status of TIS building blocks for SEVs in India.

Results from analysis of the barriers from literature

In order to understand the status of each of the TIS building blocks, and the influence of the identified barriers on the status of each of the building blocks, the cause or reason behind the barrier has been explored, and linked to the relevant influencing conditions. This is done by carefully analyzing all the identified barriers, influencing conditions, and the TIS building blocks.

The process of linking the influencing conditions with the barriers involved an analysis where each identified barrier was correlated with the most relevant influencing condition from the TIS framework. This correlation was established by identifying the relationships between

the barriers and the underlying conditions. Schulz (2019) presented multiple combinations of links between the influencing conditions, and the TIS building blocks, represented by the four different illustrations (examples) in the figure 8.2. In the figure, only 4 influencing conditions (out of seven), and four TIS building blocks (out of 7) were shown to explain the process of linking them with each other, in a simplified manner. Each of these example illustrations presents a different set of links, resulting in the main barrier. These scenarios are explained with a few examples from the table 8.1 to show the relevant links. It was also identified that, although different sets of links are possible, it is not necessary that all seven influencing factors can be the underlying cause behind a main barrier, and have an influence on a particular building block (Schulz, 2019). And, there are certain links that are not relevant (with no direct influence on the barriers), as a result, such links have no influence on TIS building blocks (Ortt et al., 2013). Therefore, such links with no direct influence on the barriers are not investigated further.

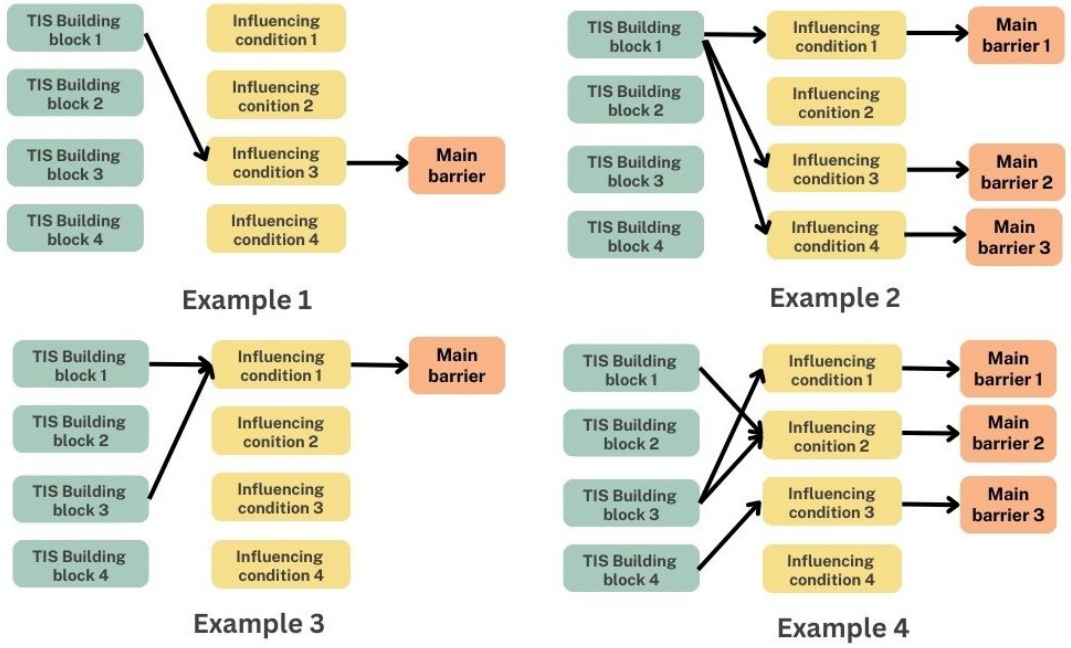

Figure 8.2: Link between TIS building blocks and underlying influencing conditions of the main barrier adapted from Schulz (2019)

- **Example 1**: In example 1, it is possible that only one influencing condition is found to be the cause behind a barrier, and possibly influencing only one TIS building block. For instance, the barrier 'lack of collaboration among stakeholders' exists because of the influencing condition 'socio-cultural aspects', ultimately affecting the TIS building block 'network formation and coordination'.
- **Example 2**: In example 2, it is possible that different barriers are caused by different influencing conditions, ultimately affecting the same TIS building block. For instance, the main barriers 'lack of awareness among customers' and 'cultural and psychological factors', are caused by different influencing conditions 'knowledge and awareness of technology' and 'socio-cultural aspects' respectively, ultimately affecting the same TIS building block 'customers'.

- **Example 3**: In example 3, it is possible that the main barrier is influenced by only one influencing condition, but ultimately affects two different TIS building blocks. For instance, the main barrier 'cost of purchase and ownership' is primarily caused by the influencing condition 'natural, human and financial resources', ultimately affecting both 'product price' and 'customer' building blocks.
- **Example 4**: In example 4, several combinations of links are possible. For instance, two TIS building blocks are influenced by the same influencing conditions which ultimately causes the main barrier. As can be seen from the barrier 'Government policy and regulatory framework', 'Macroeconomic and strategic aspects' are the underlying influencing condition that affects both the TIS building blocks of 'Innovation-specific institutions' and 'Product price'.

All the possible (direct) links can be categorized into at least one of the example illustrations provided above. The same approach and logical reasoning were used in framing all the (direct) links discussed in the table 8.1.

Table 8.1: Barriers, underlying influencing conditions, and the affected TIS building blocks

Barriers identified	Associated influencing condition(s)	Affected TIS Building block(s)
Lack of (technical) knowledge	• Knowledge and awareness of technology • Knowledge and awareness of application and market • Natural, human and financial resources	• Product performance and quality • Production system • Customers • Network formation and coordination • Innovation-specific institutions
Lack of awareness	• Knowledge and awareness of technology • Socio cultural aspects	• Customers
Supply and choice of vehicles/lack of competition	• Competition	• Product price • Customers • Network formation and coordination
Safety (due to the nature of batteries)	• Knowledge and awareness of technology • Socio-cultural aspects • Natural, human and financial resources	• Product performance and quality
Environmental impact	All	All
Reliability (depletion, wear and tear of the components such as batteries)	• Knowledge and awareness of technology • Socio-cultural aspects • Knowledge and awareness of application and market	• Product performance and quality • Production system
Maturity of technology	• Knowledge and awareness of technology • Competition • Macro-economic and strategic aspects	• Product performance and quality • Production system • Product price
Cost of purchase and ownership	• Knowledge and awareness of technology • Natural, human and financial resources • Knowledge and awareness of application and market • Macro-economic and strategic aspects	• Product price • Customers
Limited infrastructure (Charging stations)	• Macro-economic and strategic aspects • Natural, human and financial resources	• Complementary products and services
Range anxiety/driving range	• Knowledge and awareness of technology • Knowledge and awareness of application and market •Socio-cultural aspects	• Product performance and quality • Customers
Long recharge duration	• Knowledge and awareness of technology • Natural, human and financial resources • Knowledge and awareness of application and market	• Product performance and quality • Customers
Soul and character of the vehicle (Sound)	• Competition • Socio cultural aspects • Knowledge and awareness of technology	• Customers • Product performance and quality
Availability of repair/service and maintenance	• Natural, human and financial resources • Knowledge and awareness of application and market	• Complementary products and services
Cultural and psychological factors	• Knowledge and awareness of technology • Socio cultural aspects	• Customers
Lack of product satisfaction	• Competition • Socio cultural aspects • Natural, human and financial resources	• Customers • Product performance and quality
Performance	• Knowledge and awareness of application and market • Natural, human and financial resources	• Product performance and quality • Product price • Customers
Government policy and regulatory framework	• Macro-economic and strategic aspects	• Innovation-specific institutions • Product price
Demand factors	• Natural, human and financial resources • Socio cultural aspects • Knowledge and awareness of technology • Accidents and events	• Production system • Product price • Customers
Production factors/Economies of Scale	• Macro-economic and strategic aspects • Natural, human and financial resources • Knowledge and awareness of technology • Knowledge and awareness of application and market	• Production system • Product price • Network formation and coordination
Lack of access to distribution channels/networks	• Macro-economic and strategic aspects • Competition	• Network formation and coordination
Lack of network externalities	• Socio cultural aspects • Knowledge and awareness of technology • Accidents and events	• Product price • Customers
Constantly evolving markets	• Competition • Knowledge and awareness of technology • Macro-economic and strategic aspects • Natural, human and financial resources	• Product performance and quality • Innovation-specific institutions
Low resale value (value depreciation)	• Competition	• Product performance and quality • Customers
Lack of collaboration among stakeholders	• Socio cultural aspects • Competition	• Network formation and coordination

Ultimately, all links obtained from the analysis were assessed, and once all the relevant links were formed, potential strategies circumventing the barriers are proposed in the section 8.3.

Results from interviews in phase 2

It is interesting to highlight that perspectives from both interviews conducted during phase 2 are different. Expert A is associated with research (academia), while Expert B is involved in policy-making (government) with a focus on electric mobility. It can be observed from the table 8.2 that validation received on the identified (list of) barriers, i.e., the ranking of a barrier from high to low, and the results from both interviews align for the most part. However, a clear distinction can be observed in the validation received for the barriers such as lack of infrastructure, government policy and regulatory framework, constantly evolving markets, and the collaboration among stakeholders. Since the perspectives of both interviewees are different, the barriers highlighted above have been validated from different perspectives.

Table 8.2: Validation received from experts A and B on the barriers

No.	Barriers	Expert A		Expert B	
		Information gathered on particular barrier during open discussion	Level of threat to large-scale diffusion	Information gathered on particular barrier during open discussion	Level of threat to large-scale diffusion
1	Lack of technical (knowledge)	✓	High		Medium
2	Lack of awareness		High		High
3	Supply and choice of vehicles/lack of competition	✓	High	✓	High
4	Safety (due to the nature of batteries)		High		Medium
5	Environmental impact		Low		Low
6	Reliability (depletion, wear and tear of the components such as batteries)		High		High
7	Maturity of technology	✓	High		High
8	Cost of purchase and ownership	✓	High	✓	High
9	Limited infrastructure (Charging stations)	✓	High	✓	Low
10	Range anxiety/driving range		Medium	✓	High
11	Long recharge duration		High	✓	Medium
12	Soul and character of the vehicle (Sound)		Low		Low
13	Availability of repair/service and maintenance		Medium		Low
14	Cultural and psychological factors		Low		Medium
15	Lack of product satisfaction (fun)		Low		Low
16	Performance		Medium		Low
17	Government policy and regulatory framework	✓	High	✓	Low
18	Demand factors	✓	High	✓	High
19	Production factors/Economies of Scale	✓	High	✓	High
20	Lack of access to distribution channels/networks		Medium		Medium
21	Lack of network externalities		High	✓	High
22	Constantly evolving markets		Low	✓	High
23	Low resale value (value depreciation)		Medium		Low
24	Lack of collaboration among stakeholders	✓	High	✓	Low

For instance, expert B (2023) highlighted the fact that the majority of EV charging is taking place, overnight in residential charging stations (EV charging points at home). Hence the consumers do not find the lack of infrastructure to be as challenging, compared to the high initial cost of the vehicle. This scenario also depends upon the use case, and the region in question. Expert B (2023) gave an example of consumers traveling within a city (New Delhi), with daily travel requirements being under 50 km. Hence it is labeled as a low-level barrier. However, expert A (2023) claims that the availability of infrastructure (charging stations) is concentrated in the cities (urban areas) and the states with favorable policies. Expert A (2023) perceived this as a high-level barrier, from the point of view of India (as a whole), including the population living in rural areas where the availability of infrastructure is a challenge. According to Dwisatyawati (2022), the lack of sufficient charging infrastructure can be considered as the enabler for SEV technology, as the reliance of SEVs on the charging infrastructure is less compared to traditional EVs. The author of the present work agrees

that SEVs indeed require fewer charging sessions, thereby reducing the reliance on charging infrastructure. Considering the scope geographical scope of this thesis (urban setting), the barrier of 'Limited infrastructure (charging stations)' is considered to be low.

Both, Expert A (2023), and Expert B (2023), emphasized that the cost of purchasing an electric vehicle is higher compared to the other options available in the market. It was also emphasized that the high costs are mainly due to the lack of competition and collaboration among responsible stakeholders, resulting in limited models of EVs in the market.

Based on the current status of (S)EV technology in India, the barriers identified from the literature review are also classified based on the level (or magnitude) of their threat to large-scale diffusion.

Categorizing the barriers on their level of threat to the technology diffusion

They are classified into high, medium, and low levels of influence they have on large-scale diffusion, from the perspective of multiple stakeholders such as the government (policy makers), companies (industry), and customers. High-level barriers (highlighted in red color) pose a major problem and are an immediate threat to the large-scale diffusion of SEVs in the market, from the perspective of all the stakeholders involved. The barriers are labeled as Low-level barriers (highlighted in green color) if they are a threat to none or only a small proportion of the stakeholders. Medium-level barriers (highlighted in orange color) are still a threat to some proportion of the stakeholders but not all.

Status of TIS building blocks based on the barriers identified

According to Ortt & Kamp (2022), the building blocks are required to be complete and compatible in order for large-scale diffusion to be possible. If the building blocks are not complete or absent, it poses a challenge for innovation. Therefore, the completeness or the status of TIS building blocks is determined by associating the identified barriers with the building blocks. The link between the barriers and the building blocks is explained in section 8.1. If all (or multiple) of the barriers associated with a particular building block are identified as high-level barriers, then the function is incomplete. On the other hand, if the majority of the barriers associated with a particular building block are low-level barriers, then the function is complete or full. A building block is partially complete if not all the barriers influencing that particular function are high-level barriers (so, multiple medium and low-level barriers). Ultimately from this analysis, the influence of a barrier on a particular building block will be determined.

Through this analysis, it was observed that out of seven TIS building blocks, two are incomplete, four are partially complete, and only one is complete. The confirmation received from 6 out of 8 experts as discussed in the section 7.4 on the most important barrier ('Cost of purchase and ownership', corroborates the result obtained on the status of the building block, 'Product price', as can be observed from the table 8.3.

Table 8.3: Status of TIS building blocks for SEVs in India

TIS building blocks	Identified barriers that influence a particular building block	Status of TIS building block	Perspectives/ Stakeholders
Product performance and quality	Performance Safety Maturity of technology Reliability Lack of product satisfaction Constantly evolving markets Lack of (technical) knowledge Low resale value Environmental impact	Partially complete	Customers, Industry, and Government
Product price	Economies of scale/Production factors Demand factors Performance/Lack of competition Maturity of technology Lack of network externalities Lack of (technical) knowledge Cost of purchase and ownership	Incomplete	Customers, Industry, and Government
Production system	Production factors/Economies of scale Demand factors Lack of knowledge and awareness Maturity of technology	Incomplete	Industry, Government
Complementary products and services	Availability of repair/service and maintenance Infrastructure (charging stations)	Complete	Customers, Industry
Network formation and coordination	Production factors/Economies of scale Lack of (technical) knowledge Lack of competition (supply and choice of vehicles) Lack of access to distribution channels Lack of collaboration among stakeholders	Partially complete	Industry
Customers	Cost of purchase and ownership Low resale value (value depreciation) Reliability and Safety Performance/lack of competition Range anxiety/driving range, Long recharge duration, Limited infrastructure (charging stations) Soul and character of vehicle (sound)/ Lack of product satisfaction, Cultural and psychological factors Lack of knowledge and awareness Lack of network externalities	Partially complete	Customers
Innovation-specific institutions	Government policy and regulatory framework Lack of (technical) knowledge Collaboration among stakeholders Constantly evolving markets	Partially complete	Industry, government

8.2 Results from phase 3

The validation received from the expert interviews is primarily based on the feasibility of the implementation of the strategies identified. These strategies are ranked from high to low based on the feasibility of implementing a particular strategy (to circumvent barriers) to diffuse SEVs at a large scale in India.

Categorizing the strategies on the feasibility of implementation

In order to have a clear understanding of the status of each of the strategies, the interviewees were asked to rank the strategies from high to low. A high (indicated in fill color green in the table) ranking indicates that the feasibility of applying that particular strategy (from the perspective of the expert) in India is potentially high (or good). Similarly, a low (indicated in the fill color red in the table) ranking denotes the potential feasibility in India is low (or limited).

After validating the results from expert interviewees C and D, it was determined that the timeline of the application of strategies is crucial. For example, the Indian EV market was already liberalized, therefore the "Liberalizing the market strategy" is already in place and it has proven to be a highly effective strategy. On the other hand, a few strategies such as the "buy-one give-one strategy" or "stepping stone strategy" were relatively new and their applicability in the initial stage of their implementation is potentially low. Finally, according to Expert D (2023), strategies such as "Hybridization or Adaptor niche strategy" were already tested while introducing technologies such as hybrid electric vehicles in India and were proven to be the least effective among the identified strategies. It was inferred from the interview that the Indian government is not supporting the use of hybrid electric vehicles because battery-electric vehicles were given the preference. Hence 'Hybridization or Adaptor niche strategy' is given a low ranking.

After interviewing Expert F (perspective of Vayve Mobility), it was identified that by offering the product at a cheaper price of about $6000, they (Vayve Mobility) eliminated the need to implement multiple different strategies in order to diffuse their product in the market. By doing so, multiple barriers were circumvented at once, thereby, proving the feasibility of those strategies (from the perspective of the company) to be low. Especially, the barrier ('cost of purchase and ownership') that has been identified to be the biggest threat to SEVs can be circumvented by introducing the product at a cheaper price.

The final results obtained from the validation of the identified strategies are presented in table 8.4

Table 8.4: Validation received from experts C and D and F on the strategies

No.	Main strategies	Expert C		Expert D		Expert F	
		Information gathered on particular strategy during open discussion	Validation on the feasibility	Information gathered on particular strategy during open discussion	Validation on the feasibility	Information gathered on particular strategy during open discussion	Validation on the feasibility
1	Liberalizing the market strategy		High		High		Medium
2	Guaranteed markets strategy		Medium		High		Medium
3	Economic/financial incentives strategy	✓	High	✓	High		High
4	Investment strategy		High	✓	High		High
5	Promotion/awareness campaign strategy	✓	High	✓	Medium	✓	High
6	Supportive demonstration and cost-reduction strategy		High		Medium		Medium
7	Initiate (technical) training strategy		Medium		High		High
8	Research & development (niche) strategy	✓	High	✓	High	✓	High
9	Human resource management strategy	✓	High		High	✓	Medium
10	Education niche strategy	✓	High		High		Medium
11	Lead-user niche strategy		High		High		Low
12	Finance sourcing strategy		High		High		High
13	Subsidized niche strategy	✓	Medium	✓	High		Low
14	Redesign niche strategy		Low		Low	✓	Low
15	Dedicated system or Stand-alone niche strategy	✓	Low		Low		Low
16	Hybridization or Adaptor niche strategy		Low		Low		Low
17	Lobbying strategy (Advocacy strategy)		High	✓	High		Low
18	Collaborative product utilization strategy		High		High		Low
19	Buy-one, give one niche strategy		Low		Low		Low
20	Geographical niche strategy	✓	Medium	✓	High	✓	High
21	Top-end niche strategy		Medium		Medium		Low
22	Partnerships niche strategy	✓	High	✓	High	✓	Medium
23	Integrated network strategy	✓	High	✓	Medium	✓	Medium
24	Marketing strategy		Medium	✓	High	✓	High
25	Stepping stone strategy		Low		Medium	✓	High
26	Product variants strategy	✓	High	✓	High	✓	High
27	Cross-selling strategy		Low		Depends on value addition (High or low)	✓	Low
28	Result-oriented contracting strategy	✓	Medium	✓	Medium		Low
29	Blue ocean strategy		Medium		Medium	✓	High
30	Explore multiple markets strategy		High		Medium	✓	Medium
31	Formulate requirements strategy		Low	✓	Low	✓	High
32	Influential community member strategy	✓	Medium		Medium		High
33	Word of mouth strategy	✓	High	✓	High		High
34	Continuous user engagement strategy	✓	High		High		High

8.3 Results from phase 4

A guideline was followed to link the barriers with suitable strategies. This guideline was prepared based on the insights gained from the Best Strategy Framework. According to Dwisatyawati (2022), a strategy could potentially circumvent multiple different main barriers. On the other hand, a particular main barrier could be circumvented by many different

strategies. As a result, multiple combinations of links between barriers and strategies are possible. Therefore, the author of the present work identified the linkages based on the links identified by Dwisatyawati (2022), i.e., by mapping relevant strategies with every underlying cause (influencing condition) behind a barrier, as explained in the figure 8.3.

Dwisatyawati (2022) argued that expert interviews can be conducted to assign ranking (points) to the barriers and strategies to validate the links. Expert validation improves the credibility of the links that were formed based on the analysis of the links identified from the literature. Agreeing with Dwisatyawti (2022), in this thesis, experts were asked to rank the strategies that have the potential to circumvent a maximum number of barriers. The higher the number of barriers they have the potential to circumvent, the better rank is assigned to those strategies. As shown in table 7.5, these strategies are ranked based on expert opinion.

Although the scoring model proposed by Dwisatyawati (2022) can be followed to decide the best strategy, it can only be followed to assign the best strategy from the perspective of a company (industry). Therefore, the scoring model has been extended to this thesis research to identify the best strategy per perspective, also referred to as the 'important strategy' in this thesis. This is extended to the perspectives of the present work by mapping the important strategies ranked by the experts to the perspectives of the strategies classified in the chapter 6. These perspectives/stakeholders involved are incorporated into the table 8.5.

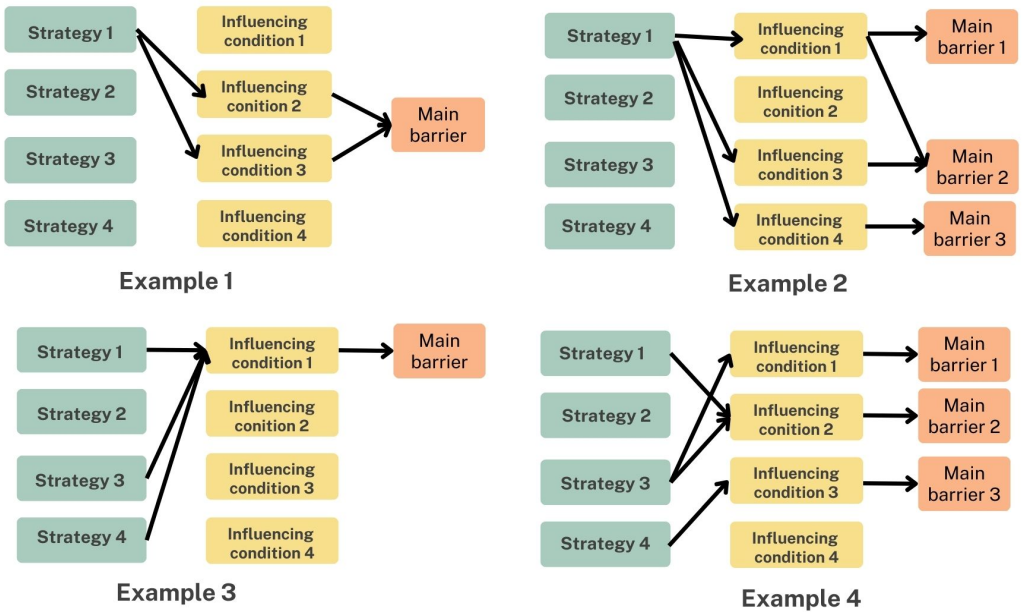

Figure 8.3: Guideline on multiple sets of links between the underlying influencing conditions of a main barrier and the suitable strategies

Firstly, all the relevant strategies (per barrier) are linked based on the guidelines presented in figure 8.3. Secondly, from the multiple strategy links present per barrier, the important strategy decision is made by identifying those strategies that are ranked the highest by experts.

Example: As can be observed from the table 8.5, the barrier 'Demand factors', can be circumvented using 11 different strategies, based on 4 different underlying influencing conditions.

And, these underlying influencing conditions can be addressed by different stakeholders from different perspectives. This barrier (Demand factors) can be circumvented from the perspective of the government by providing (tax) incentives to attract potential customers *(Economic/-financial incentives strategy)*. From the perspective of the industry, it can be circumvented by relocating or establishing the company at a location where the demand for the technology is higher *(Geographical niche strategy)*. Also, from the perspective of the end users, it can be circumvented by actively engaging throughout the development process of the technology *(Continuous user engagement strategy)*. Based on the insights gained from Experts G and H, it could be inferred that, although multiple strategies are possible to circumvent the barrier **'Demand factors'**, **'Economic/financial incentives strategy'**, is the most important strategy. This is determined by the ranking provided in the table 7.5.

If there is more than one strategy present that is ranked by the expert in the available links per barrier, the important strategy decision is made by identifying the strategy that could benefit a maximum number of stakeholders, upon its implementation. As shown in table 8.5, the barrier 'limited infrastructure' can be circumvented by two different strategies, 'Economic/financial incentives strategy' and 'Investment strategy' (both given the rank 1) that have been identified to be important according to experts. In order to make the important strategy decision for the barrier 'limited infrastructure', it has been identified that when the government implements an 'Economic/financial incentives strategy' all the stakeholders involved including the industry and customers can directly benefit from this strategy. However, when an 'Investment strategy' is implemented, only the companies involved in improving the infrastructure are directly benefited. Therefore, the 'Economic/financial incentives strategy' has been chosen. A similar approach and logical reasoning were used to form all the remaining links shown in the table 8.5. This table shows that although each barrier can be circumvented by implementing multiple different strategies, there is one important strategy that can be chosen, based on the ranking provided by the experts and the justification provided above.

Table 8.5: Linkages between barriers and strategies, along with the perspectives/stakeholders involved

Barriers identified	Influencing condition(s)	Niche strategies that are applicable	Important strategy decision	Perspective/stake holders involved
Lack of (technical) knowledge	Knowledge and awareness of technology	Initiate (technical) training strategy, Research and development (niche) strategy	Finance sourcing strategy	Government, Industry (companies)
	Knowledge and awareness of application and market	Initiate (technical) training strategy, Supportive demonstration and cost reduction strategy		
	Natural, human and financial resources	Research and development (niche) strategy, Finance sourcing strategy Human resource management strategy		
Lack of awareness	Knowledge and awareness of technology	Promotion/awareness campaign strategy, Marketing strategy	Promotion/awareness campaign strategy	Government, Industry and Customers
	Socio-cultural aspects	Influential community member strategy		
Supply and choice of vehicles/lack of competition	competition	Liberalizing the market strategy, Guaranteed markets strategy, Product variants strategy	Product variants strategy	Industry (OEMS)
Safety (due to the nature of batteries)	Socio-economic factors	Continuous user engagement strategy	Research and development (niche) strategy	Industry (OEMS), Customers
	Natural, human and financial resources	Initiate (technical) training strategy, Education niche strategy		
	Knowledge and awareness of technology	Research and development (niche) strategy		
Environmental impact				
Reliability (depletion, wear and tear of the components such as batteries)	Socio-cultural aspects	Result-oriented contracting strategy, Promotion/awareness campaign strategy, Education niche strategy	Research and development (niche) strategy	Industry (OEMS), Customers
	Knowledge and awareness of application and market	Redesign niche strategy		
	Knowledge and awareness of technology	Research and development (niche) strategy		
Maturity of technology	Knowledge and awareness of technology	Top end niche strategy	Investment strategy	Government, Industry
	Macro-economic and strategic aspects	Lobbying strategy		
	competition	Research and development (niche) strategy, Investment strategy		
Cost of purchase and ownership	Macro-economic and strategic aspects	Lobbying strategy	Economic/financial incentives strategy	Government, Industry and Customers
	Knowledge and awareness of application and market	Subsidized niche strategy		
	Knowledge and awareness of technology	Supportive demonstration and cost-reduction strategy, Hybridization niche strategy		
	Natural, human and financial resources	Education niche strategy, Promotion and awareness campaign strategy, Economic/financial incentives strategy		
Limited infrastructure (Charging stations)	Natural, human and financial resources	Investment strategy Subsidized niche strategy, Product variants strategy, Collaborative product utilization strategy	Economic/financial incentives strategy	Government, Industry and Customers
	Macro-economic and strategic aspects	Economic/financial incentives strategy, Initiate (technical) training strategy, Supportive demonstration and cost-reduction strategy, Education niche strategy		
Range anxiety/driving range	Knowledge and awareness of application and market	Marketing strategy, Word of mouth strategy	Marketing strategy	Industry and Customers
	Socio-cultural aspects	Supportive demonstration and cost reduction strategy		
	Knowledge and awareness of technology	Formulate requirements strategy		
Long recharge duration	Knowledge and awareness of application and market	Research and development (niche) strategy	Research and development (niche) strategy	Industry and Customers
	Natural, human and financial resources	Result-oriented contracting strategy, Marketing strategy		
	Knowledge and awareness of technology	Investment strategy, Geographical niche strategy, Human resource management strategy		
Soul and character of the vehicle (Sound)	Competition	Research and development (niche) strategy	Research and development (niche) strategy	Industry and Customers
	Socio-cultural aspects	Product variants strategy, Partnerships niche strategy		
	Knowledge and awareness of technology	Word of mouth strategy		
Availability of repair/service and maintenance	Knowledge and awareness of application and market	Research and development (niche) strategy, Word of mouth strategy	Research and development (niche) strategy	Industry and Customers
	Natural, human and financial resources	Integrated network strategy, Initiate (technical) training strategy		
Cultural and psychological factors	Knowledge and awareness of technology	Human resource management strategy, Initiate (technical) training strategy	Promotion and awareness campaign strategy	Government, Industry and Customers
	Socio-cultural aspects	Education niche strategy, Promotion and awareness campaign strategy		
Lack of product satisfaction	competition	Promotion/awareness campaign strategy	Product variants strategy	Industry, Customers
	Natural, human and financial resources	Product variants strategy, Integrated network strategy		
	Socio-cultural aspects	Collaborative product utilization strategy, Cross-selling strategy, Result-oriented contracting strategy		
Performance	Knowledge and awareness of application and market	Continuous user engagement strategy, Result-oriented contracting strategy	Research and development (niche) strategy	Industry
	Natural, human and financial resources	Research and development (niche) strategy		
Government policy and regulatory framework	Macro-economic and strategic aspects	Investment strategy, Economic/financial incentives strategy Promotion and awareness campaign strategy	Economic/financial incentives strategy	Government, Industry and Customers

	Natural, human and financial resources	Liberalizing the market strategy, Economic/financial incentives strategy, Lobbying strategy, Research and develop (niche) strategy		
	Knowledge and awareness of technology	Buy-one give one niche strategy, Geographical niche strategy Blue ocean strategy		
	Accidents and events	Promotion/awareness campaign strategy, Marketing strategy, Continuous user engagement strategy		
Demand factors (NA)	Socio-cultural aspects	Promotion/awareness campaign strategy,	Economic/financial incentives strategy	Government, Customers
	Macro-economic and strategic aspects	Lobbying strategy		
	Knowledge and awareness of application and market	Promotion/awareness campaign strategy, Word of mouth strategy, Influential community member strategy, Continuous user engagement strategy, Geographical niche strategy		
	Knowledge and awareness of technology	Supportive demonstration and cost reduction strategy, Research and development (niche) strategy		
Production factors/Economies of Scale	Natural, human and financial resources	Research and development (niche) strategy, Finance sourcing strategy	Finance sourcing strategy	Industry
	Macro-economic and strategic aspects	Human resource management strategy, Investment strategy, Economic/financial incentives strategy, Geographical niche strategy, Partnerships niche strategy, Integrated network strategy		
Lack of access to distribution channels/networks	Competition	Liberalizing the market strategy, Investment strategy, Geographical niche strategy, Blue ocean strategy	Economic/financial incentives strategy	Government, Industry
	Socio-cultural aspects	Integrated network strategy, Blue ocean strategy, Explore multiple markets strategy		
	Knowledge and awareness of technology	Collaborative product utilization strategy, Cross-selling strategy, Geographical niche strategy		
Lack of network externalities	Accidents and events	Marketing strategy, Word of mouth strategy	Geographical niche strategy	Industry (OEMs), Customers
	Macro-economic and strategic aspects	Liberalizing the market strategy, Guaranteed markets strategy		
	Natural, human and financial resources	Continuous user engagement strategy, Word of mouth strategy		
	competition	Human resource management strategy, Investment strategy, Economic/financial incentives strategy, Geographical niche strategy		
Constantly evolving markets	Knowledge and awareness of technology	Investment strategy, Blue ocean strategy, Explore multiple markets strategy, Geographical niche strategy	Investment strategy	Government, Industry and Customers
Low resale value (value depreciation)	competition	Research and development (niche) strategy, Promotion and awareness campaign strategy, Supportive demonstration and cost reduction strategy	Research and development (niche) strategy	Government, Industry
	Socio-cultural aspects	Result-oriented contracting strategy, Supportive demonstration and cost-reduction strategy		
Lack of collaboration among stakeholders	competition	Partnerships niche strategy, Integrated network strategy	Partnerships niche strategy	Industry (OEMS and institutes)

9 Conclusion and Recommendations

In this chapter, the conclusions obtained and the recommendations originating from this research are discussed. Firstly, the conclusions are discussed by answering the sub-research questions including the main research question in the section 9.1. Also, the final recommendations for the different stakeholders involved/perspectives are outlined in the section 9.2.

9.1 Conclusion

In this section, firstly, the answers to the sub-research questions will be discussed, ultimately leading to the answer to the main research question.

Why does solar mobility present a viable option, and how can parallels between the electric vehicle (EV) sector and Solar Electric Vehicles (SEVs) be drawn to understand their applicability and potential in India?

In the past few years, there has been more awareness and emphasis on the transition to electric mobility in India. This provides an opportunity for innovation within electric mobility, and SEVs are one such innovation. SEVs present a viable option in India because of their ability to solve the problems associated with EV technology, as the efficiency of solar PV technology improves. Additionally, there is also the geographical advantage for SEVs as India receives ample sunlight throughout the year. Moreover, the policies (namely FAME I and II) from the government supporting the transition to electric mobility have the ability to support further innovations in this sector. Altogether, these factors present a viable option for SEVs in India.

In order to justify the viability of SEVs in India, and draw parallels between SEVs and EVs three layers of rationale were provided. A calculated assumption was made that the base architecture of a Solar Electric Vehicle is that of a Battery Electric Vehicle (Rationale I). It was also evident from the research that SEVs and EVs share a similar architecture, with solar roof as an additional component in SEVs. Therefore, in this thesis research, the socio-technical aspects of EVs were studied in detail and logical parallels were drawn between EVs and SEV technology. In order to prove the credibility of the parallels drawn between EVs and SEVs, expert interviews were conducted (Rationale II). Additionally, the outcome of the case study on the companies, Lightyear and Aptera Motors corroborated the findings from the literature, particularly on strategies implemented (Rationale III). These case studies were used as a means to extend the findings from the literature to SEV technology. Additionally, the establishment of Vayve Mobility, as the first SEV company in India, and by interviewing the Co-founder and COO of the company (Expert F), it was clear that SEVs have the potential to disrupt urban mobility in India.

What according to the existing theories in literature could be labeled as barriers that hinder and opportunities that facilitate the introduction and diffusion of SEVs in India?

In this thesis, it was found that a total of 24 barriers hinder and 10 opportunities that facilitate the market diffusion of SEVs in India, from three different perspectives, government (policymakers), industry (companies), and customers (end users).

Firstly, the barriers discussed in several pieces of literature on EVs were identified and highlighted in this thesis. Due to the similarities between EV and SEV technologies, the barriers to EVs have been extended to SEVs based on the validation received from the experts on these barriers through expert interviews. Identifying these barriers was crucial to determine the status of the building blocks of TIS for SEVs in India. Based on the guidelines provided in the TIS framework by Ortt & Kamp (2022), and Schulz (2019), the links between the identified barriers from literature and the underlying influencing conditions were formed, and highlighted in the table 8.1. After identifying the links between the barriers and their underlying influencing conditions, their effect on the building blocks was also determined and discussed in table 8.3. It was found that only the complementary products and services building was complete, whereas the building blocks, product price, and production system were incomplete. As discussed in section 8.1, the availability of repair/service and maintenance centers, including the less reliance of SEVs on the charging infrastructure makes the status of the building block 'complementary products and services', complete. In addition to that, it was also evident from this research based on the opinions of 6 out of 8 experts, that the upfront cost of the vehicles is the biggest threat to the market diffusion of SEVs in India, thereby rendering the status of the building block, 'product price', incomplete.

Moreover, the remaining building blocks, product performance, and quality, network formation and coordination, customers, and innovation-specific institutions remain partially complete.

What are the strategies available to address the barriers faced by SEVs (high-tech innovations) according to the existing literature? How can these identified strategies be used to develop and diffuse SEV technology at a large scale in India?

A total of 34 strategies have been identified in this thesis, which has been divided into the strategies applicable to the government, industry, and customers. All the identified strategies have been highlighted in the table 6.4. As SEVs are considered a high-tech innovation, the niche strategies developed by Ortt et al. (2013) were used as a starting point to explore the strategies that could potentially be implemented to diffuse SEVs at a large scale, by addressing the barriers identified (according to the previous research question).

In order to understand their feasibility in the Indian market, expert interviews were conducted. Interviews with experts C and D were conducted to understand the strategies that are already being implemented in the market, and also validate the feasibility of the strategies obtained from the literature. On the other hand, interviews with experts E and F focused on strategies that are being implemented now and also in the future.

Every barrier identified in this thesis can be circumvented using multiple strategies that were discussed. In order to facilitate the development and diffusion of SEVs in India, identifying the cause behind a particular barrier, and circumventing that cause by implementing strategies is essential. This way, by determining the cause behind a particular barrier, relevant strategies can be selected and implemented. Ultimately, these strategies can be implemented by stakeholders (perspectives) individually or multiple stakeholders can come together to overcome those barriers.

Based on existing frameworks, what are the possible links between the barriers and the strategies identified? From the established link between strategies and barriers, how can the best strategy be selected per barrier?

The possible links between the barriers and strategies were framed by identifying all the (direct) underlying causes of the barriers. By identifying these causes, all the relevant strategies with the potential to circumvent that particular barrier are mapped. These links were framed using the guidelines formulated based on the Best Strategy framework proposed by Dwisatyawati (2022). This framework discusses the scoring models that can incorporated to link the barriers with the strategies. Additionally, the insights gained from expert interviews were used to rank the most important strategies, and the justification for these ratings was provided in the table 7.5. Based on the guidelines provided in the best strategy framework and the ranking given to strategies by the experts, it was identified that strategies associated with the financial aspects take precedence over other strategies, because the lack of required financial resources prevents the development, and launching of the product, ultimately, preventing the introduction of the product in the market. Similarly, ranking (and the justification) was also provided for other strategies.

The best strategy per barrier can be selected by considering the strategies that received the highest ranking from the experts, followed by checking if the highly-ranked strategy is in the list of relevant strategies linked with that specific barrier. In the case when two or more strategies are given the same ranking, the important strategy decision is made by selecting the strategy that can benefit multiple stakeholders upon its implementation.

This section puts forward the main research question of this thesis "**What are the socio-technical conditions that affect the market diffusion of Solar Electric Vehicles in the Indian market?**"

After identifying the disruptive nature of SEVs, it was evident that SEV technology is in its early stages of innovation in India. Therefore, as it is a technology that is in the phase prior to its large-scale diffusion, the Technological Innovation System framework proposed by Ortt & Kamp (2022) has been incorporated into the present work. In this thesis, all the socio-technical that affect the market diffusion of Solar Electric Vehicles in India, specifically, a total of 24 barriers, 10 opportunities, and 34 different strategies from three different perspectives were proposed. These perspectives are of the government (policy makers), industry (companies/OEMs), and customers (end users).

There are multiple barriers that pose an immediate threat to SEV technology such as the high upfront cost of the vehicle. This is a barrier because of the price-sensitive nature of the Indian market, and the limited purchasing power of the majority of the population belonging to the middle-class income range. As a result companies or SEVs with high upfront costs (>17000 EUR) such as the existing SEV models from Lightyear and Aptera Motors are expected to face market entry barriers from a financial point of view, as well as a design point of view. This barrier can be circumvented by making SEVs more affordable by SEV companies or implementing 'affordable financing' policies through financial institutes such as banks. By offering the SEV at a cheaper price ($6000), Vayve Mobility is expected to eliminate the biggest threat (barrier) and also the necessity to implement some of the other strategies discussed in this thesis. Ultimately, the barriers associated with the financial aspects can be circumvented by implementing either affordable financing options or offering the product at a competitive price. This way, the TIS building block 'Product price' can be addressed, thereby facilitating the success of SEVs in the mass market in India.

An interesting observation made during the interviews was that there were many instances where the opinions of the interviewees aligned, but there were also instances where the opinions sought from the experts seemed to not align. For example, most of the experts agreed that the 'lack of (technical) knowledge and awareness', 'lack of competition', and 'cost of purchase

and ownership' are some of the immediate threats to the adoption of SEVs. However, as a result of interviewing experts from different backgrounds, a few differences in the opinions were identified. For example, Expert B (Deputy Director at the Ministry of Transport) highlighted that the government has been taking various initiatives to develop electric vehicles. However, Expert A (Assistant Professor at the Indian Institute of Technology (IIT) raised the issue of lack of funding from the government, and the private sector towards research institutes for the R&D of SEVs, resulting in a lack of innovation. From these insights, it could be inferred that although the government has implemented supportive policies to support the development of Battery Electric Vehicles, due to the limited presence of SEVs in the Indian market, there is limited attention, particularly towards SEVs. Ultimately, this also reflects the lack of awareness among the end users (customers).

It was also identified that there is a lack of initiative from research institutes in collaborating with high-tech companies such as Vayve Mobility to conduct projects jointly. Therefore, there is a gap that needs to be bridged between academia and industry in order to facilitate an innovative environment to develop the technology as a whole.

In the context of the Indian SEV industry, a complex vicious cycle of barriers (pattern) was discovered. The key issue revolves around the limited advancement in technology and the limited availability of SEV models in the market. This not only affects consumer awareness but also limits the development of required policies. Policymakers require a diverse range of SEV models to formulate effective and favorable policies that are needed. However, in order to encourage companies to develop more SEV variants, there is a need for government initiatives (investment) and incentives. As a result, there is less awareness among consumers, and as a result, there is insufficient demand from the perspective of the companies. This creates a vicious cycle of barriers, where each barrier contributes to another, making it challenging to break this cycle to facilitate the growth of the SEV industry in India. In order to overcome this loop of barriers, the implementation of the strategies ranked by the experts, highlighted in the table 7.5, are considered crucial Therefore, in line with the vicious cycle problem discussed above, the following set of recommendations is provided in this thesis.

9.2 Recommendations

The recommendations originating from this thesis research are discussed in this section and are divided into the perspectives identified in this thesis.

9.2.1 Government of India

The following recommendations apply to the actors/stakeholders involved in policymaking and related ministries within the Government of India.

1. **Government-backed solar panel innovation**: Collaborate with research institutes and private companies to accelerate the development of innovative (curved) solar panel technologies tailored for SEVs. Government funding and incentives can facilitate breakthroughs in solar technology. By doing so India, not only can catch up to the global advancements in solar PV technology but also develop self-sustaining SEVs.

2. **Streamlined solar panel material supply chain**: Establish partnerships with suppliers to ensure a consistent supply of materials for manufacturing solar panels. Encourage domestic production and explore sustainable sourcing options to meet the rising demand.
3. **Collaborative Loan Programs**: Collaborate with financial institutions to introduce specialized loan programs for SEV purchases. These programs can ease the financial burden, especially on middle-class consumers, and make SEVs more accessible and attractive to potential customers.
4. **Research Grant Allocation**: Increase government and private sector funding for research institutions such as IITs, NITs, and companies specializing in SEV technology. Funding research and conducting projects jointly can lead to valuable insights and technological advancements.
5. **Collaboration Platforms**: Establish knowledge-sharing platforms that bridge the gap between academia, government, and industry. Regular seminars, webinars, and workshops can promote collaboration, fostering a holistic ecosystem for knowledge diffusion.
6. **Affordability Measures**: Implement policies that encourage the development and adoption of more cost-effective SEV models, particularly in the middle-class price range. This could involve providing incentives, subsidies, or tax benefits to manufacturers and consumers.
7. **Incorporate Zero Emission Mandate**: Implement a New Energy Vehicle mandate similar to China's and a zero-emission vehicle mandate akin to California's, setting ambitious targets for EV adoption and emissions reduction. Enact regulations requiring OEMs to manufacture new energy and zero-emission vehicles, driving industry-wide innovation and sustainable practices.
8. **Revise Subsidy Criteria**: Tailor FAME I and II schemes to explicitly include SEVs, considering their potential for cost reduction through solar panels. Adjust subsidy conditions to accommodate high-performance solar-equipped vehicles.
9. **Battery Regulation**: Develop clear regulations for battery end-of-life and second-life usage to ensure responsible disposal and repurposing of batteries. This can also boost consumer confidence and environmental sustainability.

9.2.2 Industry: Companies, OEMs, research institutes

The following recommendations apply (and are not limited) to the actors/stakeholders involved in creating, designing, prototyping, developing, and introducing SEVs in the market.

1. **University Collaborations**: Universities in India and abroad should join and actively collaborate on SEV research. Joint research initiatives between Indian and international universities can accelerate knowledge development and diffusion in the field. Many university student teams such as Eindhoven University of Technology and Delft University of Technology have been working on solar electric vehicles for quite a while now. Universities and research institutes in India could benefit from the knowledge that can be exchanged by collaborating with these university teams.

2. **Cross-industry collaborations**: Within the industry itself, partnerships with research institutes and (technical) training centers to collectively address skill gaps and accelerate the transition to electric mobility. Prioritize skill development programs to build the workforce to design, develop, and manufacture SEVs.
3. **Market-Oriented Branding**: Leverage (social-media) influencers and brand ambassadors to promote SEVs and improve consumer confidence by creating a trend. Also, collaborating with non-profit organizations to advocate and lobby for SEV adoption, creates a positive public perception.
4. **Strategic Market Development**: Focus on creating awareness and demand for SEVs, especially among the younger (tech-savvy) generation, through promotion campaigns in platforms like nationwide sports events (like Indian Premiere League) to increase visibility.
5. **Supply Chain Resilience**: Explore diverse sourcing options for critical materials, reducing dependency on specific regions. Collaborate with international partners to ensure a stable supply chain for SEV components. Collaborating with international parties, in the early stages of the development of SEVs, facilitates the possibility of becoming independent by building a robust domestic supply chain.
6. **Futuristic Design**: Follow the trends set by Aptera Motor's approach by incorporating autonomy, connectivity, and advanced (curved) solar technology features into SEVs. Designing vehicles that are future-proof appeals to potential investors and attracts potential consumers.
7. **Market Diversification**: Identify niche markets like service goods and delivery vehicles under the blue ocean strategy. Focus on less competitive sectors with high demand, such as fleet operations, for SEV deployment. As ride-sharing and ride-hailing services are quickly growing in India, tapping into those markets will attract fleet operators toward SEVs.
8. **Collaborative Utilization Models**: Consider innovative business models like leasing or renting SEVs for multiple users, as implemented by Lightyear through their collaboration with LeasePlan (Lightyear, 2022). This strategy could make SEVs financially viable while addressing the challenge of low-profit margins.

9.2.3 Customers (end users)

The following recommendations apply to the end users, in adopting, supporting, and spreading awareness regarding SEVs.

1. **Consider long-term cost savings**: Being aware of the long-term cost savings associated with SEVs, including lower operational and maintenance costs compared to internal combustion engine vehicles, can help the end users make an informed decision. One such way of saving costs over the long term includes exploring the available subsidies and incentives that can help reduce the financial burden of high upfront costs.
2. **Awareness and adoption campaigns**: The concept of network externalities applies equally to both, industry and customers. As the number of people using SEVs increases the value of the product will also increase (Stringham et al., 2015). Spreading a (positive) word through WOM and E-WOM platforms has proven to be successful in making the end users informed decisions (Krishna, 2021). Launch targeted awareness campaigns

highlighting the benefits of SEVs in specific use cases, such as short-distance commuting or ride-hailing and sharing applications. Leverage media trends and community participation to create curiosity and interest.

3. **Participation in Feedback Loops**: Actively engage with companies like Vayve Mobility that are introducing innovative SEVs by providing real-time data on the performance of the vehicle. Participate in early-stage purchases and provide valuable feedback for improvements. Co-operating by providing real-time data and feedback can help the companies in improving and making the technology more efficient.

9.2.4 Limitations and recommendations for future research

In this section, first, the limitations that were observed during this thesis are explained. The recommendations originated from the limitations of this thesis and are presented as future scope.

1. **The influence between Actors**: The study provides limited insight into the interplay and influence of one actor on another within the context of SEVs and their strategies, as the main focus of this thesis was identifying the role of each actor (perspective) and their influence on the market diffusion of SEVs. Therefore, less emphasis was given to how each of these identified actors influence each other.
2. **Geographic and Economic Constraints**: The findings are applicable mainly to developing countries like India and areas with ample sunlight. It may not fully encompass nations outside these criteria. As the spending capacity of the people in other countries may be higher or lower than in India-like markets, some of the findings in this thesis may not apply. Similarly, countries that receive less sunlight compared to India might have a different set of barriers, which may need a different set of strategies.
3. **Dynamic Future Scenarios**: The applicability of findings is applicable for the current landscape of EV technology based on the data gathered from the literature might be outdated. As circumstances evolve, new barriers may emerge, necessitating adjustments in strategies.
4. **Specific Vehicle Focus**: The research concentrates on Solar Electric Vehicles that share the foundational architecture of Battery Electric Vehicles, with the addition of solar panels, limiting its scope to this specific vehicle type.
5. **Barrier Confirmation**: Due to limited data availability on companies like Aptera Motors and Lightyear, the rationale analysis primarily focuses on strategies. Further research and validation could add more credibility to the identified barriers comprehensively.
6. **Strategy Effectiveness and ranking**: The research evaluates the feasibility of the implementation of the strategies in the Indian market but doesn't delve deeply into the impacts of post-implementation of the strategies. As the insights gained into strategies before their implementation will vary from insights gained on the post-implementation and the success of the strategy. For example, the subsidized niche strategy is one strategy implemented to remove the barrier of high upfront costs of new technology. However, in the long term, the same strategy can work against the technology. Therefore, such post-implementation (long-term) impact of these strategies is yet to be analyzed. Also, the strategy ranking was only provided to the most important strategies in the opinion

of the experts. In the expert interviews, after carefully reviewing the list of strategies, experts ranked only a few of the strategies that were important (from 1 to 5). In order to keep the interviews within the time limit requested by the experts, although all the strategies were validated and categorized based on their feasibility, all 34 strategies were not ranked by the experts (in order of importance).

7. **Linkages between strategies and barriers**: Hundreds or even thousands of (direct and indirect) linkages are possible among the 24 barriers and 34 strategies, including the data obtained from interviews. While only the links that are relevant and make sense logically (from the point of view of the framework) are discussed, there may also be some in-direct links that are (logically) possible but are not discussed due to time-constraint.

Recommendation for future research

As SEVs are a radically new innovation, there is huge potential for future research in this area. Therefore, the limitations of this research can be forwarded as a recommendation for the future scope.

The primary scope for the area of research in SEVs is the perspectives from which the barriers and strategies can be evaluated. In this thesis, primarily, government, industry, and customer perspectives have been identified. Although these perspectives provide an overview of the most important stakeholders involved, it has been identified that there is more scope for further and more in-depth research pertaining to certain actors such as the challenges encountered by research institutes, (curved) solar PV suppliers, entrepreneurs, electricity companies, charging point operators, fleet operators, financial institutes, etc. There is a scope for researching in depth from all the perspectives mentioned above. Also, the opportunities identified in this thesis can be linked to strategies. Due to the limited number of opportunities for SEVs identified in this thesis, the links between the opportunities and the strategies could not be framed completely. Once more such opportunities (drivers) are discovered for SEVs, a complete set of links between the opportunities and the strategies can be formulated. This research can also be carried forward to countries outside the geographical and economic constraints mentioned in this thesis. For example, it has been pointed out by Expert F (2023) that the purchasing power (capacity to afford a vehicle) in European countries is relatively higher than in India, therefore the opportunities to introduce high-end SEVs are plenty. Similarly, the experts with knowledge particularly on SEVs are very limited, particularly in India, therefore, an expert from the only SEV company in India was interviewed. On the other hand, there are other SEV companies outside India, such as Sono Motors (from Germany) and Lightyear (from the Netherlands) who are focusing on the European market. An interesting research focus could be the comparison between the experience of these two companies as the pioneers of SEVs in Europe. Due to the recent layoffs from both of these companies, it was difficult to interview experts from these companies. However, with the advancements in Solar EV technology, there is great potential for these companies to grow and introduce SEV models in the market soon.

9.3 Contribution of this research

As discussed in section 1.4, there is limited attention towards SEVs in the Indian market, and also limited research directly addressing the barriers and strategies that influence the

market diffusion of SEVs in India. This research bridges this knowledge gap by identifying and discussing the barriers and strategies for SEVs relevant to the Indian context. More importantly, the valuable expert opinions on the socio-technical conditions discussed in this thesis provide insights into the current market conditions that are posing a threat to SEV technology, and the measures that can be taken or implemented to address those threats. Additionally, this thesis was successful in emphasizing the barriers and strategies from the point of view of the important stakeholders, such as the policymakers, companies, and end users, and their roles in facilitating the large-scale diffusion of SEVs in India.

The TIS framework proposed by Ortt and Kamp (2022) is based on the conditions in the European and North American countries. By implementing the TIS framework for the context of SEVs in India, it has been adapted to the situation in a developing country. Additionally, this thesis builds up on the research on the niche strategies discussed by Ortt et al. (2013) and other strategies discussed in the literature by extending and modifying those to address the barriers encountered in the Indian market, from multiple perspectives. Upon validating the barriers by categorizing them from a high to low level of threat, and that of the strategies on the feasibility of implementation from their high to low level of influence on the market diffusion of SEVs, this thesis corroborated the barriers and strategies discussed by various researchers.

Also, this thesis complemented the Best Strategy Framework proposed by Dwisatyawati (2022), by validating the links between the barriers and strategies through expert interviews, thereby consolidating the approach to map the strategies applicable to the barriers. Ultimately, by studying the links proposed in this thesis, the readers can identify all the strategies that are applicable and the most important strategy that can selected to address a particular barrier encountered during the large-scale diffusion of SEVs in India.

9.4 Relevance of this research

9.4.1 Relevance to Sustainable Energy Technology (SET)

The Delft University of Technology offers a master's program in Sustainable Energy Technology, with a deep focus on the societal transition towards self-sufficient and sustainable energy alternatives. The relevance of this thesis on Solar Electric Vehicles aligns with the author's specialization in Electric Mobility, Power, and Economics & Society. The concept of SEVs was particularly introduced in the courses Electrical Machines and Drives, Electric Vehicles and Charging Technology. The frameworks implemented (particularly Technological Innovation Systems, and Niche Strategy Framework) in this thesis were first introduced in the course Sustainable Energy Innovations and Transitions. In this course, the relevance of these frameworks to various sustainable energy technologies (SETs) was discussed. The courses mentioned above served as the foundational basis for the research on this thesis topic. Ultimately, by utilizing the knowledge gained on the technical aspects of SEVs, and societal aspects of SETs, the socio-technical aspects of SEVs in India were discussed in this thesis.

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Appendix A

1 Functions of Innovation Systems: A broader perspective

Technological change is not always purely technical. In order for it to be sustainable, changes in social aspects such as user practices, regulations, and industrial networks are needed. Therefore, it is imperative to understand technological growth from a broader perspective by paying attention to the dynamics of innovation processes (Hekkert et al., 2007).

According to Hekkert et al., the innovation system approach revolves around the idea that the innovation and diffusion of technology depend on both individual and collective actions (Hekkert et al., 2007).. The rate and direction of technological change in a society are determined by the institutions and economic structures in that innovation system. In addition to that, they are also affected by the competition between the existing incumbent and emerging technologies. Therefore, it is crucial to understand the relationship between incumbent technology (and its innovation system) the emerging technology, and its innovation system. Hence the innovation systems of incumbent technologies are given the name 'regime', while that of the emerging technologies are labeled 'niches'.

In modern society, these innovation systems are not always associated with a single nation or region because basic knowledge creation happens in different geographical areas and among various sectors around the world. As a result, national innovation systems (NSI) and sectoral innovation systems (SSI) often influence technological progress. Due to the presence of a large number of actors, network relations, and institutions at a national level, mapping the dynamics within NSI is a complex activity. NSI typically contains indicators such as R&D efforts, patents, educational institutions, university-industry collaborations, and the availability of venture capital. When compared to NSI, Technology Specific Innovation Systems (TSIS) have less number of actors, network relations, and institutions, which makes a dynamic analysis of TSIS possible.

Similar to Ortt and Kamp's TIS building blocks, Hekkert et al. also elaborate on several sets of functions that apply when relating one key activity of an innovation system with another. They are briefly described below.

1. **Entrepreneurial activities**: To generate new business opportunities, entrepreneurs put a lot of effort into creating knowledge, networks, and markets. In order to create knowledge and understand the functioning of technology, entrepreneurs experiment with technology under various circumstances. Moreover, entrepreneurs can either be new entrants or incumbent companies with an aim to diversify their business strategy.
2. **Knowledge development**: Research and development, and knowledge creation are essential for any innovation system as knowledge is considered to be a fundamental resource for the functioning of the modern economy (Åke Lundvall, 2010). R&D projects, patents, and investments in R&D are considered to be the crucial aspects of 'learning by searching' and 'learning by doing'.

3. **Knowledge diffusion through networks**: This function associated R&D with the governments, competitors, and the market and is essential for exchanging information among different networks. Policy decisions and R&D go hand in hand. Workshops and conferences are ideally the way to change the information within various networks.
4. **Guidance of search**: Industry, government, and the market are the components that influence this function. However, these components alone are not the influence on the guidance of search. In order to keep the process of guidance of search interactive, exchanging knowledge and ideas between technology producers and users is essential.
5. **Market formation**: New technologies (and new entrants) into the market after often considered inefficient on the date of their recognition in the market. This is a huge barrier to the market diffusion of such technologies. Therefore, creating niche markets can assist the actors associated with such technologies to learn about them and develop them further.
6. **Resources mobilization**: Apart from knowledge, financial and human capital are the basic resources required within an innovation system. These resources (especially funds) can be made available either by the government or the industry to develop specific technological knowledge.
7. **Creation of legitimacy**: In order for a technology to diffuse in the mass market, it either has to become a part of the incumbent regime or overthrow it. Therefore, a certain degree of resistance from the parties with vested interests is expected. To overcome this resistance, advocacy coalitions are essential to put new technology on the agenda, lobby for resources and favorable tax regimes.

These functions address the two major flaws identified in the concept of the innovation system. The static nature and the lack of sufficient attention at the micro level are the two flaws that are solved by applying the FIS framework (proposed by Hekkert et al.) to an innovation system. Mapping these seven functions provides insights into the dynamics of the innovation system.

Appendix B

1 Expert interviews

The type of interviews conducted are semi-structured. The questions asked during the expert interviews are listed below. These questions are discussed here in order to provide an understanding of the flow of the interviews. The discussion during the interviews is focused on gathering new information and validating the results obtained from the desk research. These questions are used as a guide to ensure a proper flow of conversation throughout the interview.

Introductory questions:

1. May I request you to kindly introduce yourself and your role in the Solar Electric Vehicle industry in India, just for the purpose of context-setting for our conversation?

Next, I would like to have an open conversation about SEVs in India:

2. What is your opinion on the development and adoption of Solar Electric Vehicles in India?

3. What kind of learnings that we got from the EV sector can also be applied to Solar Electric Vehicles?

3. In my research I've seen the opportunities that SEVs bring to India especially because it has abundant solar energy available, such as the reduced load on the electricity grid, and reduced emissions. What according to you are some opportunities or problems that SEVs will solve?

4. We have seen that some barriers like high cost of purchase and limited charging infrastructure were there when EVs were introduced and are still prevalent. What are some of the major barriers that SEVs would face while introducing the technology?

Other questions (Knowledge barrier and opportunities):

1. What challenges do you think exist from the perspective of manufacturers, distributors, of EVs, or SEVs in general? 2. What are some of the key research areas that need to be addressed in order to advance the development of SEVs? 3. What are the barriers in collaborating with companies outside India, like Tesla? Could you give some insights on how such collaborations can help and what are some of the other examples that you can provide? 4. One of the main barriers for any customer to buy EVs is the price. What other problems or complaints do you hear from an average or potential EV consumer?

Policy-related questions

1. What are some of the existing regulatory or policy barriers that could prevent the adoption of Solar Electric Vehicles in India, and how can they be addressed?

2. What kind of support or incentives can the government offer to encourage the adoption of Solar Electric Vehicles in India, and what impact might these measures have on the industry and the economy?

3. What are the barriers, according to you, that policymakers will face when introducing favorable policies for Solar Electric Vehicles in India?

4. One of the problems which I hear quite often is that if the incentives to purchase or manufacture solar EVs, many people will adopt them. What are the problems that government will face in increasing the incentives?

5. Do you think there are any favorable policies in place specifically for SEVs, or are the existing policies such as FAME II enough to introduce the product into the market?

Perspectives from the point of view of different stakeholders

1. How can collaboration between academia, industry, and government be facilitated to promote the development of SEVs? And what are the challenges that you face in encouraging such collaborations?

2. Can you provide any insights on how the barriers to SEV adoption may evolve in the future, and how stakeholders can prepare for these changes?

BARRIERS THAT WERE IDENTIFIED FROM THE LITERATURE REVIEW WERE DISCUSSED AFTER THESE QUESTIONS.

Final remarks:

1. Do you have any remaining remarks on this interview?

2. Do you know anyone else in your network or if you can refer me to anyone else that can provide more insights for my research that would be great.

3. Are you interested to receive the final report?

4. Could I contact you later to ask questions for additional information if needed?

Appendix C

1 List of strategies based on master thesis reports

Table 1: Strategies applicable to radical innovations in niches by Schulz (2019)

No.	Strategies	Perspective/Stakeholders involved	Source
1	Technological research & develop niche strategy	Industry	Schulz (2019), Dwisatyawati (2022)
2	Pilot research & develop niche strategy and Pilot project niche strategy	Industry	Schulz (2019)
3	Market research & develop niche strategy	Industry	Schulz (2019), Dwisatyawati (2022)
4	Human resource niche strategy	Industry	Schulz (2019), Dwisatyawati (2022)
5	Crowdsourcing niche strategy	Industry/customers	Schulz (2019), Dwisatyawati (2022)
6	Finance sourcing niche strategy	Industry	Schulz (2019), Dwisatyawati (2022)
7	Changing behaviour strategy	Industry/customers	Schulz (2019), Dwisatyawati (2022)
8	Adaptor Niche Strategy	Industry	Schulz (2019), Dwisatyawati (2022)
9	Direct- and Indirect lobbying niche strategy	Industry/government/customers	Schulz (2019), Dwisatyawati (2022)
10	Campaign funding & Joining regulatory agency niche strategies	Industry/government	Schulz (2019), Dwisatyawati (2022)
11	Leasing niche strategy	Industry/customers	Schulz (2019), Dwisatyawati (2022)
12	Sharing platform niche strategy	Industry/customers	Schulz (2019), Dwisatyawati (2022)
13	Buy-one, give-one niche strategy	Industry/customers	Schulz (2019), Dwisatyawati (2022)
14	Partnerships niche strategy	Industry	Schulz (2019), Dwisatyawati (2022)
15	Different application niche strategy	Industry/customers	Schulz (2019), Dwisatyawati (2022)
16	Education niche strategy	Industry	Schulz (2019), Dwisatyawati (2022), Ortt (2013)
17	Lead-user niche strategy	Industry/customers	Schulz (2019), Dwisatyawati (2022), Ortt (2013)
18	Subsidies niche strategy	Industry/government	Schulz (2019), Dwisatyawati (2022), Ortt (2013)
19	Redesign niche strategy	Industry	Schulz (2019), Dwisatyawati (2022), Ortt (2013)
20	Stand-alone niche strategy	Industry	Schulz (2019), Dwisatyawati (2022), Ortt (2013)
21	Dedicated System Niche Strategy	Industry	Schulz (2019), Dwisatyawati (2022), Ortt (2013)
22	Hybridization niche strategy	Industry	Schulz (2019), Dwisatyawati (2022), Ortt (2013)
23	Geographical niche strategy	Industry	Schulz (2019), Dwisatyawati (2022), Ortt (2013)
24	Top-end niche strategy	Industry	Schulz (2019), Dwisatyawati (2022), Ortt (2013)

Table 2: Strategies applicable to multiple actors associated with sustainable energy technologies by 't Veld (2020)

No.	Strategies	Stakeholders involved/perspectives	Adapted from/Source
1	Liberalize energy sector	Government	't Veld (2020), Painuly (2001)
2	Provided guaranteed market	Government	't Veld (2020), Painuly (2001)
3	Provide financial incentives	Government	't Veld (2020), Balachandra et al. (2010), Painuly (2001), Sen & Ganguly (2017), Zafar et al. (2018)
4	Investments	Government	't Veld (2020), Painuly (2001)
5	Initiate information and awareness campaigns	Government	't Veld (2020), Balachandra et al. (2010), Painuly (2001)
6	Provide standards and regulations	Government	't Veld (2020), Balachandra et al. (2010), Painuly (2001)
7	Take institutional measures	Government	't Veld (2020), Painuly (2001), Zafar et al. (2018)
8	Set up R&D programs	Government	't Veld (2020), Painuly (2001)
9	Adopt facilitating measures	Government	't Veld (2020), Painuly (2001)
10	Provide supportive demonstration and cost-reduction strategies	Government	't Veld (2020), Reddy & Painuly (2004)
11	Public sector participation	Government	't Veld (2020), Zafar et al. (2018)
12	Improved accessibility to information	Government	't Veld (2020), Zafar et al. (2018)
13	Stimulate educational institutes to initiate related workshops and training	Government	't Veld (2020), Zafar et al. (2018)
14	Establish collaborations and alliances with focal actor to reduce power position of incumbent firms	Competitors (Industry)	't Veld (2020), Gabriel et al. (2016)
15	Competitor grants the focal actor access to company resources	Competitors (Industry)	't Veld (2020), Ang (2008)
16	Exchange certain skills, knowledge and information	Competitors (Industry)	't Veld (2020), Tuchman (2015)
17	Teach focal actor skills to strengthen their position in the market	Competitors (Industry)	't Veld (2020), Tuchman (2015)
18	Explore new markets with focal actor	Competitors (Industry)	't Veld (2020), Bloem (2018)
19	Open up opportunities for economies of scale	Competitors (Industry)	't Veld (2020), Bloem (2018)
20	Provide financial resources to focal actor and customers of focal actor	Financial institutes (industry)	't Veld (2020)
21	Provide risk capital	Financial institutes (industry)	't Veld (2020), Sen & Ganguly (2017)
22	Commercialize scientific research outputs	Educational institutes (industry)	't Veld (2020), Fromhold-Eisebith & Werker (2013)
23	Provide human resources	Educational institutes (industry)	't Veld (2020), Davey et al. (2018)
24	Diffusion of information	Educational institutes (industry)	't Veld (2020), Fromhold-Eisebith & Werker (2013)
25	Technology transfer through collaborative R&D	Educational institutes (industry)	't Veld (2020), Fromhold-Eisebith & Werker (2013)
26	Provide cheap consultancy services	Educational institutes (industry)	't Veld (2020), Fromhold-Eisebith & Werker (2013)
27	Facilitate external R&D investments	Educational institutes (industry)/government	't Veld (2020), Fromhold-Eisebith & Werker (2013)
28	Provide education and training	Educational institutes (industry)	't Veld (2020), Fromhold-Eisebith & Werker (2013)
29	Provide education and training	NGOs and IDOs	't Veld (2020), Yaqoot et al. (2016)
30	Initiate information and awareness campaigns	NGOs and IDOs	't Veld (2020), Yaqoot et al. (2016)
31	Assist with product demonstrations	NGOs and IDOs	't Veld (2020), Yaqoot et al. (2016)
32	Assist government with policy making	NGOs and IDOs	't Veld (2020), Van Alphen et al. (2008)
33	Act as intermediary between customer and focal actor	NGOs and IDOs	't Veld (2020), Van Alphen et al. (2008)
34	Formulate clear system requirements	Customers	't Veld (2020), Chaurey & Kandpal (2010)
35	Influential community members can create trust	Customers	't Veld (2020), Urmee & Md (2016)
36	Engage in word-of-mouth advertising	Customers	't Veld (2020), Kenton (2016), Krishna (2021)
37	Community participation	Customers	't Veld (2020), Urmee & Md (2016)
38	Influence and shape regulatory changes	Incumbent firms (industry)	't Veld (2020), Hekkert & Negro (sd)
39	Cooperate with focal actor and become early movers	Incumbent firms (industry)	't Veld (2020), Hekkert & Negro (sd)

Table 3: Strategies pertaining to the mass adoption of solar electric vehicles by Dwisatyawati (2022)

No.	Strategies	Perspective/ Stakeholders involved	Source
1	Blue ocean strategy	Industry	Dwisatyawati (2022), Sharma (2016), Kim & Mauborgne (2004)
2	Preannouncing strategy	Industry	Dwisatyawati (2022), Monataguti et al. (2001)
3	Aggressive penetration strategy	Industry	Monataguti et al. (2001), Hardman et al (2013), Sharma (2016), Dwisatyawati (2022)
4	In-house network strategy	Industry	Dwisatyawati (2022), Hardman et al. (2013), Thomas & Maine (2019)
5	Market positioning strategy	Industry	Dwisatyawati (2022), Hardman it al. (2013), Thomas & Maine (2019),Kamp (2017), Sharma (2016)
6	Local implementation strategy	Industry/customers	Dwisatyawati (2022), Alam et al. (2010)
7	Incentives strategy	Industry/government	Dwisatyawati (2022), Iqbal et al. (2021)
8	Turnkey product strategy	Industry	Dwisatyawati (2022), Strupeit & Palm (2015)
9	Return oriented contracting strategy	Industry/customers	Dwisatyawati (2022), Strupeit & Palm (2015)
10	Existing social network strategy	Industry	Dwisatyawati (2022), Strupeit & Palm (2015)
11	Cross-selling and financing strategy	Industry	Dwisatyawati (2022), Strupeit & Palm (2015)
12	Product variants strategy	Industry	Dwisatyawati (2022), Naor et al. (2015), Kamp (2017), Sharma (2016)
13	Complimentary technologies, products and services strategy	Industry	Dwisatyawati (2022), Naor et al. (2015), Hardman et al (2014), Sharma (2016)
14	Local strategy	Industry	Dwisatyawati (2022), Van den Berg (2017), Strupeit & Palm (2015), Iqbal et al. (2021), Alam et al. (2010)
15	Stepping stone strategy	Industry	Dwisatyawati (2022), Olsthoorn (2017)
16	Network building strategy	Industry	Dwisatyawati (2022), Olsthoorn (2017), Van den Berg (2017)
17	Get specified strategy	Industry	Dwisatyawati (2022), Olsthoorn (2017)

2 Strategy description

1. **Liberalizing the sector strategy**: Liberalizing the sector strategy mainly involves restructuring, privatization, facilitating competition, and establishing independent regulatory bodies to establish the market and initiate the competition. The objective of this strategy is to aim to create a transparent and fair market environment that facilitates investment and growth (Painuly, 2001).
2. **Guaranteed markets strategy**: Guaranteed markets strategy focuses on creating a stable and secure market for a technology (for example, SEVs) by implementing necessary policy regulations that facilitate a guaranteed demand for the technology. This includes having targets for technology adoption, providing financial incentives, etc. By guaranteeing a market, the objective of this strategy is to attract investments, encourage innovation, and accelerate large-scale diffusion (Pratiwi, 2016).
3. **Economic/financial incentives strategy**: The economic/financial incentives strategy aims to encourage the adoption and diffusion of a technology by providing various financial incentives and benefits to consumers, manufacturers, and other stakeholders. This strategy includes implementing tax credits, subsidies, and grants to reduce the upfront costs of purchasing technology and to incentivize its use (Painuly, 2001).

4. **Investment strategy**: The investment strategy, particularly in the context of government investments, aims to bring in (private) investments to support the growth and development of a specific industry. This strategy facilitates an environment that attracts private investors through incentives, favorable policies, and support mechanisms. By promoting external investments, governments can tap into additional financial resources and expertise, bringing in innovation, job creation, and overall economic progress (Pratiwi, 2016).
5. **Promotion/awareness campaign strategy**: The promotion/awareness campaign strategy focuses on spreading awareness among stakeholders through various channels such as educational workshops, seminars, and webinars. These initiatives aim to raise awareness about the benefits and potential of a particular technology or concept, in this case, promoting SEVs. By providing basic information, these campaigns educate stakeholders, encouraging their active participation and support in the adoption and diffusion of SEVs (Balachandra et al., 2010).
6. **Technological research & develop (niche) strategy**: The technological research & development (niche) strategy involves R&D, funding research centers, and bringing in external investments to advance solar electric vehicle technology. It encourages innovation, addresses challenges, and facilitates necessary collaborations for researching and developing the technology (Dwisatyawati, 2022), (Fromhold-Eisebith and Werker, 2013).
7. **Supportive demonstration and cost-reduction strategy**: The supportive demonstration and cost-reduction strategy aims to promote technology adoption by demonstrating the capability of the technology and reducing associated costs. This strategy involves organizing technology demonstrations and initiating pilot projects to provide experience and build confidence among customers/end users. It also focuses on bringing down the costs of technology through economies of scale and technological advancements (Reddy and Painuly, 2004).
8. **Initiate (technical) training strategy**: The initiate (technical) training strategy aims to improve accessibility to technical information and develop the necessary skills and expertise for the development and diffusion of technology. This strategy involves making available the technical resources and knowledge, such as manuals, guidelines, and online platforms. It also focuses on leveling up the skills of the current workforce aligned with the specific roles associated with the technology (Zafar et al., 2018).
9. **Human Resource Management Strategy**: The Human Resource Management Strategy involves hiring skilled employees, generating human capital through educational institutes, and providing necessary human resources to support organizational goals. This strategy aims to attract talented individuals, develop their skills, and create a supportive work environment. By implementing an effective Human Resource Management Strategy, organizations can optimize their workforce, enhance employee capabilities, and drive sustainable success (Dwisatyawati, 2022), (Fromhold-Eisebith and Werker, 2013), ('t Veld, 2020).
10. **Education niche strategy**: The education niche strategy involves providing necessary education and training within an organization to improve employee knowledge and skills. This strategy involves conducting training programs, workshops, and educational initiatives to facilitate continuous learning and professional development. Additionally, it promotes internal knowledge sharing, collaboration and information exchange among employees (Dwisatyawati, 2022), (Zafar et al., 2018), (Ortt et al., 2013).

11. **Lead user niche strategy**: The lead-user niche strategy involves identifying and collaborating with lead users who are at the forefront of innovation and have unique needs and preferences. This strategy focuses on understanding the lead users' requirements and insights to develop innovative solutions that can meet their specific demands (Ortt et al., 2013), (Schulz, 2019).

12. **Finance Sourcing Strategy**: The Finance Sourcing Strategy involves exploring ways to secure financial resources for the implementation of projects or initiatives. This strategy includes seeking loans from different lenders, launching crowd funding campaigns, and seeking investments from financial institutions (Schulz, 2019), ('t Veld, 2020).

13. **Subsidized Niche Strategy**: The Subsidized Niche Strategy involves implementing product subsidies and tax subsidies to incentivize the adoption and usage of specific products. Product subsidies provide direct financial support or discounts on the purchase of the intended product, making it more affordable for consumers. Tax subsidies involve providing tax incentives or exemptions to individuals or businesses that are associated with the product (Ortt et al., 2013), (Dwisatyawati, 2022).

14. **Redesign niche strategy**: The Redesign Niche Strategy involves exploring alternative applications of a product to meet the immediate needs and preferences of the target market. This strategy potentially involves redesigning the product to make it simpler, adaptable more user-friendly, or more cost-effective (Ortt et al., 2013), (Schulz, 2019).

15. **Dedicated system or Stand-alone niche strategy**: The Dedicated System or Stand-alone Niche Strategy involves changing the physical aspects of a product or the associated system to create a self-sustainable solution with less reliance on complementary products or services. This strategy aims to provide customers with a comprehensive and self-sufficient solution that meets their needs without the need for additional components (Ortt et al., 2013), (Schulz, 2019).

16. **Hybridization or Adaptor niche strategy**: The Hybridization or Adaptor Niche Strategy involves combining a new product with an existing product to improve compatibility for a better user experience. This strategy focuses on improving the compatibility between the new product and existing complementary services by providing necessary adaptors or converters that bridge the gap between the two (Ortt et al., 2013), (Schulz, 2019).

17. **Lobbying strategy**: The Lobbying Strategy involves directly or indirectly influencing policymakers to influence public policy decisions. Direct lobbying involves engaging in direct contact with policymakers, to advocate for specific policies or changes. Indirect lobbying involves influencing policymakers through channels like NGOs, public opinion, and media campaigns. This strategy may also involve lobbying through financial contributions to political campaigns or having company representatives join regulatory agencies to influence decision-making processes (Schulz, 2019), (Hardman et al., 2013).

18. **Collaborative product utilization strategy**: The Collaborative Product Utilization Strategy focuses on facilitating shared access, utilization, and ownership of a particular product/technology. Through this strategy, consumers can maintain ownership of the product while the company maintains juridical ownership. It may involve offering leasing options where the company retains ownership throughout the lease contract. Through this strategy subscriptions also can be provided to the customers, allowing them to spread out the cost of purchase over a period of time (Schulz, 2019), (Strupeit & Palm, 2016).

19. **Buy-one, give-one niche strategy**: The Buy-One, Give-One Niche Strategy involves selling a product to top-end/upper-class customers while simultaneously donating the same product to a target market in need. This strategy aims to create a positive social impact by addressing the needs of poor or lower-class communities (Dwisatyawati, 2022), (Schulz, 2019).
20. **Geographical niche strategy**: The Geographical Niche Strategy involves targeting and focusing on a specific geographical area with relatively high demand for a product. Companies implementing this strategy identify regions or markets where there is a specific need or preference for their product and concentrate their efforts on serving those areas effectively (Ortt et al., 2013), (Schulz, 2019).
21. **Top-end niche strategy**: The Top-End Niche Strategy focuses on producing high-quality products on a small scale and targeting a particular group of customers or a specific market segment composed of high-end customers (Ortt et al., 2013), (Schulz, 2019).
22. **Partnerships niche strategy**: The Partnerships Niche Strategy involves collaborating and forming partnerships with other stakeholders involved to collectively address (common) barriers and challenges. By working together with partners, companies can leverage their combined resources, expertise, and networks to overcome challenges that may be difficult to overcome individually (Dwisatyawati, 2022), (Strupeit & Palm, 2016), (Hardman et al., 2013).
23. **Integrated network strategy**: The Integrated Network Strategy focuses on building and expanding networks, both within and outside the organization, to accelerate the market diffusion process. It involves leveraging external networks and partnerships to enhance market reach, tap into new customer segments, and utilize existing distribution channels (Dwisatyawati, 2022), (Hardman et al., 2013).
24. **Marketing strategy**: The Marketing Strategy involves various approaches to raise awareness and promote a particular technology, company, or product. One approach is to bring in the influencers who have a strong presence and following in the (target) market. Another strategy is the preannouncing strategy, which involves building anticipation and excitement by introducing the idea of the product or announcing it ahead of the official launch or release of the product (Dwisatyawati, 2022), (Schulz, 2019).
25. **Stepping stone strategy**: The Stepping Stone Strategy involves targeting culturally and geographically closer markets as a stepping stone to gain validation and establish the presence of the company in that market first. Focusing on similar markets or those with closer proximity to the company's existing operations or customer base allows for a relatively easier entry and reduces potential barriers or challenges associated with entering completely new and unfamiliar markets (Dwisatyawati, 2022), (Olsthoorn, 2017).
26. **Product variants strategy**: The Product Variants Strategy involves expanding or diversifying the product portfolio to serve a larger target market for the large-scale diffusion of the product. This strategy involves offering products with different designs, specifications, or features that address a diverse range of needs and preferences of end users (Dwisatyawati, 2022), (Sharma, 2016).
27. **Cross-selling strategy**: Cross-selling strategy involves offering the product in combination with other related or attractive products. This strategy aims to attract customers and bring in revenue by encouraging the customers to purchase additional products that

complement or enhance their main product (Strupeit & Palm, 2016), (Dwisatyawati, 2022).

28. **Result-oriented contracting strategy**: Result-oriented contracting strategy involves promising the customers of guaranteed results from the use of the product, such as good performance, etc. By providing such assurances regarding the benefits and value customers can expect, this strategy builds confidence and trust in the product. Companies communicate the guaranteed results to end users, highlighting the return on investment (ROI) (Dwisatyawati, 2022), (Strupeit & Palm, 2016).

29. **Blue Ocean Strategy**: Blue Ocean Strategy encourages organizations to create new demand and explore untapped market spaces by offering innovative products in similar/new markets at lower costs and higher efficiency, thus rendering competition irrelevant. It involves finding new and alternative ways to solve customer needs and challenges while creating a unique customer experience (Sharma, 2016), (Kim and Mauborgne, 2004).

30. **Explore multiple markets strategy**: The explore multiple markets strategy involves expanding the reach of the technology by exploring and entering different or new markets, and serving different customer needs. This strategy requires understanding the current trends, demand, and competition in those markets to identify opportunities and potential challenges. It may involve collaborating with other stakeholders, including competitors, to overcome common barriers and utilize collective resources and expertise (Ortt et al., 2013), ('t Veld, 2020), (Bloem, 2018).

31. **Formulate requirements strategy**: The formulate requirements strategy emphasizes the importance of aligning with customer and end-user requirements in the product, to gain trust and acceptance. Customers have the opportunity to clearly articulate their expectations and specifications for the technology while complying with safety standards and government regulations ('t Veld, 2020), (Chaurey and Kandpal, 2010).

32. **Influential community member strategy**: The influential community member strategy involves utilizing the influence and trust that influential members within a community hold. The role of an influential community member is to actively promote and create awareness about the technology among the community members ('t Veld, 2020), (Urmee and Md, 2016).

33. **Word of mouth strategy**: The word of mouth strategy involves utilizing (electronic) Word of Mouth (eWOM) platforms and traditional Word of Mouth (WOM) to spread the (positive) word and promote the technology. eWOM platforms, such as social media, online forums, and review websites, allow for the diffusion of information and recommendations about the product ('t Veld, 2020), (Krishna, 2021).

34. **Continuous user engagement strategy**: The continuous user engagement strategy focuses on actively engaging and maintaining a strong connection with users throughout their entire journey with the technology. It emphasizes interaction, feedback, and communication from customers to ensure user satisfaction and establish a sense of loyalty and involvement ('t Veld, 2020).