Analysis of Sustainable Socio-Technical Transition -

Unpacking the Development of the NEV Sector from the Early 2000s through an Innovative Conceptual Framework

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Abstract

This research investigates the significant growth of China's New Energy Vehicle (NEV) sector from the early 2000s to the 2020s, evolving from a niche market to a central player in the automotive industry. While previous studies have focused mainly on singular factors, such as policy impacts, this study introduces the Global, Internal, and External Socio-technical System (GIESTS) Framework, an advanced adaptation of the Multi-Level Perspective (MLP), to analyse China's NEV transition comprehensively through providing a multidimensional view of China's electrification journey.

Additionally, the study introduces the Resources-Capabilities Analytics (RCA) Framework to examine firm-level transitions, drawing on the resource-based view and dynamic capability theory. This framework allows for comparisons between different types of automakers, offering more profound insights into how firms navigate the NEV sector's challenges and opportunities.

Using a mixed-methods approach, combining secondary data analysis, participatory observation, and expert interviews, the research explores the roles of key stakeholders, transition pathways, and how China's government's role compares to that of developed countries. It also examines interactions between various transition layers using the GIESTS Framework, revealing how the various factors have influenced the sector's growth.

The findings provide strategic insights for policymakers and industry leaders, proposing a systematic methodology for understanding complex transitions in socio-technical systems. This thesis significantly contributes to scholarly discussions on socio-technical transitions and offers a valuable guide for stakeholders involved in the ongoing transformation of the NEV industry.

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Author declaration

'I declare that, except where explicit reference is made to the contribution of others, this thesis is the result of my work and has not been submitted for any other degree at the University of Glasgow or any other institution.'

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Signature:

List of Abbreviations

A.C.E.S.	Autonomous driving, Connected vehicles, Electric vehicles, and Shared mobility
ADAS	Advanced Driver Assistance Systems
BEV	Battery Electric Vehicle
CAFE	Corporate Average Fuel Economy
DC	Dynamic Capabilities
EV	Electric Vehicle
FYP	Five-Year Plan
GIESTS Framework	Global, Internal, and External Socio-technical Systems Framework
ICE	Internal Combustion Engine
ICV	Intelligent Connectivity Vehicles
IVI	In-Vehicle Infotainment
JV	Joint Venture
MLP	Multi-level Perspective
MIIT	Ministry of Industry and Information Technology
MOF	Ministry of Finance
MOST	Ministry of Science and Technology
NDRC	National Development and Reform Commission
NEV	New Energy Vehicle
OEM	Original Equipment Manufacturer
OTA	Over-The-Air
PHEV	Plug-in Hybrid Vehicle
RBV	Resource-based View
RCA Framework	Resources-Capabilities Analytics Framework
SNM	Strategic Niche Management
SOE	State-Owned Enterprise
TIS	Technological Innovation System
TM	Transition Management
SCOT	Social Construction of Technology
HEV	Hybrid Electric Vehicle
MPV	Multi-Purpose Vehicle
OEM	Original Equipment Manufacturer
SOE	State-Owned Enterprise
V2G	Vehicle to Grid
V2X	Vehicle to Everything
WTO	World Trade Organization

Chapter 1. Introduction

1.1 Overview and research significance

In recent years, there has been a remarkable surge in the market performance of new energy vehicles (NEVs), particularly in China and Europe. This surge is evidenced by the fact that in 2020, the number of battery electric vehicles (BEVs) in China exceeded 3.5 million, while European countries like Germany and Norway boasted more than 400 thousand BEVs in active use. Notably, the sales of BEVs and plug-in hybrid vehicles (PHEVs) in China reached a staggering 1.1 million in 2020, representing a remarkable 39.1% of total global sales (IEA, 2021). This surge in sales has prompted numerous scholars to initiate research endeavours focused on developing NEVs in China (Yu et al., 2019, Zhang and Qin, 2018).

The trajectory of China's automotive electrification journey is intricate, involving extensive interactions between China's automotive sector and foreign automotive sectors. The development of other sectors in China, such as the internet and telecom sector, also significantly influences this transition. Crucial actors from these various sectors have engaged in numerous interactions. This transition is shaped by interactions among sectors and actors, underscoring the value of providing a comprehensive analysis to decipher it.

While there has been considerable research interest in China's burgeoning NEV market, focusing on aspects such as market dynamics, policy impacts (Dong and Liu, 2020, Hsiao et al., 2023), and regional studies (Liang and Lu, 2022), comprehensive assessments that consider the full breadth of the socio-technical system are notably rare. As mentioned previously, for emerging markets like China, external impacts are influential for socio-technical transition, including interactions among geographical locations and technical sector markets like China, and external impacts are influential for socio-technical transition, including interactions among geographical locations and technical sectors. To fill this gap, our study explores socio-technical transition theories from the late 1990s and early 2000s, including strategic niche management (SNM) by Kemp et al. (1998) and the multi-level perspective (MLP) by Geels (2002), aiming to capture the complex interplay of factors driving the NEV transition in China.

The MLP concept has provided insights into socio-technical transitions by examining them across three layers: niche, regime, and landscape (Geels, 2002). However, this framework's application to the rapidly evolving context of developing countries like China, which are heavily impacted by external forces, reveals a need for a more nuanced analytical approach. Our research introduces the Global, Internal, and External Socio-technical System (GIESTS) Framework, an innovative extension of the MLP concept designed to capture the multifaceted dynamics of China's NEV sector between the early 2000s and 2023. This framework has been applied to five distinct phases of the sector's evolution, from niche innovation to becoming a dominant force within the automotive industry. Both domestic developments and global pressures significantly influence this socio-technical transition trajectory, yet it ultimately achieves the same societal function, as noted by Turnheim et al. (2015).

Employing the GIESTS Framework, complemented by insights from expert interviews and participant observation along with secondary data, this thesis aims to provide a comprehensive analysis of the critical sectors, actors, and environmental factors shaping the expansion of China's NEV sector. Our research seeks to advance the field of socio-technical transition studies by offering a refined framework capable of addressing the complexities of transitions in environments shaped by significant external socio-technical systems. Through a detailed examination of the sector's landscape, this study highlights the interconnections between different socio-technical systems, the pivotal roles of both central and local governments, and international dynamics in shaping the trajectory of China's NEV sector. The scope of the NEV sector discussed in this thesis includes BEVs, PHEVs, range extensions, and fuel cell vehicles (FCVs), but with a focus on BEVs and PHEVs.

Moreover, I also recognise the importance of understanding the firm-level transition for our focal case. Therefore, this study analyses the relationship between firms' capabilities to react appropriately to dynamic environments, gain competitive advantages, and sustain market performance. This is achieved through another multi-level framework, the Resources-Capabilities Analytics Framework (RCA Framework), which incorporates resource-based view (RBV) and dynamic capabilities (DC) concepts. Such an analysis helps us better understand the rationale behind the behaviours and decisions of these automakers during the transition.

In summary, this research significantly contributes to understanding the intricate socio-technical transition unfolding in China's automotive electrification context. The GIESTS Framework, designed for systematic analysis of the entire transition and firm-level analysis using concepts from the resource-based view and dynamic capabilities, offers a robust analytical approach. This study promises to provide a comprehensive and insightful perspective on this transformative journey, coupled with insights from industry experts and the author's eight-year experience in participant observation within the automotive industry in China and other APAC countries. This contribution extends beyond academic knowledge and has the potential to serve as a valuable reference for policymakers and industry stakeholders alike.

1.2 Research question and goals of the research project

The research project is dedicated to studying the transition of the NEV sector from a niche sector to a critical player in the mainstream, or the regime, of the automotive market in China. The primary theoretical framework utilised in this study is the MLP concept developed by Geels (2002), which focuses explicitly on the interactions between different socio-technical systems. We will adopt the spatial dimension of MLP, as identified by Coenen et al. (2012), to gain deeper insights into the influence of the spatial factor on the transition process. Moreover, the concept of strategic niche management will also be employed to analyse the evolution of the niche and the development of protective spaces that support niche growth (Smith and Raven, 2012).

Besides sector-level transition, I am also interested in firm-level analysis to understand why automakers react in specific ways to the new challenges arising from the changing environments and how these reactions result in varying market performances. By delving into these phenomena from the perspective of the capabilities of these automakers and adopting concepts such as DC and RBV, this study aims to provide a more comprehensive analysis. These insights will complement the broader GIESTS Framework by uncovering the rationale behind the behaviours and performances of automakers, thus offering a deeper understanding of the socio-technical transition in China's NEV sector.

The research will cover the transition process from the early 2000s to the early 2020s, examining various levels, including global, internal, and external dimensions and sub-levels such as associated and peer socio-technical systems. Additionally, it will analyse how the capabilities of automakers influence their performance in a disruptive changing environment from the mid-2010s.

The two central research questions addressed in this project are as follows:

- What are the primary factors and entities responsible for the evolution of China's NEV sector from a niche entity to a dominant force within the automotive sector between the early 2000s and the early 2020s?
- Why are these factors and entities influential in driving this transition, and how do they shape and impact the trajectory of this transformation?

This research project has two main objectives:

- **Expanding the Scope of MLP as Theoretical Contribution**: While existing research on the multi-level perspective primarily focuses on interactions among the three levels (niche, regime, and landscape) within targeted socio-technical systems, there is the limited exploration of interactions between the targeted socio-technical system, external socio-technical systems, and global factors. This project seeks to contribute insights into the interactions between different socio-technical systems and global factors by developing a new conceptual framework based on MLP, incorporating concepts of 'internal and external' and 'peer and associated' as extensions to the existing multi-level perspective.
- **Providing a Comprehensive Chronological Study of the Automotive Electrification of China as a Practical Contribution**: The project aims to offer a detailed longitudinal analysis of the transition process within the electric vehicle industry in China, spanning from the initial goal-setting phase to the growth phase. This analysis will be conducted based on the conceptual framework developed, shedding light on the various factors influencing the industry's development over time. Additionally, capabilities-related concepts will be applied to explain the automakers' diverse behaviours and market performance during the period at the firm level when the NEV sector rapidly evolved from a niche market to a mainstream component.

By exploring these objectives and addressing the core research questions with a novel conceptual framework and systematic research approaches, this project seeks to deepen our comprehension of socio-technical transitions, spotlighting the interconnections between emerging technologies and the dynamics of global-local interactions.

1.3 Research approach

This doctoral research adopts a qualitative methodology to explore the evolution of China's NEV sector from a niche market to a dominant player in the automotive industry since the early 2000s. The study centres around the development and application of the GIESTS Framework. This proposed framework is designed to dissect the complex socio-technical transition within China's NEV sector, considering various influential factors from broader environmental contexts, related socio-technical systems, and the critical actors within these systems.

Using the GIESTS Framework, the research analyses the NEV sector primarily through secondary data and extensive eight-year participant observation. The insights obtained from this analysis are further enriched by expert interviews, offering a detailed perspective on the factors that have propelled the growth of the NEV sector in China post-2020. The results of this study are expected to provide valuable insights for stakeholders in the automotive industry and those involved in socio-technical transitions across various sectors. Moreover, the effectiveness of the GIESTS Framework in analysing complex transitions will be evaluated and illustrated.

The selection of China's automotive electrification as the focal case adheres to several critical criteria, ensuring a well-reasoned choice. Firstly, due to its complexity, the automotive sector maximises learning and significantly contributes to the research objectives (Tellis, 1997). Additionally, it addresses central issues crucial for understanding and answering the main research questions (Tellis, 1997, Yin, 2009b). The availability of relevant data sources, including expert interviews, documents, and field observations, is a crucial factor for the success of case studies (Yin, 2009b). Moreover, my eight years of industry experience provide me with access to the required data. The case study in China's rapidly evolving NEV sector represents a complex ecosystem with many actors and influences. It involves systematic data collection from various sources, emphasising participant observation and expert interviews to provide deep, contextual insights often missing in secondary data.

In Chapter 5, the research utilises the GIESTS Framework to identify and analyse global factors, key sectors, and their respective actors influencing the transition. This analysis will be complemented, supplemented and validated through expert interviews, providing a comprehensive understanding of the transition. The findings from the case study, combined with insights from the GIESTS Framework and expert interviews, will form the basis of the critical research findings. Chapter 7 delves into the firm-level analysis based on RBV and DC, using an integrated framework combining these concepts. These findings will be discussed in detail in Chapters 8 and 9. More details of the case study execution will be elaborated in Chapter 3.

Overall, this approach aims to construct a detailed, multifaceted view of the development of China's NEV sector, contributing significantly to the understanding of the complex socio-technical transition within this evolving industry.

1.4 Thesis structure

The content structure of this thesis is as follows:

1.4.1 Chapter 1: introduction

The present Chapter offers a comprehensive overview of the research project, encompassing key aspects such as research questions, expected outcomes, and the chosen research approach.

1.4.2 Chapter 2: literature review

This chapter explores key concepts for analysing socio-technical transitions fuelled by disruptive innovations. It focuses on multi-level perspectives, multi-scalar MLP, and SNM as foundational concepts for the GIESTS conceptual framework. Additionally, it discusses dynamic capabilities, resource-based view, and stakeholder theory to enhance the framework's development and application in the case study. The primary purpose of this chapter is to provide the theoretical foundation for developing the conceptual framework and case study.

1.4.3 Chapter 3: research design

This chapter begins by exploring the research's philosophical stance, followed by a detailed discussion of the chosen methodologies. It covers data collection and analysis methods, explicitly focusing on the methodology used for expert interviews.

1.4.4 Chapter 4: The GIESTS conceptual framework

This chapter provides an in-depth examination of the GIESTS Framework, encompassing its constituent building blocks, practical applications, and a thorough exposition of its various layers. Additionally, key concepts integral to the framework are elaborated upon and succinctly summarised for clarity.

1.4.5 Chapter 5: Case study

This chapter offers an exhaustive exploration of the developmental trajectory of China's NEV sector, segmented into five distinct stages. The chapter delves into the intricacies of each developmental stage, shedding light on the underlying dynamics and critical milestones that have shaped the NEV sector's growth in China.

1.4.6 Chapter 6: summary of expert interviews

This chapter synthesises insights from interviews with industry experts, bridging the gap between theoretical frameworks and practical industry experiences. It presents the methodology behind conducting and analysing the interviews and how these insights contribute to understanding the NEV sector's transition.

1.4.7 Chapter 7: firm-level analysis

This chapter uses the RCA Framework to analyse the capabilities, performances, and behaviours of different automakers during the rapid changes of the mid-2010s. Examining three iconic automakers provides complementary insights to the GIESTS Framework results, uncovering how different capabilities and strategic responses have influenced their success and adaptation in the evolving NEV sector.

1.4.8 Chapter 8: Government's roles in the transition

This chapter discusses the Chinese government's role in the NEV sector's development, evaluating its strategic use of policy tools, initiatives, and collaborations with external actors. It highlights how governmental actions have influenced the sector's transition trajectory.

1.4.9 Chapter 9: Discussion

This chapter presents and elaborates on the primary findings from the case study. It summarises key insights into transition patterns and pivotal influencing factors. Additionally, it assesses the efficacy and utility of the GIESTS Framework, discussing its merits and limitations. The conclusion section highlights key takeaways for policymakers and practitioners, addresses the research's limitations, and outlines potential future research directions to advance our understanding of socio-technical transitions.

Chapter 2. Literature Review

2.1 Introduction

In the early 2000s, socio-technical transitions began to gather significant scholarly momentum. The foundational theories of this field were rigorously tested through historical case studies, laying the groundwork for their application in analysing sustainability transitions (Zolfagharian et al., 2019). In this context, a socio-technical transition is a systemic innovation process to guide society towards sustainability. This involves structural changes within socio-technical systems that cater to specific societal functions such as mobility, energy, or food systems, aligning with the broader goals of sustainable development (Zolfagharian et al., 2019, Bergek et al., 2010, El Bilali, 2019). Sustainable development is an integrative process that harmonises economic growth with environmental stewardship and social well-being (Giddens, 1987).

The prevailing academic approach to analysing these transitions has shifted from examining isolated dimensions to adopting a systemic perspective. This approach recognises transition as a multifaceted process involving the coordination and governance of various actors and resources within the socio-technical system. It acknowledges the complexity of transitions, incorporating both the intended strategies and the emergent dynamics that unfold over time (Smith et al., 2005).

Zolfagharian et al. (2019) have identified four prominent theoretical frameworks related to sustainable transition studies, which include the multi-level perspective (MLP), strategic niche management (SNM), technological innovation systems (TIS), and transition management (TM). This research project will primarily focus on MLP and SNM, drawing additional insights from the spatial dimension of MLP (multi-scalar MLP) to enrich the analysis. Furthermore, dynamic capabilities (DC) and resource-based view (RBV) will be reviewed as input for firm-level analysis in Chapter 7. Finally, I will review some theories regarding the definition of actors in the transition to provide theoretical support for the actor definition in the discussion part of this thesis, including stakeholder approach and innovation diffusion.

The literature review section of this thesis aims to exhaustively explore existing research in the socio-technical transitions and innovation domain. This will lay the theoretical foundation for developing the research project's conceptual framework and guide the empirical investigations. The rationale behind selecting MLP as the core theory, supplemented by SNM and the spatial dimensions of MLP, will be explained, delineating how these theories collectively inform this project's research approach and objectives.

2.2 Multi-level perspective

Given technological innovation's nonlinear and unpredictable nature, socio-technical transitions present various challenges, including costly failures, lock-in mechanisms, the hype-disappointment cycle, and tensions among stakeholders (Verbong et al., 2008; Geels. MLP emphasises that socio-technical transitions encompass not only innovations but also the involvement of multiple social groups (such as firms, consumers, policymakers, and researchers) engaged in various activities (exploration, learning, and power struggles) within the context of rules and institutions (Geels, 2019, Geels, 2002). The mutual promotion of technical and social change has compelled socio-technical change; in other words, there is a co-evolution between technological change and the changes in the social system (Liu et al., 2018).

This approach's application examines sustainability-related topics, including sustainable technological transitions, industrial transformation, and socio-technical change (Geels, 2002). Technological innovation, in particular, has become a pivotal process within sustainable socio-technical change, significantly influencing the sustainability of entire industries (Hekkert and Negro, 2009). These topics encompass a wide range of areas, such as the transition to low-carbon electricity (Geels, 2014, Geels et al., 2016), the shift from internal combustion engine vehicles to electric vehicles (Berkeley et al., 2017, Rao, 2020, Wu et al., 2021c), and the transformation of the heat energy system (Dzebo and Nykvist, 2017), as well as the agricultural industry and food system (El Bilali, 2019).

However, it’s worth noting that even though we’ve seen a growing number of empirical studies focusing on China after 2020, such as in the telecom sector (Lee and Yu, 2022). In the power sector (Zhang et al., 2020, Yang et al., 2022), the majority of existing research projects have predominantly centred on socio-technical systems within the European region. Studies relating to automotive electrification often focus on single aspects, such as policy (Tian et al., 2024, Yin and Huang, 2023) or standards (Sun et al., 2023). Considering the complex nature of China’s electrification transition, we believe an integrated approach could provide a clearer explanation of the transition trajectory. This discrepancy can be attributed to the European origins of these theories and the concentration of empirical studies within that region.

MLP distinguishes three heuristic and analytical conceptual levels, comprising niche innovations, socio-technical regimes, and socio-technical landscapes, encompassing socio-technical changes’ micro, meso, and macro levels (Geels, 2002, Rip and Kemp, 1998). The socio-technical regime extends the technological regime concept introduced by Winter and Nelson (1982), conceptualising coordination as the outcome of organisational and cognitive routines. Furthermore, Geels (2002) asserts a ‘nested’ hierarchy of these three levels: regimes are embedded within landscapes, and niches are embedded within regimes.

2.2.1 Three conceptual levels of MLP: regime

The concept of the socio-technical regime was introduced to account for the inertia and path dependence observed during transformative transitions. It reflects the co-evolution of institutions and technologies over time (Fuenfschilling and Truffer, 2014). A technological regime comprises a set of rules encompassing scientific knowledge, engineering practices, production processes, product characteristics, skills, procedures, institutions, and infrastructures shaped by engineering practices and routines associated with the dominant technology (Rip and Kemp, 1998, Kemp et al., 2001). The socio-technical regime includes public authorities, research networks, societal networks, user groups, producer networks, suppliers, and financial networks (Geels, 2002).

Various actors influence technical trajectories in the socio-technical regime, including engineers, policymakers, societal groups, suppliers, scientists, and bankers (Geels, 2002). Those who contribute significantly to the regime's reproduction are considered 'core members', while those with less involvement are deemed 'peripheral members' (Smith et al., 2005). In addition, the technological regime is not a monolithic entity but involves coordination among lower-level agencies, encompassing institutions, social networks, and actors (Johnson and Jacobsson, 2001). Thus, regimes are multifaceted and nested phenomena, encompassing natural and physical elements within social, cultural, cognitive, and economic dimensions (Smith et al., 2005, Geels, 2002, Kemp et al., 1998, Rip and Kemp, 1998).

For sustainable transition to occur, radical transformation at the regime level is often necessary (Rotmans et al., 2001a, Rotmans et al., 2001b). Rip and Kemp (1998) define regime as a rule-set or framework entrenched in a complex of engineering practices, production process technologies, product specifications, skills and procedures, methods of interacting with relevant artefacts and individuals, and approaches to problem definition. All these components are deeply ingrained within institutions and infrastructural systems. In essence, the socio-technical regime represents a relatively stable component of the socio-technical system, characterised by consistent rules, practices, and networks that guide incremental technological development and adoption (Smith et al., 2005).

Moreover, regimes can change various paths, including internal conflict, external pressure, or pressure from niche-level initiatives in a bottom-up manner. In response to these pressures, regimes may adopt different strategies, ranging from defensive approaches to resisting change to reactive approaches seeking continuous improvement and innovative approaches proactively cooperating and contributing to the transition process (Rotmans et al., 2001a, Rip and Kemp, 1998). Smith et al. (2005) identify three key factors that influence transformation at the regime level: (1) the articulation of the selection pressure directed towards a specific issue or direction to coordinate actors and resources, (2) the resources required for successful transformation, and (3) the degree of coordination among these actors' responses.

Adaptive capacity plays a crucial role in the regime's ability to absorb shocks while maintaining functions through change buffering, learning, and development (Folke et al., 2002). Adaptive capacity involves four functions: (1) creating new knowledge, (2) supplying resources, (3) creating positive external economics, and (4) forming markets (Johnson and Jacobsson, 2001). When the selection pressure from the environment intensifies, regimes with greater adaptive capacity are better equipped to maintain their functions effectively (Smith et al., 2005). However, adaptive capacity is not confined to incumbent regimes; emerging networks with qualified actors may possess superior adaptive capacity and generate innovative solutions to address selection pressure, challenging dominant regimes (Geels, 2002, Christensen, 2013).

2.2.2 Three conceptual levels of MLP: niche

Unlike regimes, niches are embedded within the regime, originating at the micro-level where initial innovations emerge (Kemp et al., 1998, Geels and Schot, 2007). Generally, niches emerge when the existing regime fails to align with user preferences due to changes in the technological or environmental landscape (van Mossel et al., 2018).

The niche can be likened to an ‘incubation room’ or a ‘protective space for fledgling socio-technical configurations which lack the competitiveness to withstand the pressure from the dominant regime or technologies (Geels and Schot, 2007, Smith and Raven, 2012). Smith and Raven (2012) identify three essential protective mechanisms that niches offer to the transition process: shielding, nurturing, and empowerment. Empowerment, in particular, can be further divided into two distinct processes: the ‘fit-and-conform’ process, aimed at enhancing the competitiveness of innovations to compete with established players in the regime within an unchanged environment. The second process, known as ‘stretch-and-transform’, is a means to induce changes in the selection pressure from the mainstream environment by challenging incumbent regimes and transmitting niche-derived institutional reforms into restructured regimes. The goal is to shift the selection environment, favouring niche innovations over mainstream technologies.

Furthermore, the size and stability of heterogeneous socio-technical configurations contribute to the differentiation between niches and regimes. Niches, by nature, exhibit lower structure, fewer actors, and less mature technologies compared to regimes. Nonetheless, it is worth noting that despite these disparities, Kanger (2021) has identified critical similarities between niches and regimes, which hold significance within the conceptual framework of this research. These include the presence of mutual supporting actors, the delineation of boundaries for both levels and their shared objective of achieving a joint societal function.

Geels (2002) introduces the concept of nested niches within regimes, forming a hierarchical relationship within the MLP framework. This nested structure entails that niches exist at the micro-level within the broader macro-meso-micro hierarchy. Niches draw upon the knowledge, capabilities, and problems of the regimes they are embedded in, further underlining their importance in shaping transitions (Geels, 2002).

In essence, niches are dynamic spaces offering alternative solutions to fulfil the same societal functions as regimes. While niches are typically less structured, house fewer actors, and support less mature technologies than regimes, they play a critical role in fostering radical innovations (Geels, 2005). The protective nature of niches shields these innovations from market selection mechanisms, enabling them to develop alternative structures and challenge the dominance of regimes. Niches thus represent a crucial driver of socio-technical transitions, especially when external factors create windows of opportunity for their innovations to thrive in a changing landscape.

2.2.3 Three conceptual levels of MLP: landscape

Geels (2002) defines the socio-technical landscape as an external framework or context for actor interactions, encompassing a set of deep structural trends. This socio-technical landscape forms an exogenous environment beyond the regime's scope, including macroeconomics, deep cultural patterns, macro-political developments, infrastructures, and urban spatial arrangements. The pace of change in the socio-technical system is generally slower than that of the regime and may span decades (Geels, 2002, Geels and Schot, 2007).

Van Driel and Schot (2005) further elaborate on the landscape, categorising it into three types: (1) factors that change slowly or not at all, such as climate; (2) long-term changes, such as industrialisation; (3) rapid external shocks, such as war or fluctuations in material prices (Smith et al., 2005). In addition to the rigid societal structure and global trends, like political ideologies, societal values, and demographic trends, environmental shocks, such as global currency fluctuations, also play a role (Sirmon et al., 2007, van Mossel et al., 2018).

2.2.4 The additional spatial dimension of MLP (multi-scalar MLP)

Raven et al. (2012) emphasise the importance of spatial scale and the temporal and structural scales represented by niches, regimes, and landscapes. They argue that the existing research often imposes territorial boundaries on different levels, which may not be necessary for conducting socio-technical analyses. For example, research on regimes tends to focus on national features, while niche research often concentrates on local or regional aspects. However, the differences within boundaries and the interactions between actors within these locations significantly influence socio-technical transitions. These boundaries need not be exclusive; elements like networks can have relevance across various levels (Berkhout et al., 2011).

Coenen et al. (2012) also highlight the increasing importance of geographical elements, mainly when infrastructure or local actors, networks, cultures, or resources significantly influence transition success. The significance of interactions between actors, institutions, and economic structures across different spatial scales within unequal and diverse protective spaces for innovation toward sustainable transition is underscored by several scholars (Bunnell and Coe, 2001).

Furthermore, the spatial scale can be viewed as a territory, which can aid in understanding the transition and its associated factors and processes (Raven et al., 2012). There are two types of spatial scales: (1) absolute spatial scale and (2) relational spatial scale (Raven et al., 2012). The absolute spatial scale includes different levels, such as nations, cities, regions, and others. These places contain spatial factors like territorially bounded resources, labour forces, and institutions for analysing transitions (Gibson et al., 2000, Raven et al., 2012). On the other hand, scholars in economic geography have differentiated the concept of relational assets at various levels of development (Yeung, 2005). Relative and comparable advantages can be derived from relational assets that are territory-specific and challenging, if not impossible, to imitate. These relational assets encompass social relations, conventions, and endowments.

Unevenly distributed relational assets can significantly determine niche emergence (Raven et al., 2012). In other words, niches are more likely to emerge in territories with more suitable relational assets for their development. The transition does not solely occur within a single territorially bounded space, such as a nation or a city. Multi-scalar interactions among actors at different spatial scales and levels within the multi-level framework are observed during the transition (Raven et al., 2012).

These studies emphasise the significance of the spatial dimension in MLP and provide a foundation for future analysis of interactions between actors across different socio-technical systems.

2.2.5 Key elements and actors of the socio-technical system

The socio-technical regime comprises three core elements: institutions (rules), networks (actors), and infrastructures (Raven, 2007, Geels, 2002). These elements are interdependent and contribute to the socio-technical regime's stability. Notably, actors are not confined to specific levels and often play diverse roles across different levels, facilitating the circulation of ideas, people, and goods and shaping the relational aspects of action and change (Raven et al., 2012). Within socio-technical systems, there are two primary categories of actors: demand-side actors (e.g., users, special-interest groups, media) and supply-side actors (e.g., companies, institutions, policymakers, universities). These actors are instrumental in creating, maintaining, and refining the elements of the system (Geels and Kemp, 2007). Such concepts help the GIESTS Framework to identify its elements at different levels.

Institutions, or rules, form the belief systems and norms that maintain the stability of the socio-technical regime (Geels, 2019). They serve as the 'deep structure' of the socio-technical regime, influencing actor behaviour and shaping the context and outcomes of their actions (Geels, 2011). Institutions stabilise the socio-technical system through institutional commitments, power relations, and shared beliefs among incumbent actors or political lobbying (Geels, 2011, Unruh, 2000).

In response to external forces driving socio-technical transitions, regime elites may adapt institutions to incrementally address external pressures and avoid radical change (Geels, 2011). Institutional structures encompass both formal elements (e.g., financial schemes) and informal aspects (e.g., cultural norms), which can pose barriers to new alternatives(Jacobsson and Lauber, 2006). Developing new institutions often requires cooperation among actors and creating protective spaces to shield them from direct challenges to existing rules (Smith and Raven, 2012). Institutions are often viewed as lock-in mechanisms that impede socio-technical system transitions (Klitkou et al., 2015).

Infrastructure plays a crucial role in sectors reliant on mainstream infrastructure systems (Geels, 2002, Kemp, 1994, Kemp et al., 1998). These infrastructures often require significant investment during the emergence of new niches led by government initiatives. For example, the shift from horse-drawn carriages to automobiles necessitated the construction of paved roads (Geels, 2005). Similarly, the competitiveness of electric vehicles depends on the development of charging networks (Geels et al., 2016, Berkeley et al., 2017, Krätzig et al., 2019). Conversely, existing infrastructures can become lock-in mechanisms, as sunk costs and stakeholder resistance hinder socio-technical transitions. For instance, the investment already incurred by oil companies in infrastructure such as gas stations and oil storage tanks could be a reason for them to resist the change, as the foreseeable reduced demand for gas would leave these assets underutilised (Straubinger et al., 2020).

Actors, or networks, maintain and transform elements within the socio-technical system. These actors encompass a broad spectrum, including firms, industries, politicians, policymakers, consumers, engineers, researchers, and civil societies (Geels, 2011). Actors are integral to the development and evolution of the socio-technical regime. They often assume diverse roles across levels and are essential for transitions. Critical actors in this research project include:

- **Governments, Civil Societies, and Public Authorities**: These entities establish rules, subsidies, and tax policies, providing direction and goals for sectors. They use policy tools to guide key actors towards these objectives, focusing on public welfare and promoting greener niches (Elzen et al., 2011).
- **Institutions and Universities**: These entities advance technologies, optimise standards, and supply talent to the sector. They are critical in research, standards development, and talent supply (Elzen et al., 2011).
- **Associations and Unions**: These organisations facilitate communication, interaction, and information sharing among key sector players. They set criteria and rules but may

also oppose radical changes, favouring incremental ones or the status quo (Unruh, 2000).

- **Large Firms**: These entities possess substantial resources and complementary capabilities, playing a pivotal role in accelerating transitions. They often have competitive capabilities, close relationships with governments and institutions, and influence sector decisions. International firms bridge internal and external socio-technical systems, facilitating information and technology exchange.
- **Value Chain Players**: Suppliers, service providers, and distributors contribute to the operation of socio-technical transitions. They may be core actors in different socio-technical systems and can disrupt or support transitions.
- **End-Users and Consumers**: Crucial for any transition, these actors influence the adoption of new products and behaviours. They develop routines, lifestyles, and understandings that shape the sector's culture (Geels, 2002, Smith et al., 2005, Geels, 2005). Building a culture that encourages customer participation in the transition can expedite the replacement of the regime by niches or accelerate the overall process.
- **Other Key Actors**: These actors, such as head-hunters, can significantly impact the sector by facilitating the flow of talent. Their role is essential for maintaining talent supply and enhancing the sector's attractiveness and vitality. However, they can also lead talent out of the regime during transitions.

Along with end-users and consumers, these actors shape behaviours, routines, and cultures within the socio-technical system. Their involvement is vital for transitions to new products and behaviours (Geels, 2002, Geels, 2005). The complex interplay of these elements and actors within socio-technical systems presents a dynamic landscape for researchers.

While the multifaceted nature of socio-technical systems and transitions may not allow for a comprehensive examination of all elements in a single research project, the foundational elements and actors identified here provide a robust basis for analysis. Researchers may further delineate specific elements relevant to their investigations as needed.

2.2.6 Transition pathways

Transition pathways refer to the trajectories of change within sociotechnical systems that evolve over time, ultimately giving rise to novel approaches for fulfilling specific societal functions (Turnheim et al., 2015). MLP argues that socio-technical transitions result from the interplay of processes at three distinct levels (Geels and Schot, 2007). Geels (2002) has delineated seven dimensions within socio-technical regimes, encompassing technology, user practices, application domains (markets), the symbolic meaning of technology, infrastructure, industry structure, policy, and techno-scientific knowledge. Geels (2002) suggests that while these dimensions may co-evolve and interconnect, they can also harbour internal tensions stemming from differing opinions.

Socio-technical regimes exhibit patterns of incremental changes with ongoing processes across various dimensions (Geels and Raven, 2006). Niche innovations initially draw influence from external actors through expectations and networks. A limited network of actors supports these innovations based on shared expectations and visions. Niche innovations gain momentum through learning processes spanning different dimensions (co-construction), price/performance enhancements, and backing from influential groups (Smith and Raven, 2012). As the landscape evolves, regimes face pressure from these changes, destabilising them. This environmental shift creates an opportunity window for niche innovations.

As niche innovations mature and become more competitive, a dominant design may emerge, leading to a breakthrough that transforms the socio-technical regime. Eventually, niche innovation can become a socio-technical regime that reshapes the landscape (Geels and Schot, 2007). Changes in the landscape can fundamentally alter the selection pressures, offering new and unforeseen directions for innovation (Smith et al., 2005). However, it’s important to note that the level of uncertainty in the transition process is significant. There is no guarantee that new technologies and behaviours will replace the old ones, and factors like technology, system elements, and compatibility with incumbent systems are crucial to the outcome of transitions (van Rijnsoever and Leendertse, 2020).

Suarez and Oliva (2005) distinguish four attributes of external changes: (1) frequency, which denotes the number of environmental disturbances per unit of time; (2) amplitude, measuring the magnitude of deviation from initial conditions caused by a disturbance, (3) speed, indicating the rate of change of disturbance, and (4) scope, reflecting the number of environmental dimensions affected by simultaneous disturbances. These attributes combine to form five categories of environmental change (Suarez and Oliva, 2005):

- **Regular Change**: Characterized by low intensity and gradual change.
- **Hyperturbulence**: Involves high-frequency, high-speed changes in one dimension.
- **Specific Shock**: Rapid changes with high intensity, infrequent occurrence, and relatively narrow scope. These shocks may either dissipate and return to baseline or result in structural, stepwise changes.
- **Disruptive Change**: Occurs infrequently, develops gradually, but has high-intensity effects in one dimension.
- **Avalanche Change**: Very infrequent, high-intensity changes that develop rapidly, simultaneously affecting multiple dimensions of the environment, leading to permanent environmental changes.

These transition pathways can be regarded as comprehensive and generally encompass most cases. However, it’s essential to acknowledge that specific scenarios may involve different environmental changes at various stages of the transition process, which should also be considered.

2.2.7 Lock-in mechanism

In addition to structural factors contributing to the lower diffusion rate of sustainable technologies, such as inadequate infrastructure for sustainable transitions (e.g., charging stations for electric vehicles), demand patterns among end customers, and the readiness of regulatory and institutional systems (Smith et al., 2005), the existing regime itself has been identified as a significant impediment to transition, primarily due to the lock-in mechanism. Geels (2004) argues that landscape changes do not directly impact regimes and innovation niches; instead, actors must perceive and translate the landscape's impact to exert influence. Subsequently, innovation niches and regimes influence action through sociological structuration, encompassing material exchanges, R&D investments, strategic alliances, power struggles, and competition (Smith et al., 2005, Geels and Schot, 2007).

In addition to employing prevailing regulatory, normative, and behavioural practices to resist the transition and maintain their position, regimes also utilise active defence and other resistance strategies (Turnheim et al., 2015). However, even under pressure from the changing landscape, regimes find it challenging to undergo radical transformation due to lock-in mechanisms. Existing systems and regimes establish the preconditions that shape the development of new transition pathways.

Klitkou et al. (2015) identify nine lock-in mechanisms based on sustainability transition cases in Nordic countries. These mechanisms include learning effects, economies of scale, scope, network externalities, informational increasing returns, technological interrelatedness, collective action, institutional learning effects, and power differentiation.

Geels (2019) further consolidates these mechanisms into three categories: (1) techno-economic lock-in mechanisms, encompassing substantial investment, low costs, and high-performance characteristics of existing technologies; (2) social and cognitive lock-in mechanisms, involving routines and shared mindsets that may hinder actors from recognising developments outside their established focus; and (3) institutional and political lock-in mechanisms, which comprise existing regulations, standards, and policy networks that favour incumbent technologies.

These lock-in mechanisms can lead to relatively rigid technological trajectories (Hekkert et al., 2007). Established technologies and their associated features, such as design, have undergone numerous evolutionary improvements to enhance cost-competitiveness and performance, alongside a better understanding of user needs. Furthermore, the socio-economic aspects of these technologies, including knowledge bases, capital investments, infrastructure, required skills, production capacities, social norms, lifestyles, and regulations, have been firmly established (Kemp, 1994).

2.2.8 Summary of MLP

The review highlights the strengths of the MLP framework in analysing socio-technical transitions but also points out its limitations in capturing the interactions between external and domestic socio-technical systems, especially within China's automotive electrification transition. Our research proposes an expanded MLP framework integrating spatial dimensions to offer a comprehensive view of these transitions.

While traditional studies emphasise the importance of cross-system actor interactions yet lack a systematic methodology for examining such complex interdependencies, our augmented framework addresses this gap by incorporating multi-scalar insights and introducing ‘global, internal, and external’ dimensions, enhancing the analysis of socio-technical transitions in dynamically evolving sectors like China’s NEV industry.

2.3 Strategic niche management

SNM provides a complementary perspective within the broader framework of the multi-level perspective, allowing scholars to explore and analyse niche dynamics and intricacies in-depth. The concept can be defined as the deliberate creation, development, and controlled phase-out of protected spaces intended for the advancement and experimentation of promising technologies, which aims to foster learning about the desirability and feasibility of new technologies while enhancing their further development and the rate of their application (Kemp et al., 1998). These niches within the socio-technical transition system are ‘socially constructed’, formed through the engagement of social networks and actors who believe in the potential of the niche and are willing to invest resources to nurture innovative developments (Schot and Geels, 2008).

This theoretical concept amalgamates two critical theories related to the transition of technological innovation: social constructivism and evolutionary economics (Verbong et al., 2008). While Social Construction of Technology (SCOT) primarily focuses on socio-cognitive dimensions and defines learning and network building as crucial processes in niche development, the concept of strategic niche management distinguishes three internal processes: articulation of expectations and vision, building of social networks and learning processes encompassing various dimensions such as technical aspects, design specifications, market and user preferences, cultural and symbolic meanings, infrastructure and maintenance networks, industry and production networks, regulations and government policies, and societal and environmental effects (Schot and Geels, 2008, Kemp et al., 1998, Brown and Michael, 2003, Verbong et al., 2008).

The theory of evolutionary economics underscores the need for protection due to competitive pressures in mainstream markets (Verbong et al., 2008, Smith and Raven, 2012). The strategic niche management method is also considered a bridge between R&D and market introduction, particularly for new technologies, as they are often developed through R&D efforts in their early stages (Verbong et al., 2008, Raven et al., 2010). Verbong et al. (2008) delineate the effects of experimental projects within the concept of strategic niche management, which includes uniting actors from both the variation environment (e.g., researchers, firms, developers) and the selection environment (e.g., users and policymakers), propelling the development of networks and learning processes, and adjusting expectations based on project outcomes. A fundamental assumption of strategic niche management is that niche innovations can thrive within technological niches that nurture innovation and experimentation with the co-evolution of technology, user practices, and regulatory structures (Schot and Geels, 2008).

In summary, this approach enriches our understanding of niche phenomena and their role in shaping socio-technical transitions. In the GIESTS framework, SNM serves as an essential building block to enhance the effectiveness of explanation and analysis of the development of the niche.

2.4 Capability-associated concepts

In the previous discussions, I have focused on sector-level literature. However, I recognise that the reactions and interactions of actors, especially automotive companies, with the changing environments are crucial for explaining the transition trajectory. Therefore, I will delve deeper into the concepts for firm-level analysis in this section, which will support the firm-level discussion in Chapter 7.

2.4.1 Dynamic capabilities

From the late 1980s onward, scholars began to take notice of the challenges confronting companies operating in rapidly changing environments, acknowledging the growing frequency of significant and disruptive environmental changes across various domains, including competition, technology, society, and regulation (Barreto, 2010). The imperative of devising effective strategies and cultivating temporary advantages to navigate these changes became a critical task for firms (Eisenhardt and Martin, 2000). For example, Thomas Iii (1996) explores how firms' behaviours differed in dynamic environments compared to static ones. Eisenhardt delved into the strategic decision-making required in high-velocity environments.

In response to these circumstances, Teece et al. (1997) introduce the concept of dynamic capabilities to address how firms could develop and sustain competitive advantages amid changing environments. Teece (2007) argue that a firm's success in dynamic environments hinged on its ability to identify opportunities, harness and develop resources, and devise effective strategies to create and maintain competitive advantages. This was a shift from focusing solely on optimising activities against known constraints and seeking scale economies.

Since the publication of these influential papers, dynamic capabilities have been applied across various business administration domains beyond strategic management, including human resources (Garavan et al., 2016, Arpentieva et al., 2020), business models (Teece, 2018a), big data (Rialti et al., 2019), marketing (Wilden and Gudergan, 2015), supply chain management (Siems et al., 2021), and operations management (Bititci et al., 2011). Furthermore, the concept has found relevance in diverse industries, such as the automotive sector (Teece, 2019, Rotjanakorn et al., 2020), the high-tech industry (Yu-Yuan Hung et al., 2007), the food industry (Siems et al., 2021, Gruchmann et al., 2021), and service industry (Janssen et al., 2016).

While the concept of dynamic capabilities initially evolved from the resource-based view (RBV), which explains how firms sustain competitive advantages based on the combinations of their resources (the stocks of factors controlled or owned by the firm) and capabilities (the capacity owned by the firm for achieving goals through deploying the resources) (Wernerfelt, 1984, Barney, 2001a, Barney, 2001b, Amit and Shoemaker, 1993), RBV primarily focuses on static environments and doesn't address how firms maintain competitive advantages in dynamic settings (Wang and Ahmed, 2007). The emergence of dynamic capabilities fills this research gap by explaining firms' abilities to integrate, build, and reconfigure their internal and external resources in response to changing environments (Teece et al., 1997, Priem and Butler, 2001). In addition to RBV, various other concepts have been referenced as sources of inspiration, including organisational routines, distinctive competence, architectural knowledge, core capability and rigidity, and combinative capability (Wang and Ahmed, 2007).

In Teece and his colleagues' papers (Teece et al., 1997, Wang and Ahmed, 2007), critical facets of dynamic capabilities are outlined, including:

- These capabilities are cultivated by the focal firms rather than acquired from external sources. The organisational processes of these firms shape their development and evolution and may be influenced by path dependency.
- Depending on the nature of the firm in terms of unique paths, processes, and asset positions, dynamic capabilities exhibit heterogeneity.
- Dynamic capabilities, encompassing the ability to integrate, reconfigure, and build internal and external competencies, can directly impact a firm's performance,

particularly in disruptive environments.

Teece further categorises dynamic capabilities into different capacities (Teece, 2007, Teece, 2012), including:

- Sensing and shaping opportunities and threats.
- Seizing the opportunities sensed and shaped.
- Maintaining competitive advantages through enhancing, protecting, combining, and reconfiguring tangible and intangible assets

These capacities enable dynamic capabilities to support firms in sustaining long-term business performance by creating, deploying, and safeguarding intangible assets (Teece, 2007). Additionally, dynamic capabilities are routines, processes, and capacities or abilities (Barreto, 2010).

Moreover, Winter (2003) introduces a hierarchical perspective on firm capabilities, distinguishing between 'zero-order' capabilities employed in stable processes to ensure short-term survival and dynamic capabilities, considered 'higher-order' capabilities that extend and modify but also create zero-order capabilities. Similarly, Zollo and Winter (2002) identify two types of routines: operational routines, employed in day-to-day activities, and dynamic capabilities, dedicated to processes such as experience accumulation, knowledge articulation, and knowledge codification, which drive the evolution of both dynamic and operational routines. Furthermore, scholars have presented varying viewpoints regarding the heterogeneity of dynamic capabilities; while Teece et al. (1997) that such capabilities are unique and firm-specific, Eisenhardt and Martin (2000) contend that there are best practices standard to multiple firms

2.4.2 Dynamic capabilities and the automotive industry

Dynamic capabilities are applicable in studies related to the automotive industry. For instance, Teece (2018b) analyses the impact of Tesla's emergence and how the new paradigm of A.C.E.S. (autonomous driving, connectivity, electrification, and shared mobility) influences the automotive sector. Furthermore, Knight and Collier (2009) conduct a case study in the automotive industry focusing on management accounting, uncovering the significance of organisational politics and external pressures in determining the success of companies. Rotjanakorn et al. (2020) delve into the automotive sector in Thailand by analysing mediator variables, including competitive advantages and innovation capabilities, to examine their influence on the relationship between dynamic capabilities and firm performance. Similarly, Al-Shami and Rashid (2022) explore the Malaysian automotive sector in the ASEAN market to establish connections between dynamic capabilities, sustainable innovation, and eco-innovation.

The supply chain management in the automotive industry, viewed through the lens of dynamic capabilities, has also been discussed. For example, Siems et al. (2021) have conducted a comparative case study comparing the supply chains of the automotive and agriculture industries. Additionally, Pandit et al. (2018) employ a case study of electric cars in India to address the topic of disruptive innovations in emerging economies. Murmann and Vogt (2023) present a capabilities framework capable of comparing different types of firms, including start-ups, traditional automakers, and technology companies.

Most of these papers have sought to link the latest trends in the automotive sector with dynamic capabilities, focusing on developing countries in South and Southeast Asia. As a developing country with a larger market and more disruptive changes over the past decade, China has garnered substantial attention from scholars, particularly in the late 2010s. China's leading position in the domain of A.C.E.S. has prompted research into the reactions of multinational companies, previously leaders in the sector. Scholars have evaluated whether these trends could offer a window of opportunity for local automakers to compete internationally (Teece, 2019). Additionally, Huang (2023) proposes a case study to investigate the impact of ordinary and dynamic capabilities on electrification in China.

The review above shows that dynamic capabilities can effectively evaluate automotive OEMs' capacity to seize opportunities in evolving environments. This concept will be applied as a theoretical foundation for analysing the reactions of different kinds of automakers in Chapter 5 and Chapter 6.

2.4.3 Resource-based view

RBV presents a comprehensive framework for evaluating the contribution of tangible and intangible resources to a firm's competitive advantage (Zahra, 2021). Embedded within the concepts of path dependence and firm heterogeneity (Lockett et al., 2009, Lockett and Thompson, 2001), RBV emphasises a wide array of valuable resources firms utilise for competitive enhancement and operational efficiency through strategic formulation and execution (Barney, 1991, Barney, 2001a). A core principle of RBV is the durability of competitive advantages, predicated on the inability to easily substitute the underlying resources with strategically equivalent alternatives (Barney, 1991, Lockett and Thompson, 2001). These resources must adhere to the VRIN framework—valuable (V), rare (R), inimitable (I), and non-substitutable (N) (Barney, 1991, Barney and Wright, 1998).

In stable markets, these resources allow firms to navigate through predictable changes, reinforcing their competitive stance effectively. Such capabilities are often explicit, systematically structured, and built upon existing knowledge, highlighting their importance for sustained competitive advantage and strategic clarity (Helfat et al., 2007, Eisenhardt and Martin, 2000, van Mossel et al., 2018). RBV clarifies that the strategic decision-making processes engender these advantages (Zahra, 2021).

2.4.4 Comparing dynamic capabilities and resource-based view

While DC and RBV are adopted for the understanding of competitive advantage (Wernerfelt, 1984, Barney, 2001a, Amit and Shoemaker, 1993), DC distinguishes itself from RBV by clearly separating resources from capabilities and emphasising resource reconfiguration through dynamic capabilities (Cardeal and Antonio 2012; Cavusgil, Seggie, and Talay 2007). This focus is essential in dynamic markets where resource values can rapidly decline, highlighting the importance of adaptability and resource reconfiguration (Cavusgil et al., 2007).

While RBV targets static environments and stresses the long-term sustainable advantage derived from the unique resources a firm possesses, offering a clear lens for analysing variations in firm performance (Lockett et al., 2009), DC addresses how firms adjust their resources in response to evolving environments (Teece et al., 1997, Priem and Butler, 2001). Ambrosini and Bowman (2009) note that DC provides deeper insights into the evolutionary process of firms' resources and capabilities, aiding in understanding how competitive advantages are developed and maintained. Thus, DC is especially suited for dissecting strategic management and competitive dynamics within fast-evolving industries.

Table 2-1 compares the RBV and DC frameworks based on the literature discussed, highlighting their approaches to explaining competitive advantage.

Table 2-1 Comparison between RBV and DC

Aspect	RBV	DC
Focus	Concentrates on the long-term sustainability of competitive	Emphasises agility, adaptability, and the continuous renewal of the

	advantage, deriving from the uniqueness of resources meeting VRIN criteria.	resource base to adapt to environmental shifts.
Context Suitability	Relative, stable, and predictable environment.	Relative dynamic and fast-changing environment.
Resource/ Capability Distinction	It makes a less clear distinction between resources and capabilities, focusing on how resource bundles impact firm performance. Some capabilities are categorised as intangible resources.	Differentiates between resources and capabilities, underscoring the importance of dynamic capabilities in reconfiguring resources.
Use Cases	Effective in analysing inter-firm performance variations based on resource ownership and utilisation.	It is used to assess firms' responses to environmental changes, emphasising the processes of sensing, sensemaking, and resource reconfiguration.

Although DC and RBV differ, they are not mutually exclusive but complementary, offering a more holistic view of the factors influencing firm performance.

2.4.5 Implication of the research project

The application of DC in automotive industry research, particularly in the post-mid-2010s, has been significant in understanding firms' adaptability to rapid environmental changes. Notable works include Teece (2018b), who analyse Tesla's rise and the impact of ACES (autonomous driving, connectivity, electrification, and shared mobility) on the sector; Knight and Collier (2009) explore the role of management accounting and Organisational politics in automotive companies. Studies by Rotjanakorn et al. (2020) in Thailand and Al-Shami and Rashid (2022) in Malaysia examined the interplay between dynamic capabilities and factors like innovation and eco-innovation in the automotive industry. These studies underscore DC's critical role in equipping automakers to navigate the challenges of the last decade.

These concepts are practical for analysing firm-level cases and are suitable for our focal case. Even though DC could be too narrow to tell the whole story, I believe RBV's complementarity could better explain automakers' various performances and behaviours.

For instance, startups like Nio may initially thrive due to adaptability but eventually falter against more established competitors like BYD. This indicates a gap in the literature of DC without the complementarity of RBV on the elements essential for long-term success in volatile markets.

The research introduces the Resources-Capabilities Analytics Framework (RCA Framework), incorporating the two concepts in Chapter 7. This framework aims to provide a more nuanced understanding of firm success by incorporating both dynamic capabilities and the strategic management of resources. Designed to be flexible, comprehensive, and user-friendly, the proposed framework facilitates a deeper analysis of how firms leverage their unique resources and capabilities across different levels. Its versatile structure promises broader applicability beyond the automotive industry, offering valuable insights for researchers and practitioners across various sectors seeking to navigate the complexities of dynamic and competitive landscapes.

2.5 Actor definition in transition

As the research questions highlight, the project aims to identify how the critical actors shape the transition trajectory; thus, it is crucial to categorise actors. In transition studies, scholars have offered various references that can aid the research project in identifying and defining these actors. This section provides an overview of these relevant scholarly works, which will subsequently inform the definition of actors in the later stages of the thesis.

In the context of innovation diffusion studies, Rogers et al. (2014) categorise adopters of innovation into five distinct types based on their level of innovativeness. These categories include:

- **Innovators**: The first to adopt, willing to take risks, and vital for introducing new ideas.
- **Early Adopters**: Influential and respected, they help an innovation gain visibility and acceptance.
- **Early Majority**: Deliberate in adoption; this group helps an innovation reach a tipping point in acceptance.
- **Late Majority**: Sceptical adopters who follow after the majority, influenced by social norms and pressures.
- **Laggards**: The last to adopt, typically driven by necessity or increasing societal pressures, and often focused on traditions.
- In addition to adopters, actors assume distinct roles throughout the diffusion process. Caiazza and Volpe (2017) have compiled and synthesised relevant studies defining different roles for actors. These roles include:
- **Opinion Leaders**: These are actors who are sought after for advice in complex situations. They are perceived as experts and credible sources, often influencing the opinions and decisions of others in the system.
- **Facilitators**: Facilitators work closely with adopters to implement change. They play a supportive role, helping adopters navigate the complexities of adopting new technologies or practices.
- **Champions**: These transformational actors can influence others to support specific projects or innovations. They are often pivotal in driving change and garnering support for new initiatives.
- **Linking and Change Agents**: These actors act as mediators between innovators and adopters, facilitating the diffusion process. They play a crucial role in bridging gaps and ensuring the smooth transition of innovations from development to widespread adoption.

In addition, Freeman (2010) delineates two conceptual systems to characterise actors in the context of internal and external change. The conceptual system for internal change encompasses owners, customers, employees, and suppliers. Internal change transpires within the existing conceptual framework of the world, adhering to well-established rules and regulations. It is the type of change that individuals and organisations are accustomed to dealing with in their daily operations.

Conversely, external change has the potential to impact virtually every facet of the conceptual system governing internal change. This includes emerging new groups, events, and issues that introduce uncertainty and defy easy comprehension within the confines of an existing model or theory. Freeman identifies key actors crucial for external change, including governments, competitors, consumer advocates, environmentalists, special interest groups, and the media. These external actors can significantly influence the dynamics of change and adaptation within socio-technical systems.

In the context of this research, which examines the transition in the NEV sector, these theoretical perspectives are adapted to focus on consumers as adopters and different types of automakers. The actors' roles in the diffusion process are expanded beyond traditional consumer-focused models to include various stakeholders within the automotive industry. In addition, Freeman’s conceptual systems offer insights into how internal changes within organisations (automakers) and external forces (such as government policies and market competition) shape the transition dynamics (Freeman, 2010).

To summarise, the concept of different adopters from technical diffusion theory helps define the roles of various automakers in the transition. Freeman’s framework on external change is particularly relevant for identifying influential actors beyond automakers, emphasising the critical role of government and other external stakeholders. The synthesis of these frameworks provides a multi-dimensional view of actor roles and interactions, which is essential for understanding the complexities of the transition process in this research project. In Chapter 7, I will adopt this concept as the foundation for the categorisation of automakers.

2.6 Summary of literature review

In this chapter, I have conducted an in-depth review of various theoretical frameworks and concepts underpinning the study of socio-technical transitions, focusing on their relevance to the development of the GIESTS Framework and the broader research project.

- **Multi-Level Perspective (MLP):** As the foundational concept for the GIESTS Framework, MLP has been extensively reviewed. This includes exploring its three core layers (niche, regime, and landscape), the additional spatial dimension, the concept of lock-in mechanisms, and various transition paths identified in previous studies. This comprehensive review of MLP lays the groundwork for understanding the complex dynamics of socio-technical transitions and serves as a basis for the GIESTS Framework.
- **Strategic Niche Management (SNM):** SNM, a supplemental concept for the GIESTS Framework, has been examined for its insights into niche dynamics and the creation of protective spaces. SNM's focus on nurturing innovations within niches provides crucial insights into the early stages of socio-technical transitions, which is instrumental in understanding the initial development and scaling up of new technologies like NEVs.
- **Resource-based View (RBV) and Dynamic Capabilities (DC)**: Even though the theory lies outside the primary scope of the GIESTS Framework, it has been used to understand the strategic behaviours of different automakers and elucidate the drivers

behind their participation in the transition process in the case study part of the research project.

- **Defining Actors in Transition:** The sector reviews different types of adopters in the technological diffusion theory and the stakeholder approach's conceptual system of internal and external change, integrating these insights to inform the analysis and definition of critical actors in the NEV sector's socio-technical transition.

Building on existing scholarly work, my research has led to the formulation of several vital arguments. The interactions between different layers of a socio-technical system are instrumental in determining the course of a socio-technical transition. Moreover, the cross-scale interplay of actors or sectors is recognised as potentially significant in influencing the success of such transitions.

A thorough literature review has provided the theoretical underpinnings for these arguments and the case study's conceptual framework. Still, it has also spotlighted several research gaps within socio-technical transitions. These gaps demonstrate the limitations of previous research and pave the way for further inquiry and advancement in the study of socio-technical transitions. Addressing these gaps is pivotal for enhancing our collective understanding of the dynamics of transitions and refining the GIESTS Framework application. The specific gaps identified are:

- **Lack of Discussion of Interactions between Countries:** Even though multi-scalar MLP highlights the importance of interactions on different spatial scales (Coenen et al., 2012), there is a scarcity of research on the interaction between socio-technical systems and analogous sectors in international markets. This is particularly relevant for developing nations that cannot initiate transitions without following established global precedents. Therefore, there is a pressing need for in-depth research into how international influences affect socio-technical transitions

- **Lack of Discussion of Interactions between Sectors:** Socio-technical systems do not operate in isolation; they are interconnected with other associated sectors. Despite the evident interdependence, identifying these sectors and their embedded actors has received limited attention in the existing literature. Understanding these interconnections is essential to comprehend the complex influences on the focal socio-technical system.
- **Lack of Comprehensive Analysis of China's NEV Transition:** Empirical studies addressing China's NEV sector are notably insufficient, especially when contrasted with the extensive body of research on European sustainable transitions. Studies often lack a multi-dimensional approach, focusing on narrow aspects of the transition rather than offering a holistic view. It is vital to fill this gap to present an all-encompassing perspective on the transition's complex dynamics.

This research project aims to significantly contribute to sustainable transitions by addressing these gaps, particularly in China's NEV sector. The goal is to provide a holistic, nuanced understanding of the socio-technical transition processes, enriching the existing knowledge body and offering valuable insights for academics, industry stakeholders, and policymakers.

Chapter 3. Research Design

3.1 Research orientation

The research orientation serves as the foundational philosophical underpinning of this research project, encompassing both ontology and epistemology. Recognising that the chosen research orientation significantly shapes various aspects of the research endeavour, influencing methodologies, data collection methods, and overall project design decisions is crucial. Therefore, it is essential to establish and clarify this orientation before delving into the research project's design.

3.1.1 Ontological perspective

In the scope of this research project, the ontological position primarily aligns with relativism. Relativism posits that phenomena inherently hinge upon context and are influenced by the perspectives of those under observation (Easterby-Smith et al., 2021). This stance resonates profoundly with the diverse nature of socio-technical transitions, a domain marked by the assorted viewpoints and experiences of myriad stakeholders.

Furthermore, relativism contends that personal backgrounds, encompassing facets like culture, racial identity, or gender, can skew perceptions (Baghramian, 2004). This tenet dovetails with this research project's assertion that interviewees from varied corporate backgrounds might offer divergent insights into the socio-technical transition under study. I believe that leaning heavily on a singular perspective might distort the accurate picture. In contrast, aggregating observations from diverse vantage points augments the accuracy and validity of the findings. Given the intricate nature of the research queries, which aim to distil the unique facets of these transitions and refine theoretical frameworks based on subjective viewpoints, relativism stands out as the optimal ontological choice.

It's worth noting that the research does not chase an absolute truth; the questions are intrinsically tied to the perceptions of individuals entangled in socio-technical transition endeavours. This realisation distances my ontological stance from realism. Additionally, nominalism, viewed as an antithesis to realism, argues against a concrete truth, positing that our perceived reality is a human construct (Garrett and Cutting, 2015). While the fluidity of nominalism resonates with certain aspects of my research, it doesn't wholly align. Focusing solely on individually constructed meanings is inadequate for a topic as expansive as mine, encompassing participants in socio-technical transition processes and broader societal frameworks like macroeconomics, international politics, and climate change.

3.1.2 Epistemological perspective

The epistemological stance adopted in this research project leans towards a constructionist perspective. Constructionism contends that knowledge is not merely discovered but is constructed actively through interactions and interpretations within the social milieu. Given the research's focus on socio-technical transitions in China, understanding the intricate nuances demands more than just detached observation. It calls for an active immersion and engagement with the various actors steering these transitions. This inclination is congruent with the qualitative methods earmarked for this study, including interviews and case studies. Such methods are adept at probing stakeholders' subjective experiences and narratives pivotal to these transitions.

While I align with the principles of constructionism, it's pertinent to note that I might not adhere to an extreme or 'strong' constructionist paradigm. A triangulated approach appears more resonant with my research orientation, where different methods should be adopted (Datta, 1997). I advocate for adopting diverse methodologies tailored to the research context rather than an unwavering commitment to purely qualitative techniques. A judicious blend of quantitative and qualitative methods can bolster the precision of findings. Depending on the nature of the investigation, tools such as case studies, participant observation, and interviews might all be deemed appropriate. Sometimes, outcomes from varied methods might be juxtaposed for validation or deployed sequentially, like using expert interview findings to validate case study results. The primary aim of this research is to forge a theoretical model that holds potential for future explorations. While qualitative narrative forms the crux, quantitative data will augment the research, providing empirical support to the theoretical edifice.

Embracing a constructionist approach grants me the latitude to draw from a rich tapestry of data sources, enhancing the research's efficacy instead of a rigid constructionist stance. Given my professional footing in the industry, with diverse company engagements across various nations, I am strategically positioned to liaise with industry experts and access pivotal data, further enriching the study's depth and breadth.

3.1.3 Axiological assumption

As a practitioner within the industry under scrutiny, engaged scholarship offers the most apt methodology for my research interests. Given the intricate dynamics of the automotive sector and the socio-technical systems in China, a more immersive and engaged approach to study promises deeper insights than a mere external observational stance. The tangible implications of the conceptual framework I developed facilitate comprehension and furnish avenues for model refinement.

The pragmatic perspective, which contends that knowledge emanates directly from lived experiences and eschews the imposition of pre-fixed theories or frameworks, aligns well with my axiological positioning of engaged constructionism (Easterby-Smith et al., 2021). Pragmatism's inherent flexibility in selecting methodologies based on the particularities of the situation further validates its applicability to my research paradigm (Wilson, 2014).

Additionally, structuration theory provides a foundational scaffold for my axiological assumptions. This theory propounds the interdependence between societal structures and the actions of individuals within these structures, suggesting an ongoing dialectic between societal constructs and human actions (Giddens, 1987). Taking the electric vehicle sector as an example, key stakeholders have the agency to influence the trajectory of the social structure. Manufacturers, for instance, can liaise with governmental entities to adopt policies, which in turn could modulate consumer purchase intentions. Similarly, consumer perceptions regarding electric vehicles can influence entities like manufacturers, suppliers, and the government, culminating in an eventual shift in the overarching social framework.

3.1.4 Methodological approach

The chosen research orientation supports a qualitative approach, focusing on in-depth methods such as interviews and case studies to comprehensively understand socio-technical transitions (Datta, 1997). By drawing on multiple data sources, this approach ensures a thorough exploration of the research questions. It offers flexibility and adaptability, making it particularly well-suited to the intricate and multifaceted nature of the study. This qualitative orientation aligns seamlessly with the engaged constructionism perspective, where active involvement and interaction with participants are essential for constructing meaningful and comprehensive knowledge.

In summary, the research orientation for this project harmoniously combines relativism, constructionism, and engaged research. This philosophical foundation provides a robust framework for conducting the research project. It enables the exploration of the intricate socio-technical transitions occurring in China from multiple perspectives. It facilitates the construction of a conceptual framework that accurately reflects the complexity of this phenomenon. This orientation will significantly influence the subsequent phases of the research project, from data collection to analysis and interpretation.

3.2 Overview of the research project

This research project adheres to a standard research process, beginning with developing research questions grounded in research philosophy, followed by a comprehensive literature review. This initial phase is crucial for gaining insights into existing theoretical models and frameworks related to sustainable transitions. It builds a theoretical foundation, identifies the most suitable theories for developing a conceptual framework to analyse the target case, and highlights any existing research gaps.

Building upon the findings from the literature review, the project then progresses to developing a novel conceptual framework. This framework is designed specifically to address the identified research gaps. Concurrently, efforts are initiated to collect data for the case study, utilising the proposed conceptual framework. The data collection primarily comprises secondary data, participant observation, and expert interviews. Both secondary data and participant observation will be directly mapped with the developed conceptual framework for conducting the case study, supplemented by additional information from expert interviews.

Upon completing the case study, the research findings and insights are extensively discussed and elaborated. The interviewees' perspectives are also utilised to verify and offer supplementary information for the case study results and are integrated into the research findings. This discussion phase includes an examination of the research limitations and concludes with recommendations for future research directions.

The research project process is summarised in Figure 3-1 below and will be further detailed in the subsequent sections. This structured approach ensures a comprehensive and systematic exploration of the research topic, contributing to the field of sustainable transitions, particularly in the context of the NEV sector.

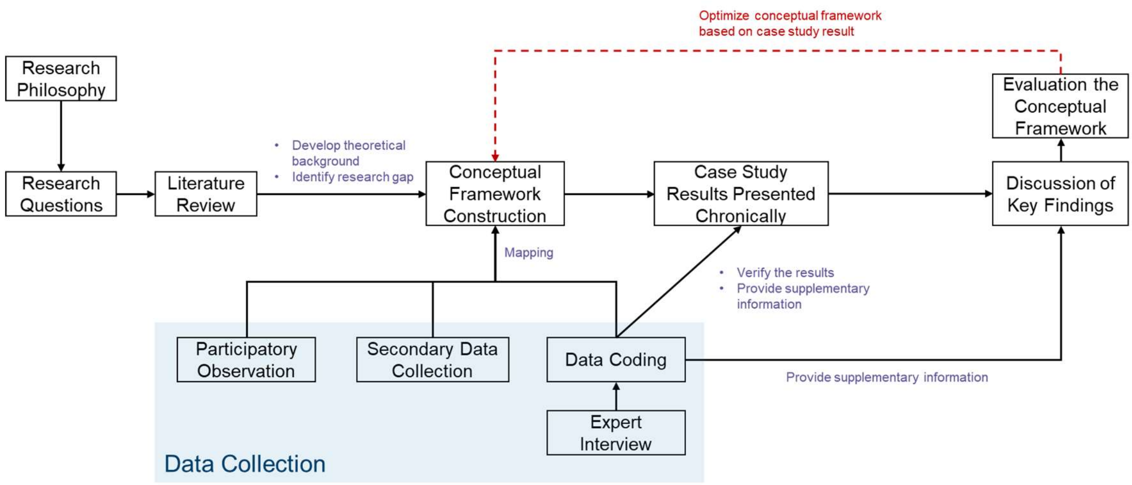

Figure 3-1 Process of the research project

3.3 Literature review

The foundation of this research project is rooted in a comprehensive and systematic literature review. Webster and Watson (2002) emphasise the critical role of literature review in evaluating the current state of knowledge, identifying factors influencing the research topic, and proposing conceptual models that synthesise and extend existing research. Cooper (1988) highlights several vital purposes of literature review, including critical analysis, integration of diverse perspectives, and identifying issues and challenges within the research domain.

In line with these principles, this research project employs an integrated literature review method (Torraco, 2016). This method aims to develop innovative frameworks and perspectives by reviewing, critiquing, and synthesising representative literature within the selected research topics. Such a method is particularly pertinent given the maturity of these topics, which originated in the late 1990s and early 2000s. The overarching objective is to synthesise the findings of existing literature into a cohesive model or conceptual framework that offers fresh insights into the research topic. Simultaneously, this approach identifies gaps and omissions in the existing body of knowledge (Torraco, 2005).

In conclusion, the literature review segment serves a dual purpose in this research. Firstly, it is a cornerstone, laying the theoretical groundwork for formulating the study's conceptual frameworks. Secondly, it is a diagnostic tool highlighting the extant research gaps within the designated domain.

3.4 Conceptual framework building

The conceptual framework that forms the cornerstone of this research project is constructed based on a set of well-defined criteria established by renowned researchers in the field. These criteria serve as guiding principles to ensure that the framework is robust, innovative, comprehensive, and relevant:

- **Multiplicity of Paradigms**: The framework draws from multiple paradigms, making it interesting, creative, comprehensive, and relevant (Lewis and Grimes, 1999, Davis, 1971). By incorporating diverse perspectives, the framework enriches its capacity to address the complex socio-technical transition under investigation.

- **Parsimony, Falsifiability, and Utility**: The framework adheres to the principles of parsimony, falsifiability, and utility (Sutton and Staw, 1995). It strives to be concise while remaining empirically testable and practically useful, ensuring it can withstand rigorous scrutiny and contribute to real-world applications.
- **Explanatory, Predictive, and Delightful**: In line with the criteria identified by Weick (1995), the framework aspires to be explanatory, predictive, and delightful. It should not only elucidate the dynamics of the socio-technical transition but also possess the capability to forecast future developments and engage and captivate its users.
- **Iterative Development**: The framework's construction is an iterative process with multiple revisions (Webster and Watson, 2002). This iterative approach allows for continuous refinement and enhancement, aligning the framework with the evolving needs of the research project.

The research gap and previous findings identified during the literature review phase in developing the conceptual framework provide essential foundations. The concept of MLP proposed by Geels (2002) serves as the fundamental building block of the analytical framework, albeit with necessary modifications to ensure suitability for the specific research context. Additional relevant concepts, including but not limited to strategic niche management (Kemp et al., 1998) and the spatial dimension of MLP (Raven et al., 2012), are also considered in the framework's development, even if not explicitly represented. As a result, the framework proposed is called the Global, Internal, External Socio-technical System framework (the GIEST Framework).

It's crucial to emphasise that the resulting analytical framework should be viewed as an updated or extended version of the multi-level perspective rather than an all-encompassing 'integrated model' of the abovementioned concepts. Instead, select elements of these concepts are integrated to enhance the analytical framework based on the multi-level perspective approach. Insights from scholars who have attempted to integrate or compare these concepts are invaluable inputs for refining and enriching the analytical model.

3.5 Case study

3.5.1 Overview

The chosen research methodology for this project aligns with the research questions and objectives; Yin asserts that case study methodology is particularly suitable for addressing ‘how’ and ‘why’ questions. Given the nature of the research questions posed in this study, which delve into the intricate socio-technical transitions within China’s NEV sector, the case study method is deemed highly appropriate. Additionally, the archival analysis method complements the case study approach, offering valuable insights into answering ‘what’ questions (Yin, 2009b). Together, these methods provide a comprehensive means of inquiry into the multifaceted dimensions of the research.

Schramm (1971) underscores the capabilities of the case study method in illustrating the decision-making processes, encompassing the ‘why’ behind decisions, how they are implemented, and their resultant outcomes. This aligns seamlessly with the research objectives, allowing an in-depth exploration of the dynamics shaping the NEV sector’s transition in China.

While there may be some overlaps between case studies and historical methods, the former offers distinct advantages in handling diverse data sources, including documentation, reports, interviews, artefacts, and observations (Yin, 2009b). Yin (1994) defines case study research as an empirical inquiry investigating a contemporary phenomenon within its real-life context. It holds particular significance for this research project, especially when the boundaries between the phenomenon and context are unclear. This is due to its focus on analysing the interactions within and between socio-technical systems.

Several key characteristics of the case study method are pertinent to this research:

- **Triangulated Strategy**: The research employs a triangulated strategy, drawing from multiple sources to confirm the validity of the research processes. This approach aligns with the perspectives of Yin (1989) and Tellis (1997) on triangulation. Specifically, two of the four types of triangulation identified by Denzin (1984) are applied: theory triangulation, which aids in interpreting the results, and data source triangulation, which verifies data across different contexts.
- **Multi-Perspectival Analyses**: The case study method does not merely consider the perspectives of individual actors but also incorporates relevant groups and examines their interactions (Tellis, 1997). This multi-perspectival approach is vital for comprehensively understanding the socio-technical transitions within the NEV sector.
- **Triangulation and Resource Utilisation**: The case study's reliance on multiple resources, nature of triangulation, and comprehensive coverage of research objects are particularly advantageous Yin (2009b). Given the varied variables within socio-technical systems, the complexity of data sources (e.g., consulting reports, company announcements, websites, government documentation), and using theoretical propositions from prior research, the case study method effectively manages these challenges.

The chosen research methodology, primarily a case study, aligns with the research objectives and questions. It offers a robust framework for investigating the socio-technical transitions within China's NEV sector, allowing for a thorough exploration of the dynamics, interactions, and complexities inherent in this context. With its triangulated strategy and multi-perspectival analyses, this methodological approach promises to deliver rich, insightful findings that address the research objectives effectively.

3.5.2 Case selection

The case selection process led us to choose China's NEV sector. This decision aligns with the defined criteria and serves as an ideal candidate for the following reasons:

- **Maximising Learning Potential**: The NEV sector in China is marked by rapid growth and transformative changes, making it an ideal choice to maximise learning potential (Tellis, 1997). The industry's dynamism allows for collecting pertinent data relatively quickly. Moreover, the author's extensive professional network in the automotive sector and practical experience provide unique access to senior industry experts—an invaluable resource for gaining insights into the sector's intricacies. Moreover, we could better understand how the automakers perform differently by picking up three representative and identical automakers for comparative analysis.
- **Focus on Key Issues** (Tellis, 1997, Yin, 2009b): The NEV sector, characterised by its multifaceted nature and numerous stakeholders, presents a rich landscape for exploration. By honing in on this dynamic sector, the research project can delve into the critical issues influencing the socio-technical transition within China's automotive industry. This approach ensures that the case study addresses critical research questions and uncovers vital insights.
- **Accessibility of Data** (Yin, 2009b): The author's position as a senior professional in the automotive industry across the Greater China region facilitates access to a wealth of data sources, industry experts, and opportunities for field observations. This accessibility ensures that the research project has a robust data foundation to draw while respecting confidentiality considerations.

In light of the criteria outlined above, the choice of the automotive sector as the unit of analysis for our research becomes evident. This sector represents a complex ecosystem with numerous stakeholders and intricate interdependencies. In China's unique context, the automotive industry’s trajectory is influenced by its internal dynamics, significant external forces, and global trends. While existing research has explored the success of China’s NEV sector, much of this work often adopts a narrow focus, overlooking the broader, interconnected landscape in which this sector operates.

Our research project is driven by the ambition to contribute a more comprehensive perspective to the discourse surrounding the NEV sector’s success in China. We advocate adopting the GIESTS Framework proposed in the above subsection to achieve this objective. This meticulously designed framework is a powerful analytical tool, facilitating an in-depth understanding of the multifaceted NEV sector.

3.6 Data collection

3.6.1 Data source

In the context of this research project, Yin’s framework (Yin, 1989, Yin, 1994, Yin, 2009b) provides a comprehensive approach to gathering evidence for the research. This study will draw upon various sources of evidence to investigate and analyse the dynamics of the automotive industry’s transition towards electrification and the implications for product strategies. The primary sources of evidence include:

- **Documentation**: The research will extensively utilise documentation sources, including company announcements related to electrification plans and new model launches, case study papers that provide in-depth analyses of relevant cases, online media posts, official accounts in prominent online forums (e.g., Zhuihu and WeChat), and reports from consulting firms and investment companies. These documents offer diverse insights and viewpoints from industry experts and external observers.

- **Archival Records**: Archival records will be crucial in analysing the automotive market, economic conditions, and carbon emissions. Data for this research will be sourced from government websites (e.g., China Passenger Car Association, CPCA), autohome.com (China's largest automotive media platform), and Statista.com, which aggregates data from various markets and industries.
- **Participant Observation**: Participant observation will be a significant component of this research project. The author, with over eight years of experience in the automotive industry in roles such as strategy planning, program management, product management, and product planning, will immerse themselves in the industry during the study period between September 2021 and May 2023. This firsthand involvement provides unique access to industry insights, networks, and individuals who may be challenging to contact from an external perspective. Participation in WeChat and LinkedIn groups and forums discussing cutting-edge topics will facilitate networking and information gathering. Regular interactions with colleagues and senior management will offer additional insights into industry perspectives. However, it is essential to acknowledge potential biases associated with participant observation, such as alignment with industry interests. While the participant-observation approach offers rich insights into the industry, it is essential to acknowledge potential limitations, including biases and confidentiality constraints due to non-disclosure agreements with companies.
- **Expert Interviews**: In-depth interviews will be conducted with mid-senior level decision-makers and strategy developers in the target industry, specifically those in strategy planning, product planning, market analysis, sales strategy, etc. A diverse selection of participants will be chosen from different types of automakers, including traditional foreign automotive OEMs, joint ventures, local automotive OEMs, and start-ups such as XPeng, Nio, and Tesla. While this approach provides valuable industry insights, it is essential to note that this research may not encompass

perspectives from government experts.

- **Physical Artifacts**: Physical artefacts, including visits to showrooms and auto shows, will complement the study. Observing actual products, understanding customer requirements through product feature analysis, and verifying industry analysis conducted by consulting firms and investment banks will be essential. Test drives will enable the identification of differences between 'niche products' and 'regime products', contributing to the analysis of socio-technical transitions about product readiness.

In summary, this research project will employ a multi-faceted approach to gather evidence, ensuring a comprehensive understanding of the electrification transition within the automotive industry and its impact on product strategies.

3.6.2 Expert interview design

In the research project, experts are defined as individuals who possess access to information about decision-making processes and bear responsibility for activities spanning the development, implementation, and control of specific solutions, strategies, or policies within the automotive industry (Meuser and Nagel, 2009). The primary objectives of conducting expert interviews are as follows:

- **To Gain Industry Insights**: The first objective is to gather insights from experts within the automotive industry, particularly those who have actively participated in the socio-technical transition from internal combustion engine vehicles to electric vehicles. This is significant because many studies on China's electric vehicle industry rely on secondary data sources, often lacking the perspectives of individuals intimately involved in the transition.
- **To Refine the Results of the Case Study**: While the case study is primarily based on

secondary data, there are certain limitations associated with secondary data, such as concerns about reliability, a lack of in-depth insight, reliance on inferred information rather than direct knowledge, and a focus on outcomes rather than the process itself.

- **To Obtain Feedback on the Conceptual Framework**: The third objective is to seek feedback and opinions from these experts regarding the conceptual model developed as part of this research. This feedback will contribute to refining the model and ensuring its alignment with the industry’s intricacies.

Expert interviews will primarily target professionals in product planning, strategy development, and related functions. These roles necessitate an in-depth understanding of market trends, strategic product portfolio development, forecasting, and engagement with government bodies and investors. Additionally, professionals in these roles are pivotal in advising senior management and contributing to long-term planning within the industry.

The expert interviews will encompass three dimensions of knowledge identified by Van Audenhove (2007): technical knowledge specific to the field, process knowledge encompassing routines and interactions, and explanatory knowledge dealing with subjective opinions, rules, relevance, and beliefs. Process knowledge will be fundamental given this research project's focus on socio-technical transitions. These interviews will adopt a systematising approach, emphasising knowledge exclusive to the experts and generally inaccessible to outsiders, fostering the comparison and integration of expert opinions.

Furthermore, since most interviewers possess over a decade of experience in the automotive industry, they will assume the role of a co-expert during the interviews. This approach anticipates deeper and more nuanced discussions, potentially skipping elementary questions and delving into more profound insights. High levels of interaction will facilitate follow-up questions for clarification.

The anticipated duration of each interview is approximately one to one and a half hours, with potential variations. Some interviewees, particularly those in director or executive positions, may have constrained schedules, making it challenging to allocate the entire duration. Conversely, interviews may extend beyond the anticipated timeframe if certain interviewees possess extensive knowledge of the subject. Nevertheless, the goal is to maintain interviews within one to two hours.

While some scholars recommend equalising the length and process of the interview (Saunders et al., 2007, Van Audenhove, 2007, Meuser and Nagel, 2009), minor variations are deemed acceptable. They may aid in more effectively gathering information.

One week before the interview, the question list will be delivered to the interviewees to allow them to prepare and clarify any confusion ahead of the interview, ensuring a more productive use of interview time. More than half of the interviewees have prepared for the interview with deeper insights.

To commence the interviews, a brief orientation regarding the research project will be provided, which is expected to take approximately ten minutes. The interviewer will have approximately sixty minutes to pose questions following this introduction. However, as previously noted, the interview duration may vary due to the nature of responses. Twenty minutes of buffer time will be allocated to accommodate these variations. Interviews will be recorded for subsequent analysis, but considering potential industry-specific confidentiality concerns, the interviewer will be prepared to take detailed notes for comprehensive data analysis.

The findings from these interviews will be integrated into my thesis. They will complement the secondary data and the GIESTS Framework analysis, enriching the research project's contributions and validating the case study results. Additionally, I will discuss the results with the interviewees to align their perspectives with the study's findings, ensuring the accuracy and relevance of the results. The process has been summarised in the flow chart presented in Figure 3-2.

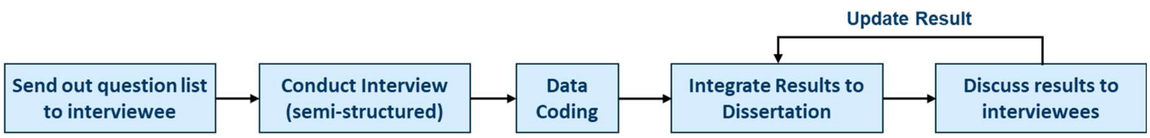

Figure 3-2 Process of expert interviews

3.6.3 Selection of interviewees

The selection of interviewees is a critical aspect of this research, ensuring diverse perspectives and in-depth insights. The research project intends to engage fifteen experts for interviews. The selection criteria hold particular importance given this relatively modest number of interviews. The five primary criteria for interviewee selection are as follows:

- **Technical or Process Knowledge**: Interviewees must fully grasp the socio-technical transition from internal combustion engine vehicles to electric vehicles, focusing on product or strategic planning roles. These roles involve analysing market trends and shaping company product portfolios accordingly. Insights from product development, finance, supply chain management, and sales professionals are also valuable, albeit to a lesser extent.
- **Diverse Backgrounds**: The selection will include experts from various companies, including state-owned enterprises, start-ups, foreign companies, joint ventures, and local private firms. Diverse backgrounds enable a comprehensive exploration of different trajectories during the socio-technical transition and interactions among actors within and outside the incumbent regime. Additionally, several interviewees

possess valuable international experience, having worked in countries such as the United States, Germany, the United Kingdom, and Japan. Their insights will be instrumental in comparing these international contexts with the unique dynamics of the Chinese market.

- **Knowledge of Value Chain and Policy**: Interviewees should possess experience or at least knowledge of other parts of the automotive value chain, such as autonomous vehicle companies, battery manufacturers, and spare parts suppliers. Familiarity with policy dynamics during the transition is a priority, as policy plays a central role in socio-technical transitions, especially in countries like China with influential government involvement.
- **Diverse Age and Experience**: Interviewees should represent different age groups and levels of industry experience. This diversity captures varying perspectives, as younger professionals may embrace change more readily, while seasoned experts may exhibit more conservative attitudes or have contributed to institutional inertia. However, ten years of practical experience in the automotive sector in China is the baseline.
- **Experience in or Knowledge of the Chinese Market**: Ideally, interviewees should have experience working in China or at least be responsible for the Chinese market. This firsthand experience offers a deeper understanding of the socio-technical system in focus, including network dynamics. Those with experience working in other regions but collaborating extensively with the Chinese automotive industry can also provide valuable insights into cross-system interactions.

The interviewees can come from different countries but should have working experience in China or should have been responsible for the Chinese market. Interviewees with working experience in China are highly preferable for the expert interviews because they possess direct experience in the focal socio-technical system and have ample opportunities to participate actively within the network. While some APAC or global teams in other countries or regions may also have responsibilities for the Chinese market, they may not be as intimately familiar with the focal socio-technical system as individuals who work within it and directly participate in the transition.

With the above selection criteria, these interviewees can offer valuable insights regarding the interactions between internal and external socio-technical systems. They may work within external socio-technical systems, such as the automotive industry in Europe or Japan, while maintaining close collaboration with employees in the automotive industry in China. Consequently, they are often well-positioned to understand how different socio-technical systems influence one another during the transition. The backgrounds of the interviewees are summarised in Table 3-1.

Table 3-1 Background of interviewees

Background		**Company Type**					**Function**			
Years of Experience	Highest Level	Start-ups	Foreign Company	Joint Venture	Domestic Company	Others	Product Planning	R&D	Strategy	Others
30	Sr. Director	V	V	V			V		V	
37	Director	V	V	V					V	Finance
20	Director		V				V	V	V	
16	Director	V	V	V			V	V		
11	Director	V	V	V	V		V	V	V	Market Analytics
16	Director		V	V		Supplier	V	V		
14	Deputy Director	V	V	V	V		V	V	V	
10	Deputy Director	V		V			V	V		
16	Sr. Manager	V		V			V	V		Program Management
10	Sr. Manager	V	V		V		V			Marketing/PR
15	Sr. Manager		V		V		V	V	V	Program Management
12	Sr. Manager	V	V				V			Sales Training
10	Sr. Manager						V		V	Consumer Insight
12	Sr. Manager		V	V	V	Telecom sector	V	V	V	
18	Manager		V			Supplier	V	V		Market Intelligence
Total Count		9	12	9	5	3	14	10	8	8

3.6.4 Questions of the interview

For this PhD thesis project, the interviews are designed to adhere to a systematised approach, focusing on the following key aspects, as outlined by Van Audenhove (2007):

- **Detailed Topic List**: The interviews are structured around a detailed topic list that encourages interviewees to provide comprehensive and extensive responses. This approach allows for a deeper exploration of the subject matter while allowing interviewees to share their insights freely. This initial interview phase is expected to take approximately five minutes and is the starting point for discussion.
- **Systematic Information Revelation**: The interviews are strategically designed to reveal information systematically.

The questions are categorised into different types to achieve specific research objectives:

- **Understanding the Transition Processes**: Questions in this category aim to gain insights into the overall stages of the transition, criteria for categorising these stages, and the development of a framework for the case study. These questions serve as the foundation for the entire case study segment of the research project.
- **Key Factors Affecting the Transition**: This set of questions delves into the crucial factors influencing the direction and trajectory of the socio-technical transition. Policy is particularly emphasised as a significant factor, given its recognised importance in shaping the transition, particularly in a developing country with a socialist system like China.
- **Understanding the Regime During the Transition**: Questions in this category seek to uncover the mechanisms that may hinder progress within the existing regime and how actors within the regime overcome these obstacles to participate in the transition. Additionally, these questions contribute to analysing interactions and influences

between different levels of the socio-technical system.

- **Interactions within the Internal Socio-technical System**: These questions probe the interactions between various levels within the socio-technical system, drawing from the multi-level perspective framework. They aim to provide a holistic view of interactions between niche actors and the established regime, shedding light on how these interactions either accelerate or decelerate the socio-technical transition.
- **Interactions Between the Internal and Associated Socio-technical Systems**: Recognizing that related systems influence socio-technical transitions, these questions explore how the focal system interacts with associated systems, potentially affecting the transition trajectory. Examples include interactions with the energy sector or shared mobility systems.
- **Interactions Between Internal and Peer Socio-technical Systems**: Designed to explore the interactions between the internal socio-technical system in focus and external systems, these questions address the assumption that globalisation leads to cross-system interactions. They are particularly pertinent for interviewees with experience in joint ventures or foreign companies, which often play pivotal roles in such interactions.
- **Changes in Individual Opinions During the Transition**: These questions focus on how individuals' perspectives evolve throughout the transition process. They explore the shifts in mindset, particularly within the automotive industry, by examining the backgrounds and experiences of employees joining electric vehicle start-ups before and after 2020.

The detailed interview questions and description of each question can be found in Table 3-2.

Table 3-2 Interview questions

Question	Purpose
Can you identify the critical turning points driving the transition towards new energy vehicles (NEVs)? What factors and critical actors have played pivotal roles in these turning points?	Understanding influential factors and timing: One of the primary aims is to grasp the perspectives of industry practitioners regarding the critical factors and their timing, which wield substantial influence over the focal socio-technical transition. Additionally, these insights contribute to the validation of the delineated transition stages.
Based on your professional experience, at what point did most automotive OEMs begin to change their product or investment strategies to focus on new energy vehicles (NEVs)? Could you highlight the key factors or influential actors that drove these strategic shifts?	Exploring regime actors' participation and behaviour: The interviews seek to ascertain the stage within the socio-technical transition at which actors within the established regime engage and investigate their behaviour throughout this transition period. Furthermore, these questions shed light on the interactions among regime actors and the decision-making processes guiding their actions.
In your view, what are the primary differences between traditional and multinational automakers compared to start-ups in the context of the NEV transition? Why did traditional automakers tend to react more slowly to this transition than start-up companies?	Uncovering 'lock-in mechanisms' in traditional and multinational automakers: These inquiries aim to pinpoint the entrenched 'lock-in mechanisms' within traditional and multinational automakers that impede their rapid response to the electrification trend. Concurrently, they help elucidate why start-up companies demonstrate agility in reacting to this trend.
Could you elaborate on the key distinctions you've observed between the transition dynamics in China and other developed markets? What unique characteristics have defined China's NEV transition journey?	Identifying distinct characteristics of the Chinese automotive sector: An objective is to discern the distinctive attributes of the Chinese automotive sector and elucidate why the transition in China may outpace other markets.
Do you believe that transitions or actions in other countries have influenced the NEV transition in China? For instance, has the presence and influence of Tesla affected the technological strategies of Chinese start-ups or impacted the decision-making process within your own company?	Exploring interactions between internal and external socio-technical systems: Delving into the interactions between the internal socio-technical systems under scrutiny and external socio-technical systems. They also can uncover global factors emanating from the established regime.
Looking ahead, what is your forecast for the future of the NEV industry in the coming years? When do you anticipate NEVs replacing gas-powered vehicles as the mainstream choice? Additionally, could you identify any existing roadblocks and suggest potential actions to expedite this transition process?	Understanding the overarching transition trends: The interviews seek to comprehend the trends characterising the transition and ascertain the requisite actions to sustain the momentum of electrification within the market.

The design of these open-ended questions aims to guide the interviews while allowing interviewees the freedom to provide valuable insights. Given the potential for responses to vary in clarity or specificity, a buffer time of 15 minutes is allocated for follow-up questions to ensure clarity and depth in the information gathered. The total interview duration is set to be 75 minutes, aligning with the research objectives and ensuring consistency across all interviews.

3.6.5 Limitations of the interview

It's worth noting certain limitations about the selection of interviewees and the nature of the interviews themselves:

- **Homogeneity of Interviewees**: Most selected interviewees hail from product planning within foreign companies, joint ventures, and start-ups. This homogeneity raises the possibility that responses may exhibit similarities due to the shared industry conditions and developments. For instance, the strategic shift from internal combustion engine cars to electric vehicles was a joint decision among many international companies in the late 2010s. This homogeneity could potentially limit the diversity of insights within the interviews.
- **Absence of Government Representatives**: The absence of government representatives in the interview pool is another limitation. These individuals, particularly those involved in policy-making processes, possess unique perspectives that could significantly contribute to the research. However, the challenges of inviting government officials, especially foreign university students, have precluded their inclusion in the expert interviews.
- **Time Constraints**: The interviews are constrained by time limitations, necessitating a concentrated focus on the conceptual framework. While the interviews are semi-

structured, the time allocated may not always permit in-depth exploration of specific topics. Consequently, valuable information may be truncated during the interviews.

- **Confidentiality Constraints**: Some interviewees may possess substantial insights or information but cannot share these details with the interviewer due to confidentiality constraints. This constraint may result in less comprehensive responses, potentially yielding answers that align more with common industry knowledge rather than delving into more profound insights.

These limitations are significant to acknowledge as they may influence the depth and diversity of insights obtained from the expert interviews. Despite these constraints, the interviews still serve as a valuable source of information and contribute to the overall understanding of the socio-technical transition within the electric vehicle industry.

3.6.6 Ethical considerations

The researcher has solemnly committed to upholding the confidentiality of all data and safeguarding the anonymity of the participating firms and individuals. This commitment was formalised through a signed declaration. Specific codes were employed to represent, address, and describe the firms and interviewees to ensure privacy. Furthermore, all raw data were securely stored in encrypted files on the researcher's laptop, protected by a password. Access to the participants' codes was restricted solely to the researcher and was exclusively utilised for research purposes.

It is important to note that the present research is not sponsored, thus preventing the need to provide open data access. The disposition of the data following the conferral of a PhD degree will be contingent upon the respondents' preferences. The data will be securely destroyed to uphold their privacy and confidentiality if they desire.

3.7 Data processing and analysis

3.7.1 Strategy

Once sufficient data has been collected, the data analysis phase will commence. This research project incorporates two modified strategies out of the four strategies distinguished by Yin (2009b):

- **Relying on Theoretical Propositions**: The analysis will be anchored in the GIESTS Framework derived from the MLP, SNM, and spatial dimension of MLP. This framework will serve as the foundation for the case study analysis, with a detailed exposition in the subsequent Chapter.
- **Working the Data from the ‘Ground Up’**: While Yin (2009b) characterises this strategy as a direct contrast to the first, it is argued that the two strategies are complementary. The first strategy lays the groundwork by offering an overarching understanding of the case’s background. In contrast, the ‘ground-up’ approach contributes uniquely to the research field by focusing on the case’s specifics.

Despite categorising actors and actions according to the three levels of MLP, this strategy emphasises exploring interactions between different levels or socio-technical systems. The semi-structured interviews are expected to be particularly valuable in this regard, as they facilitate discussions beyond the original questions and may illuminate the development of new concepts.

3.7.2 Data processing and analysis

Within the context of this doctoral thesis, I employed thematic analysis as the principal methodological approach for the comprehensive examination of the gathered data.

Thematic analysis is a robust tool for identifying, organising, and interpreting underlying themes within textual data, thereby facilitating a nuanced comprehension of significant patterns and narratives that emerge from the dataset under investigation (King and Brooks, 2018). This methodology conceptualises a theme as enduring and noteworthy elements within participants' narratives that illuminate specific viewpoints or experiences deemed central to the study's objectives (Brooks et al., 2018).

The rationale behind selecting thematic analysis as the preferred method for data analysis stems from its esteemed status as a fundamental technique for uncovering and deliberating patterns within qualitative datasets (Clarke and Braun, 2013). Given the overarching goal of this research, which is to delve into the complexities of socio-technical transitions, the devised conceptual framework aspires to encompass a diverse array of data inputs. This harmoniously aligns with the extensive scope of thematic analysis, facilitating a meticulous exploration of a wide range of data sources, from secondary materials such as insights from social media to primary data acquired through expert dialogues (King and Brooks, 2018).

Furthermore, the chosen methodology harmonises with my research philosophy. As articulated by Brooks and King (2016), this approach is particularly suited for researchers who embrace a relativist ontology and constructivist epistemology. It aids in discerning how participants construct meaning within the specified research context. This method prioritises inductive reasoning and the emergence of themes while maintaining a reasonable and tentative application of a priori themes if invoked at all. It also acknowledges the researcher's subjectivity as an integral element throughout the research process.

In the course of this research project, where I have developed a conceptual framework based on MLP for identifying various themes and subthemes about socio-technical transitions, leveraging a 'framework analysis' approach, as outlined by Ritchie et al. (1994), is considered a pragmatic methodology that offers systematic rigour while remaining adaptable to diverse study types. This choice aligns with my axiological perspective (King and Brooks, 2018). The five critical processes of framework analysis are summarised in Table 3-3.

Table 3-3 Summary of framework analysis approach, modified from Ritchie et al. (1994) and King and Brooks (2018)

Process	**Actions**
Familiarisation with the Data	• Immerse the data by reading and re-reading transcripts, field notes, and interview recordings. • For more extensive studies like the research project, a cross-sectional sample of the data may be selected to become familiar with it. • Notes are taken on exciting data features, but no systematic coding is done.
Identifying a Framework	• Develop a framework of themes and subthemes based on the data and research aims (the GIESTS Framework in this research project). • The framework is kept relatively simple, usually with two hierarchical levels of themes.
Indexing	• The entire data set is coded (indexed) using the established framework. • New themes may be added, but the framework is typically well-developed before indexing begins.
Charting	• Indexed data are organised into tables (charts) that cross-reference units of analysis (e.g., individuals, groups) against themes. • Material related to a particular theme for a specific unit of analysis is summarised analytically.
Mapping and Interpretation	• Analysts review the charts and research notes, looking for patterns and key insights. • Various strategies are employed, such as defining concepts, mapping phenomena, and developing typologies. • The goal is to address the original research questions through creative interpretation.

3.7.3 Data utilisation and presentation

The research methodology was meticulously architected to unfold in a series of structured phases, each designed to build upon the insights gleaned from the previous, thereby ensuring a thorough analysis of China's NEV sector transition.

The foundation of the research was laid with an in-depth examination of secondary data and the verification of the industrial experts, who meticulously charted the NEV sector's transition into five distinct stages, detailed in Section 5.2. This phase established a chronological framework underpinning the entire case study, providing a temporal backdrop against which the sector's evolution was scrutinised.

Subsequently, a thematic exploration delved into the intricacies of the NEV sector's evolution, articulated through these five stages. Employing the GIESTS Framework, the analysis unravelled the sector's transition dynamics, elucidating the interplay of myriad factors across the stages. The backbone of this analysis was the annual NEV blue books, authoritative compilations jointly issued by the Chinese government and key automotive stakeholders. These publications, renowned for their reliability and depth, were complemented by various secondary sources, including online media and industry reports, to provide a comprehensive perspective on the sector's progression.

The study integrated pivotal insights from expert interviews to fortify the analysis, presented in a quotation format. These primary data excerpts corroborated and enriched the thematic analysis, ensuring alignment with the GIESTS Framework and augmenting the narrative with nuanced industry perspectives.

The research further benefited from participatory observation, granting an immersive insight into the industry's operational nuances as an insider academic researcher (Brannick and Coghlan, 2007). This engagement enabled real-time observation of the industry's adaptive strategies to evolving policies and market conditions, deepening the analytical narrative. This blend of desk research and empirical engagement provided a multifaceted view, accentuating the synergy between policy directives and market responses within the dynamic landscape of China’s NEV sector.

The distilled insights from these expert interviews were synthesised in Chapter 6, unveiling pivotal themes that resonated with the GIESTS Framework analysis and illuminated additional facets of the sector’s transition. As identified by industry stakeholders, these findings highlighted critical transition influencers delineating prospective challenges and strategic foresight.

The amalgamated insights from this methodological rigour significantly shaped the discourse in Chapters 7 to 9, laying a rich empirical foundation to dissect the socio-technical transition nuances within the automotive industry. This comprehensive methodological approach ensured a profound understanding of the transition, reflecting the sector’s complexity and the multifarious factors influencing its evolutionary trajectory.

Upon concluding the data analysis, the results will be systematically presented chronologically, segmented across distinct timeframes encompassing five stages, as presented in sections 5.3 to 5.7. This structured presentation will cover multiple facets of the GIESTS Framework, intertwined with narratives that elucidate the intricate processes encapsulated within each timeframe.

While this research delves into the pivotal evolutionary trajectory from the early 2000s to the early 2020s, a pronounced emphasis will be directed towards recent events. This focus is a consequence of resource constraints and the pivotal significance of these recent events. A deliberate strategy will be employed to allocate more excellent analytical resources to these recent events, positioning them at the forefront of our analysis over older incidents. I aspire to leverage these demarcated stages to shed light on the distinct characteristics of the transition through the lens of the conceptual framework crafted for this research.

3.8 Evaluation of research design

To uphold the rigour of this case study-based research, I have adopted four essential criteria outlined by Lincoln and Guba (1985), encompassing credibility, dependability, confirmability, and transferability. These criteria serve as foundational pillars to ensure the integrity and applicability of the research findings.

- **Credibility**: This criterion is employed to ascertain the authenticity and believability of the research outcomes from the participants' viewpoint in the focal case study. Ensuring that the findings genuinely reflect the participants' perspectives and experiences is essential.
- **Dependability**: The dependability criterion is utilised to guarantee that the findings of this qualitative research are consistent and could be replicated under similar conditions with the same cohort of participants, coders, and context. This aspect underscores the reliability of the research outcomes.
- **Confirmability**: Applying the confirmability criterion is pivotal in maintaining a degree of neutrality in the research. It ensures that the findings are shaped primarily by the responses and experiences of the study participants rather than being influenced by any potential biases, motivations, or interests of the researcher.
- **Transferability**: The transferability criterion determines how the research results can be generalised or applied to other contexts or settings. This criterion evaluates the applicability of the findings beyond the immediate research scenario.

By diligently adhering to these criteria, my research aims to present credible, dependable, neutral, and broadly applicable results, thereby contributing valuable insights to the field of study while achieving the goal of trustworthiness.

3.8.1 Credibility

Credibility, as defined by Lincoln and Guba (1985), is crucial for assessing the truthfulness of research findings. To establish credibility in my PhD thesis, I have employed several strategies:

- **Prolonged Engagement and Persistent Observation**: My seven-plus years of experience in international and local start-up automakers, covering program management, product planning, and strategy planning, has been instrumental. This tenure has provided deep insights into the culture, social setting, and the trajectory of automotive electrification. It has enabled a thorough understanding of the transition from the perspectives of various automakers. Persistent observation has been vital in identifying the socio-technical transition's most relevant characteristics and elements.
- **Triangulation**: The credibility of the collected data is bolstered through diverse evidence sources. This includes interviews with industry practitioners, participant observation, and secondary data sources such as archival documentation, records, and physical artefacts. Integrating these varied sources facilitates data triangulation, reinforcing the research’s construct validity by corroborating findings from multiple perspectives.
- **Member-Checking**: Expert feedback on the developed conceptual framework was solicited during interviews, aiding in capturing essential transition elements. Following the completion of expert interviews, individuals who are recognised experts within the industry under investigation have been engaged to review the notes and summaries of their respective interviews. These key informants possess in-depth knowledge and insights relevant to the case study. By soliciting their feedback and input, I aim to ensure the information’s accuracy and validity in the case study section. This iterative review process by domain experts further bolsters the construct

validity of the research by aligning it with expert perspectives and industry insights.

These methods collectively strengthen the credibility of my research, ensuring that the findings are an accurate and comprehensive representation of the automotive electrification transition.

3.8.2 Dependability

Dependability, as Lincoln and Guba (1985) suggest, relates to the stability of research findings and the researcher's efforts to account for any changes in the phenomenon under study, the design, or methodology. To establish dependability, the researcher needs to provide ample information, allowing readers to assess the reliability of both the study and the researcher, as Ryan et al. (2007) advocated. Following the guidelines provided by Shenton (2004) and Thomas and Magilvy (2011), my thesis includes the following sections to address dependability:

- **Research Design and Implementation**: This section includes a description of the research's purpose and a justification for choosing informants and sampling methods. It elucidates the rationale behind the research approach and the selection of participants, thereby underlining the study's methodological rigour.
- **Operational Detail of Data Gathering**: A clear explanation of data collection is provided here, with detailed information on the interview process. This section offers transparency regarding the data collection methods, ensuring the process is replicable and reliable.
- **Examination Techniques for Research Quality**: This part articulates the techniques used to assess the quality of the research, showcasing the measures taken to ensure the integrity and credibility of the findings.
- **Data Analysis Discussion**: A thorough discussion of how the data was analysed is

presented. This includes the methodologies, tools, and techniques used in the data analysis, emphasising the systematic interpretation of the data.

- **Interpretation and Findings Discussion**: The interpretation of the data and the findings of the research are discussed in depth. This section, included in the sixth Chapter, explores the implications of the results, providing insights into their relevance and significance.

The first four sections are thoroughly discussed in the third Chapter of the thesis, providing a clear and comprehensive account of the research design, data collection, and analysis processes. The final section, dealing with the interpretation and findings, is elaborated in the sixth Chapter, bringing a conclusive perspective to the research project. Together, these sections ensure the dependability of the research, demonstrating a consistent and transparent approach throughout the study.

3.8.3 Confirmability

As Lincoln and Guba (1985) discussed, confirmability addresses the degree of neutrality in research findings, ensuring that they are shaped more by the respondents and less by the researcher's biases, motivations, or interests. Patton (2010) acknowledges the challenge of achieving true objectivity, noting that researcher bias is inevitable since tools like tests and questionnaires are human-designed. Lincoln and Guba (1985) also argue that in qualitative research, confirmability is grounded in the achievement of credibility, transferability, and dependability, as outlined earlier.

Lincoln and Guba (1985) recommend using triangulation and an audit trail to enhance confirmability. Triangulation, as previously discussed in the credibility subsection, involves using multiple data sources or methods to verify the findings. Following the guidance of Thomas and Magilvy (2011), the audit trail can be illustrated in two ways, including (1) a data gathering and processing diagram, which diagrammatically shows the data collection and analysis process throughout the study. It helps track data flow from its collection to its final analysis, ensuring transparency in the research process, and (2) a conceptual flow chart outlining how the concepts inherent in the research question have influenced the subsequent research work. It visually demonstrates the logical progression from the research philosophy and questions to the research findings, encapsulating the connections between various study elements.

In section 3.2, I have employed a flow chart to depict how the research philosophy and questions lead to the research findings, including the data collection and analysis stages. This approach not only provides a clear roadmap of the research process but also reinforces the confirmability of the study by visually demonstrating the systematic and unbiased approach taken in deriving the research findings.

3.8.4 Transferability

Transferability is crucial to my PhD research, assessing how the study's findings can be generalised to different contexts, populations, or settings. This dimension, crucial in qualitative research, as highlighted by Forero et al. (2018) and Lincoln and Guba (1985), examines the applicability of the case study results beyond the specific instances studied. To establish transferability, I have employed strategies inspired by Guba (1981):

- **Purposive Sampling**: The selection of interviewees was strategically designed to ensure a broad representation of perspectives. This involved choosing individuals involved in decision-making processes, primarily those holding at least mid-level managerial positions, across various functions and types of automakers. Such a diverse sample is intended to provide a range of views and perspectives on the transition, thereby enriching the study's findings.

- **Thick Descriptive Data and Development of Thick Description**: The primary goal of this research is to introduce a novel conceptual framework based on MLP for analysing socio-technical transitions, especially in developing countries with authoritative governance like China. This framework is crafted to be flexible, generalisable, and suitable for various cases. Additionally, the research focuses on a carefully selected, complex case that encapsulates multiple aspects of the target market. This selection allows for the partial application of the findings to similar cases within the market based on their relevance and contextual alignment. Such an approach enhances the transferability of the research, ensuring that the insights gained can be valuable in broader applications beyond the specific case studied.

Through these methods, the research aims to ensure that its findings and conclusions are not only relevant to the specific cases examined but also hold value and applicability in broader contexts, thereby enhancing the transferability of the study.

3.8.5 Summary of research design evaluation

In this chapter, I have applied the criteria established by Lincoln and Guba (1985) for evaluating the quality of qualitative research. My objective is to ensure that the outcomes of my research project are credible, dependable, neutral, and broadly applicable. This approach aims to deliver valuable insights into the field of study while maintaining high trustworthiness. The following summary encapsulates how these criteria have been addressed and fulfilled in my research:

- **Credibility**: Achieved through prolonged engagement in the automotive industry, diverse data sources for triangulation, and member-checking with industry experts to ensure accurate representation of the automotive electrification transition.

- **Dependability**: Addressed by providing detailed information on research design, data gathering, and analysis processes, as well as a thorough discussion of findings, to enable assessment of the study's and researcher's reliability.
- **Confirmability**: Enhanced through triangulation of data sources and an audit trail, including a data gathering and processing diagram and a conceptual flow chart, to demonstrate the neutrality of the research and minimise researcher bias.
- **Transferability**: Ensured by purposive sampling for diverse perspectives and developing thick descriptive data within a novel conceptual framework, making findings applicable to similar contexts beyond the specific cases studied.

3.9 Summary

In this chapter, the research journey commences with exploring the research philosophy. Subsequently, we delved into the intricacies of our research design, spanning from an exhaustive literature review to a conclusion. Furthermore, we expounded upon the research methodologies that will be employed to address the central research question of this doctoral project. Additionally, we elucidated the meticulous process by which we will conduct expert interviews, particularly emphasising ethical considerations.

Furthermore, a comprehensive exposition of the data analysis methodologies harnessed in this research endeavour and the approach to presenting the findings has been provided. Finally, the case-based research project is evaluated using the four criteria developed by Yin (2009a) to ensure its validity and reliability. The methodologies utilised in this study are briefly summarised in Table 3-4.

Table 3-4 Summary of research methodologies

Research Philosophy	• Relativism as the position of ontology. • Constructionism as the position of epistemology. • Pragmatism as the position of axiology.
Methodology &	• The research employs a qualitative methodology that

Approach	utilises a multi-method approach, encompassing document analysis, participant observation, expert interviews, and thematic analysis.
Research Design	• Single case study.
Data Collection	• Interviews with practitioners. • Participant observation. • Other secondary data, including archiving documentation, archival records, and physical artefacts as evidence for data triangulation.
Data Analysis	• A framework analysis approach from a thematic approach is used for systematic rigour and adaptability. • Data processing and analysis are guided by the GIESTS Framework derived from MLP.

Chapter 4. The GIESTS Conceptual Framework

4.1 Overview

The conceptual framework has been meticulously designed to provide a comprehensive lens for analysing socio-technical transitions. Its primary objective is to offer a tailored perspective for assessing socio-technical transitions influenced by complex external actors and factors, such as those in the automotive, semiconductor, or energy industries. While rooted in the traditional multi-level perspective introduced by Geels (2002), this framework has substantially adapted to better align with the specific needs of analysing socio-technical transitions in these contexts.

This adapted conceptual framework continues to be built upon the fundamental concepts of niches, regimes, and landscapes but has been enriched with novel concepts, such as 'internal and external' and 'associated and peer', each accompanied by precise definitions. The framework is designed to scrutinise the intricate interactions and influences of other socio-technical systems interconnected with the focal socio-technical transitions within the targeted system. Sub-levels have also been introduced at certain levels to facilitate a more nuanced examination of the diverse forces acting upon the focal socio-technical system. Three primary tiers are delineated: internal, external, and global.

The 'internal level', within the scope of this research, symbolises the focal socio-technical system at the geographical level. This system could encompass an entire industry within a country, a region, or even a city or town. For instance, in our case study, the internal socio-technical system pertains to the automotive sector in China. Within this internal level, two distinct layers are embedded: the internal regime, predominantly characterised by internal combustion engine vehicles in our case, and the internal niche, which serves as a protected space for electric vehicles in our study.

Furthermore, within the internal level, various categories of geographic levels exist, ranging from national to district levels, and each level may exert influence on the others. This influence can manifest in both top-down trajectories, often driven by policy interventions, and bottom-up trajectories, such as grassroots innovation initiated by local volunteers and activists, as observed in the work of Geels (2019).

Additionally, the ‘external level’ refers to socio-technical systems in other geographical spaces that operate within the same sector as the focal socio-technical transition. These external socio-technical systems may or may not be undergoing similar transitions. In our case, the focus is on the transition from ICE vehicles to NEVs in China. In contrast, the external ones represent transitions in other geographical spaces such as the European Union, the United States, or Japan. This relationship between the focal and external systems is called ‘peer’ within the conceptual framework.

In some instances, external systems may also belong to the same market or geographic area, sharing similarities with the focal socio-technical system but differing in some aspects. In such cases, they are described as ‘locally-associated’ with the focal system. Conversely, if the associated system is in a different spatial context, it is termed ‘internationally-associated’ with the focal socio-technical system. However, the research project focuses on locally-associated socio-technical systems only as the focal transition is mainly shaped by the locally-associated sectors but not the internationally-associated ones.

Most recent studies have predominantly focused on interactions within a single country or region. For instance, research has delved into niche development, niche-regime interactions in the agri-food systems in France (Bui et al., 2016), spatial variations in low-emission vehicle adoption in China (Bohnsack, 2018), factors driving the transition of electric vehicles in Iceland (Lin and Sovacool, 2020), different phases of the socio-technical transition towards new energy vehicles in China (Wu et al., 2021c), and the transition of the energy system in Greece (Nikas et al., 2020). However, it is argued that focusing solely on a single country or region and relegating all other factors to the landscape level is insufficient for analysing socio-technical transitions in developing countries like China. Such countries often lack the initial capacity to develop their niches due to knowledge and technology gaps compared to developed nations (Zhang et al., 2021).

In China, a common approach has been ‘copy first, then surpass’, especially in emerging industries like the internet, automotive, and mobile phone sectors, wherein industries in other countries can significantly impact development. In the context of our research project, the socio-technical transition of the automotive sector in leading countries such as Germany, the United States, and Japan can influence the transition in China in different stages. Joint ventures formed with companies from these countries can enhance the knowledge base and introduce new technologies to the actors within China’s socio-technical system. The policies and plans of these countries could also influence the decisions of the Chinese government, which will be further discussed in the following Chapters.

Given these circumstances, the concepts of internal and external within the framework aim to provide a foundational structure for improving socio-technical transition studies in developing countries. These concepts could help better understand how external socio-technical factors affect the focal socio-technical system and the interactions between internal and external systems and their embedded actors. This is particularly relevant for China, which lagged behind developed countries in technology and industrial capacity when transitioning from traditional gas-consuming vehicles to electric vehicles began in the late 2000s (Xue et al., 2016, Wu et al., 2018). However, China started to significantly influence the transition in developed countries in the late 2010s regarding products and perceptions toward new energy vehicles (CATRC et al., 2022). In this conceptual framework, the external level encompasses associated and peer socio-technical systems, each with its niches and regimes. In contrast, the internal level includes the niches and regime of the focal socio-technical system.

A more exogenous level, known as the global level, is defined. Within the global level, three categories of forces are identified: positive, negative, and neutral, depending on their impact on the socio-technical transition trajectory. Positive forces can further be categorised into pull forces, which incentivise actors to participate voluntarily in the transition, and push forces, which compel actors to accelerate the transition. Conversely, global factors negatively affecting the transition are considered counteractive or opposing forces. Factors that do not directly or indirectly influence the transition process are considered neutral and not discussed in this research project. Further details on these categories are elaborated in subsequent sections.

4.2 Enlightenment from MLP: niche, regime, and landscape

The foundational concepts of niche, regime, and landscape originate from the MLP concept and serve as invaluable tools for researchers seeking to understand the underlying mechanisms of transformation, particularly in the context of redefining trajectory directions and adapting to altered rules guiding innovation actions during transitions (Geels and Kemp, 2007). The theoretical underpinnings of the GIESTS Framework are grounded in the three-level concept of MLP, which is elaborated upon in the following section. This foundational concept has been instrumental in articulating the global layer of the GIESTS

Framework, mainly through MLP's definition of the landscape. Additionally, MLP's delineation of niche and regime levels has significantly enhanced the characterisation of the internal layer within the GIESTS Framework.

Scholars have identified three interrelated dimensions crucial for analysing transitions and transformations: the socio-technical system comprising tangible elements essential for delivering societal functions, the social groups responsible for maintaining and refining these elements, and the rules, or the socio-technical regime, that govern the direction of activities within these social groups (Geels, 2004, Geels and Kemp, 2007). It's essential to note that the actors within these social groups do not operate in isolation; they are embedded within specific contexts defined by social structures, normative rules, regulative rules, and cognitive rules (Geels and Kemp, 2007).

4.3 Concept of global, internal, and external

Scholars have highlighted the significance of multi-regime interaction (Raven, 2007, Konrad et al., 2008). To delve deeper into these interactions, our conceptual framework introduces the concepts of global, internal, and external levels to categorise landscapes and various socio-technical systems. These levels offer researchers a structured overview for identifying critical elements related to socio-technical transitions. For instance, researchers can identify the pertinent socio-technical systems involved in a transition, assess their influence on the transition path, and pinpoint the exogenous forces shaping different socio-technical systems and transition trajectories.

The global level within the framework of this research project is rooted in the landscape concept derived from the MLP concept (Geels, 2002, Geels, 2011, Geels and Raven, 2006). Within the MLP framework, the landscape is depicted as an exogenous force that exerts pressure on the socio-technical regime, potentially creating a ‘window of opportunity’ for niche innovations to supplant the prevailing regime and assume a dominant position. However, it is crucial to acknowledge that the landscape’s impact on socio-technical transitions is not unilaterally positive; in some instances, it may impede the transition or even contribute to lock-in mechanisms that sustain the status quo.

Furthermore, it is essential to recognise that the forces within the landscape can manifest diverse effects on the trajectory of socio-technical transitions. These effects can be further classified into distinct categories, including forces that incentivise the acceleration of the transition and forces that introduce constraints on actors participating in the transition, compelling them to expedite the process.

The conceptual framework developed for this research project could provide researchers with a comprehensive toolset for discerning and categorising the various exogenous forces that may influence the focal socio-technical transition. This framework enables a nuanced exploration of the dynamic interplay between these forces and the socio-technical systems under investigation, which will be elaborated in the global level section. The internal and external levels draw on the dimensions of ‘sector’ and ‘geographical space.’ These levels enable us to differentiate socio-technical systems based on spatial scale and sectoral distinctions.

4.3.1 (Geographical) Space

Spatial dimensions, often regarded as the ‘fourth level’ in multi-scalar MLP (Raven et al., 2012), are the foundation for these internal and external levels. Spatial dimensions have gained prominence as an extension of the multi-level perspective, emphasising the significance of geographical differences (Hodson and Marvin, 2009). Specialists operating as intermediaries at various spatial scales—neighbourhood, city, national, and international—mediate between diverse social interests, strategically coupling different networks, accessing varied resources, and driving transitions (Hodson and Marvin, 2010, Grin et al., 2010).

Furthermore, the concept of the spatial dimension encompasses diverse levels and scales, including local, regional, and global ones, as posited by Bunnell and Coe (2001). The spatial dimension is shaped by physical space and factors such as physical, economic, and social networks (Raven et al., 2012). Critical aspects of the socio-technical regime, including governance, product systems, infrastructures, value chains, and research networks, exhibit various levels of dimension, ranging from local to transnational. Thus, actors are embedded in international, national, and sub-national innovation spaces (Raven et al., 2012).

The concept of space in the GIESTS Framework represents territory, and territory aids in understanding transitions with associated factors and processes. Transitions are characterised by multi-scalar interactions among actors across different spatial scales within the multi-level framework (Raven et al., 2012). This territorial perspective is essential for grasping the nuances of socio-technical transitions, considering the distinct characteristics of territories that influence and are influenced by transition dynamics (Raven et al., 2012). Specifically, the framework zeroes in on the national scale, examining how nation-bound factors such as regulatory frameworks, resource allocation, and labour markets interplay to facilitate or constrain the growth and diffusion of NEVs (Gibson et al., 2000, Raven et al., 2012).

4.3.2 (Technological) Sector

The sectoral dimension categorises socio-technical systems based on product, service, or business model distinctions. Sectors encompass various products, services, or business models, extending beyond traditional production systems (Holstein and Tanenbaum, 2014). Sectors can be delineated based on the type of product, service, or business model they offer. Even when providing services that fulfil the same societal function, differing business models can warrant the categorisation of separate sectors. For instance, while app-based private car-hailing and traditional taxis provide transportation services, they represent distinct sectors due to differences in their business models.

In this framework, sectors are not constrained by geographic meaning, defined by the spatial (market) dimension. For instance, when referring to the 'automotive sector', we do not specify a particular automotive sector but instead refer to the broader automotive sector. Geographic location is determined by the spatial dimension, not the sectoral dimension. In analysing the transition from internal combustion engine cars to electric cars in China, the focal socio-technical systems are those of the internal combustion engine car sector in China and the electric car sector in China, representing the regime and niche, respectively.

Some socio-technical systems, whether within the same or different spatial scales, may correspond to different sectors in the spatial dimension. These systems may be interconnected by shared elements and evolve alongside each other (Raven, 2007, Konrad et al., 2008). The boundaries of socio-technical regimes are not fixed; transformations can reconfigure or even separate regimes, potentially reinforcing or attenuating one another (Konrad et al., 2008). Moreover, these systems may exert indirect influences on each other through benchmarking, unofficial network formation, third-party consultancy agencies, and other mechanisms, as elaborated in subsequent sections of this research project. Based on these two dimensions, we could identify different types of socio-technical systems involved in the transition, which will be discussed in the following sections.

In the GIESTS Framework, the 'technological sector' extends beyond the traditional confines of a production system, typically concerned with manufacturing goods or delivering services using a set of resources (Holstein and Tanenbaum, 2014). As conceptualised in our framework, the sector is a broader construct that captures a conglomerate of varying products, services, and business models, potentially transcending single industry boundaries. This expanded view acknowledges the convergence of different technological domains, policy landscapes, and market structures that collectively shape the evolution of a socio-technical sector.

4.4 Global level

As discussed in previous sections, the landscape is a critical concept within the MLP framework, serving as the external force capable of disrupting the status quo of socio-technical systems by instigating changes in demand (Geels, 2002). Such changes in demand can stem from various dimensions, including social, cultural, economic, and environmental factors. In the core tenets of the multi-level perspective, the landscape is generally portrayed as a positive force that can create opportunities for innovation niches to supersede the existing regime, which represents the mainstream. Moreover, the landscape also encompasses international governance and other international settings, encompassing geopolitical, economic, and social contexts (Morgunova, 2021).

Nevertheless, real-world scenarios reveal that the landscape can be a roadblock and not always drive change. Additionally, the landscape extends beyond global trends to include the development of other socio-technical systems. However, it’s argued here that forces of this nature should be analysed independently due to their proximity and rapid interactions compared to the broader-scale landscape, which typically takes decades to manifest change, except in cases of disruptive events (Raven et al., 2012).

4.4.1 Categorising forces applied to socio-technical systems

In contrast to the conventional notion of the landscape, this framework seeks to differentiate the various effects exerted on the targeted socio-technical system by the landscape. These effects can be categorised into four distinct types of forces:

- **Push Force**: This is one of two positive forces that can initiate or expedite socio-technical transitions. Instead of attracting key actors to participate voluntarily, the push force may impose constraints on these actors, compelling them to support the transition. Essentially, the exogenous environment ‘pushes’ the transition forward. For instance, China’s energy dependency on other countries pushed it to promote electric vehicles, creating a window of opportunity for electric vehicle niches (Ji and Huang, 2018). Similarly, the Gulf War’s impact on oil prices forced automotive companies to produce cars with smaller, more fuel-efficient engines, enabling Japanese automotive companies to transition from niche to mainstream in the U.S. passenger car sector.
- **Pull Force**: This positive force encourages or accelerates socio-technical transitions. Unlike the push force, the pull force does not rely on constraints but instead creates an environment where actors benefit from participating in the transition. In essence, the new exogenous environment ‘pulls’ the transition forward. For example, the global digitalisation trend provided new technologies and platforms for sellers, making online sales channels more cost-effective than traditional ones. This led to a widespread shift towards online sales platforms, transforming them from niches to mainstream, particularly in markets like China (Sheng and Lu, 2020). This influence extends not only to wholesalers but also to farmers who adopt online sales trends.

- **Negative Forces**: These forces can decelerate or obstruct niche development and may create a favourable environment for alternative solutions, opening opportunities for new niches while hindering others. This dynamic can slow down the progression of transitions. For example, Japan heavily invested in fuel-cell vehicles in the late 2000s, viewing them as the ultimate electrification solution. However, the high cost and risk associated with building hydrogen infrastructure limited the potential of fuel cell vehicles in many countries. Following setbacks in major markets like China and Europe, which favoured battery electric vehicles, Japanese automotive companies redirected their resources toward battery electric vehicles, slowing the transition from gasoline-powered vehicles to electric vehicles in Japan.
- **Neutral Forces**: These forces may have minimal direct or indirect influence on the targeted socio-technical system and are not critical to analysing socio-technical transitions in this research project. However, it should be noted that the forces could become influential while the environment changes.

4.4.2 Emphasising the scale of the landscape

To be categorised as elements of the landscape, specific criteria must be met, or these elements should be considered part of external socio-technical systems, which encompass peer socio-technical systems and associated technical systems, as detailed in subsequent sections:

- **Scale**: The scale of these forces should extend across more than one socio-technical system or different markets. Examples include international relationships between countries leading to shifts in sectors reliant on imports, economic condition changes affecting demand, disruptive events impacting multiple socio-technical systems, and significant global trends such as climate change, resource depletion, industrial evolution, internationalisation, and more.

- **Period**: Generally, landscape forces operate for a more extended period, except in disruptive events like wars. Conversely, regimes may take decades to evolve, while niches may emerge over shorter periods, sometimes just years or months.

While these criteria provide some guidance, categorising elements as landscape or other external socio-technical systems may pose challenges. This framework aims to accommodate flexibility, allowing other researchers to determine categorisations that optimise the analysis of socio-technical transitions. The subsequent section on external socio-technical systems will further elucidate the categorisation of diverse elements that introduce exogenous forces capable of influencing socio-technical transitions.

4.5 Internal socio-technical system

The new conceptual framework departs from the conventional notion that socio-technical systems transform in isolation. Instead, it posits that the paths of transition within targeted socio-technical systems are significantly influenced by other socio-technical systems, thereby introducing the concepts of ‘internal’ and ‘external’ dynamics as mentioned earlier. The term ‘internal’ refers to the components inherent to the targeted socio-technical system. To illustrate, in the case of examining the transition from gas-powered vehicles to electrified vehicles in China, the internal socio-technical system pertains to the Chinese automotive sector. This internal system can further be dissected into an internal regime and niches.

4.5.1 Internal regime

The internal regime is the dominant technology, product, or business model, along with the associated sectors that collectively define the ‘rules of the game’ (Geels, 2002) within the targeted socio-technical system. For example, the Chinese automotive sector primarily focuses on internal combustion engine vehicles, constituting the internal regime. Actors within this internal regime include Chinese domestic automotive companies, branches of international automotive corporations, and governmental departments directly linked to the sector.

Notably, this research project diverges from traditional perspectives that often cast the regime as resistant to change and an enabler of lock-in mechanisms. Instead, it emphasises the nuanced interactions, competition, and cooperation among actors within the regime during socio-technical transitions. For instance, actors within the regime may allocate their engineering resources to create dedicated teams for new technologies or redirect existing resources to support the development of these technologies. Multiple factors can motivate regime actors to embrace change, including government policies, perceived threats or opportunities, and internal power dynamics within companies.

4.5.2 Internal niche

On the other hand, internal niches serve as protective spaces where alternative solutions—whether in the form of new products, business models, or technologies—that are deemed more sustainable or advantageous regarding human welfare can emerge, evolve, and mature. These niches are situated within the same market as the internal regime.

It is important to note that interactions with the internal regime do not solely shape internal niches but can also be influenced by socio-technical systems in other markets or socio-technical systems within the same market that may not have had direct connections with the niche at the outset. For example, technology companies such as Huawei, Baidu, and Xiaomi have ventured into the automotive sector by establishing electric vehicle companies and incorporating advanced intelligent features from their parent organisations.

Similarly, Dahua Technology, a manufacturer of surveillance equipment, diversified into electric vehicle manufacturing through Leap Power, emerging as one of the top 20 electric vehicle manufacturers in 2021.

In certain instances, actors from both internal and external regimes can play pivotal roles within the internal niche, as exemplified by BAIC (Beijing Automotive Group Co., Ltd.). This state-owned Chinese automotive company simultaneously influences the regime and participates in the niche segment of the electric vehicle sector. More elaborations can be found in the next section.

In the unique context of a country like China, the government assumes a paramount role in industrial development. Shifts in governmental strategies can prompt state-owned companies to become early adopters of new directions, particularly in industries that have the potential to reshape the nation's industrial landscape. For instance, transitioning from gas-powered to electric vehicles in China has far-reaching implications for the entire supply chain and millions of employees. Consequently, niches in China may still comprise a substantial proportion of actors from the socio-technical regime, a phenomenon aptly illustrated by the example of BAIC.

This delineation between the internal regime and internal niches forms a foundational aspect of the conceptual framework employed in this research project, allowing for a more comprehensive understanding of socio-technical transitions within the targeted systems.

4.6 External socio-technical systems and the concept of peer and associated

External socio-technical systems can be classified along two distinct dimensions, as discussed in section 4.3. The first dimension involves categorisation by geographical space, where, for example, if the focus of the research pertains to the socio-technical system of the internet industry in China, external socio-technical systems would include internet industries in other markets like Germany or Japan. These socio-technical systems across different markets often interact with and influence each other. Synchronisations emerge due to interactions among these systems, driven by various factors such as the mobility of human resources, knowledge exchange, network formation, policy similarities, the presence of solid global players, and more. In this research project, these interrelated systems are called ‘peer’ socio-technical systems, highlighting their shared relationships.

The second dimension for categorising external socio-technical systems relates to the targeted technological sector. Within the same markets, numerous socio-technical systems, either directly or indirectly linked, can interact and impact each other. For instance, the advancement of battery technology can lower costs and improve the performance of electric vehicles, thus bolstering the competitiveness of the electric vehicle sector (CATRC et al., 2017). These socio-technical systems, closely linked within the space, are perceived as external forces affecting or modifying the targeted socio-technical system. They are called ‘associated’ socio-technical systems within the conceptual framework, underscoring their unique relationship with the targeted system.

Associated socio-technical systems can exist either within the same market as the targeted system or in different markets. However, those within the same market often wield more substantial influence than their counterparts in different markets, owing to their stronger ties to the local environment. Thus, we distinguish these systems as ‘locally-associated’ socio-technical systems for those within the same market and ‘internationally-associated’ socio-technical systems for those in different markets, as illustrated in Table 4-1. Introducing the concepts ‘peer’, ‘locally-associated’, and ‘internationally-associated’ elucidates the external forces acting upon the target socio-technical system.

Table 4-1 Identification of different socio-technical systems involved in the targeted socio-technical transition

Compared to targeted socio-technical systems.		**(Geographical) Space**	
		Same	Different
(Technological) Sector	Same	Internal socio-technical system	Peer socio-technical system
	Different	Locally-associated socio-technical system	Internationally-associated socio-technical system

While previous research has alluded to such relationships (Konrad et al., 2008, Kanger, 2021, Raven, 2007), a comprehensive perspective on these forces is still lacking in the research field. Most scholars have incorporated these forces into the landscape level, but these forces should be dissected to discern better the most influential factors driving socio-technical transitions. In this conceptual framework, the landscape level is reserved for analysing forces on a broader scale, encompassing global economic conditions, political trends, and international relations.

4.6.1 Peer socio-technical system

On a global scale, established networks between socio-technical regimes in similar sectors across different markets enable the swift dissemination of developments from one regime to another. For instance, adopting fuel cell technologies in Japan led neighbouring markets like South Korea and China to embark on similar paths. Following a visit by Ke Qiang Li, the Premier of the People's Republic of China, to Toyota's headquarters in Japan in 2019, the Chinese government initiated a series of policies and actions to promote fuel cell technology, fostering closer collaboration with Toyota.

Turnheim and Geels (2019) argue that incumbent actors in neighbouring sectors, akin to the peer social-technical system in this research, can significantly impact the focal socio-technical systems and even spearhead the development of alternative solutions. These neighbouring sectors possess fewer lock-in mechanisms than the internal regime, making it easier for them to support and advance diversified radical niche innovations that serve the same societal function as the focal regime.

Moreover, in many cases, niches in one market do not arise in isolation but are inspired by analogous niches in other markets. Leading niches can serve as examples for niches in the targeted socio-technical regime to emulate. In the early stages of development, leading niches can guide the development of lagging niches. Actors in lagging niches may learn from or even replicate the strategies of leading niche actors. For instance, the electric vehicle niche in Taiwan provides a notable illustration.

When the electric vehicle niche in China was still in its infancy compared to gas-engine vehicles, Tesla, a leading niche actor in the USA, was an exemplar for Chinese niche actors to learn from and emulate. The influence extended to product design and encompassed strategies, product specifications, marketing approaches, and even founders' styles. Nio's product strategy is a prime example of how such emulation occurs (Zhang, 2018).

4.6.2 Associated socio-technical system

Associated socio-technical systems, whether within the same sector or across sectors, have the potential to exert a profound impact on the trajectory of targeted socio-technical systems. Previous studies have explored interactions between regimes in Germany's utility sector (Konrad et al., 2008) and niches in renewable energy in the Netherlands (Verbong et al., 2008). These interactions manifest in various ways, directly or indirectly influencing the targeted system. They can lead to changes in product development, business models, policy decisions, new business opportunities, or the adoption of innovative technologies.

Associated socio-technical systems not only stimulate change and innovation in the targeted socio-technical system through communication and information exchange channels but can also engage in deeper interactions with regimes and niches within the targeted socio-technical transition. These interactions may include forming alliances and cooperative relationships. In some cases, these interactions may originate from the influence of associated socio-technical systems, with the targeted socio-technical regime actively fostering cooperation and alliances with actors from these associated socio-technical systems. For instance, the prosperity of the internet and mobile phone industries has facilitated alliances between internet companies, mobile phone companies, and automotive manufacturers. This has led to significant developments in the automotive sector, transforming it from mechanical-based products to intelligent, computer-based ones from the mid-2010s. This cooperation has resulted in alliances like Volvo, Google, and FCA (Fiat Chrysler Automotive) partnering with Amazon and Tencent.

Nevertheless, it is essential to recognise that adverse effects can also arise alongside the positive effects of socio-technical transitions, mainly when these systems compete for resources. During the early stages of niche development, significant resources are required to foster the growth of the new sector. However, given the finite availability of resources, socio-technical systems may compete for these resources, potentially leading to one socio-technical system receiving resources initially intended for another niche. Resource competition can manifest within a company, between different business units, departments, or teams, or within government funding allocation for various industries.

In summary, associated socio-technical systems catalyse change and innovation within the targeted socio-technical system. They facilitate the flow of information and bring about external transformative forces through various interaction and communication channels. These influences encompass positive outcomes of socio-technical transitions and deeper engagements such as alliances and cooperative relationships, which can profoundly alter the landscape of the targeted socio-technical systems and accelerate the trajectory of socio-technical transition. Although these influences are often categorised within the broader landscape level in other research projects, it is argued here that landscape should primarily represent external forces on a larger scale, such as economic trends and international relations among countries, while associated socio-technical systems should emphasise interactions between socio-technical systems at a smaller scale.

4.7 Summary: the GIESTS Framework

This section introduces the fundamental components of the GIESTS Framework and furnishes a concise summary of each level, sublevel, and corresponding definitions. Illustrative examples are presented to enhance clarity.

4.7.1 Hierarchical structure of the GIESTS Framework

The GIESTS Framework is structured around three core levels: Global, Internal, and External Socio-technical Systems. Within these levels, sublevels establish a hierarchical framework that comprehensively explores the multifaceted dynamics inherent in socio-technical transitions. This section examines the GIESTS Framework's hierarchical structure, which will be further elucidated in subsequent sections.

Employing a hierarchical approach, the GIESTS Framework methodically dissects socio-technical transitions, providing a structured perspective that permits a detailed examination of the underlying driving forces and intricate interactions. This hierarchical structure underpins a solid foundation for thoroughly analysing and understanding socio-technical transitions.

In the visual representation below, we present the hierarchical structure of the GIESTS Framework as a guiding schematic for the detailed exploration of each level and sublevel. It's crucial to emphasise that, for the case study, a streamlined approach will be adopted to concentrate on the core aspects of the analysis. Consequently, the dual concepts of push and pull forces will be consolidated under the umbrella of positive forces to simplify the narrative. Additionally, the internationally associated socio-technical systems will not be scrutinised in depth due to their relatively lower impact on the focal transition and to maintain analytical clarity. By curating the elements in the case study, we aim to avoid an overly complex result that could obscure the pivotal findings. The overview of the hierarchical structure of the GIESTS Framework is summarised in Figure 4-1.

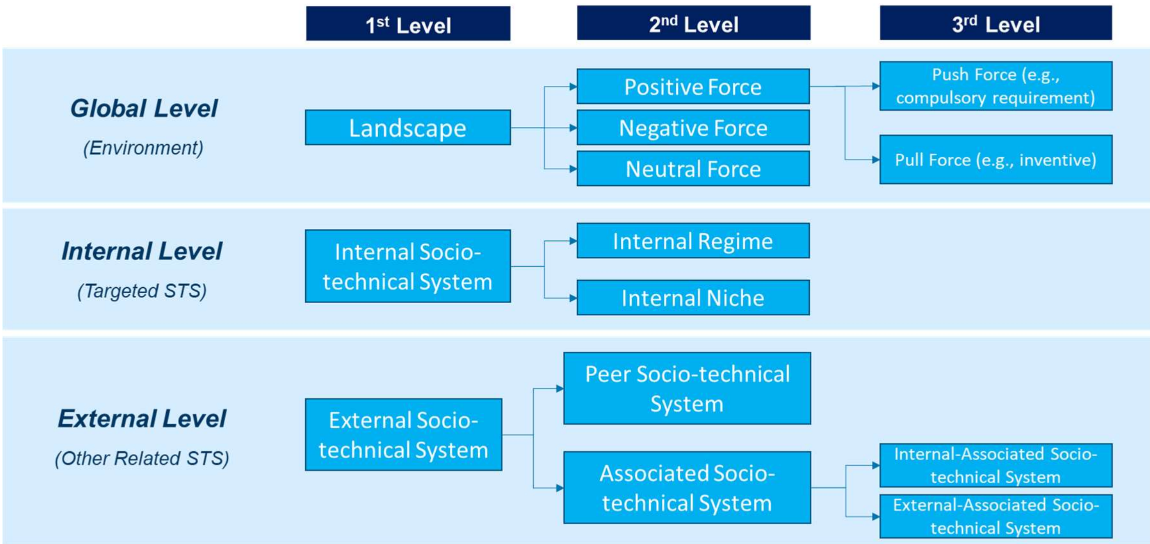

Figure 4-1 Hierarchical structure of the GIESTS Framework

4.7.2 Operation Mechanism of the GIESTS Framework

The GIESTS Framework serves as a robust analytical tool for studying socio-technical transitions. Researchers can use this framework to categorise and analyse the status quo of socio-technical transitions within specific periods, identify critical actors, understand their influence on transition pathways, and assess the exogenous environment's impact on transition trajectories. Figure 4-2 visually represents the operational mechanism of the

GIESTS Framework, depicting the direction of the socio-technical transition, positive and negative landscape forces, the internal socio-technical system, and interactions with associated socio-technical systems.

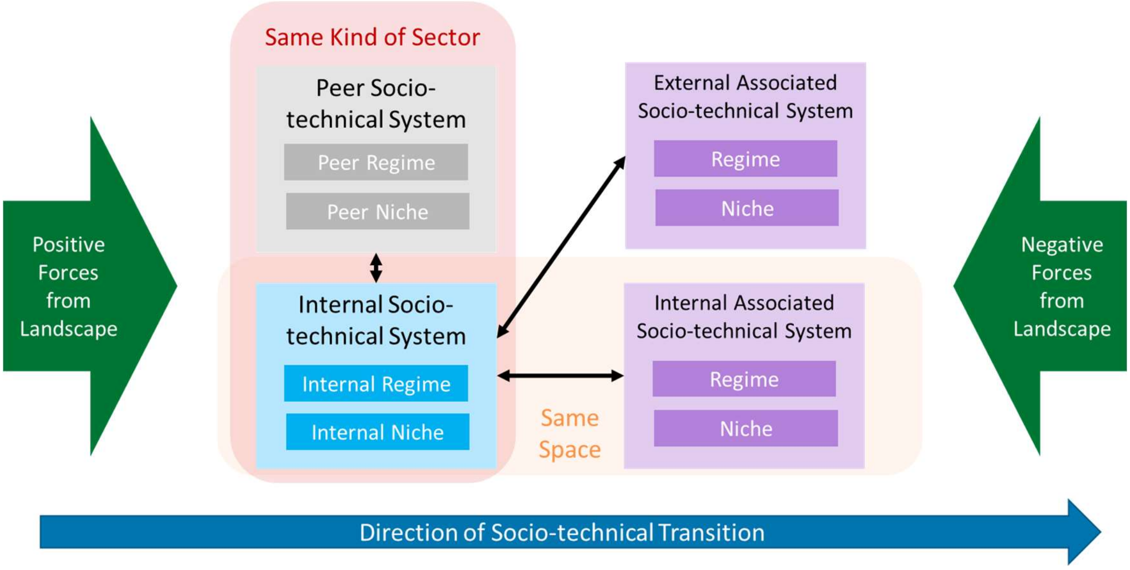

Figure 4-2 The operational mechanism of the GIESTS Framework

Researchers can employ the analytical tool derived from the GIESTS Framework, as presented in Table 4-2, to systematically assess socio-technical transitions in various periods. This table facilitates the identification of crucial transition actors, their influence, and the role of the exogenous environment in shaping transition trajectories, offering a practical and structured approach to transition analysis.

Table 4-2 Analytical tools derived from the GIESTS Framework

Level 1	Level 2	Level 3	Description
Global Level	Landscape	Positive	
		Negative	
Internal Level	Internal Socio-technical System	Internal Niche	
		Internal Regime	
External Level	Peer Socio-technical System	Peer Niche	
		Peer Regime	
	Associated Socio-technical System	Internal socio-technical system	
		External socio-technical system	

4.7.3 Compare the GIESTS Framework with traditional MLP

The concepts of MLP and the GIESTS Framework are valuable frameworks employed to analyse socio-technical transitions, each offering unique perspectives and insights. While both frameworks share a fundamental focus on understanding the dynamics of transitions, they differ in their emphasis and scope. MLP primarily delves into the interactions between niches, regimes, and landscapes within specific socio-technical domains, examining how niche innovations challenge established regimes.

In contrast, the GIESTS Framework takes a broader view by incorporating Global, Internal, and External Socio-technical Systems, encompassing both internal and external factors, including the influence of peer and associated systems. The GIESTS Framework's hierarchical structure allows for a more granular analysis of driving forces and interactions, offering a comprehensive framework for examining transitions in various sectors with global and cross-sectoral perspectives.

In summary, while MLP provides a focused lens on niche-regime-landscape interactions within specific domains, the GIESTS Framework offers a more comprehensive and adaptable approach, making it suitable for analysing transitions across diverse sectors and scales. Researchers can choose between these frameworks based on their socio-technical transition studies' specific context and objectives.

Table 4-3 highlights the key distinctions and similarities between the GIESTS Framework and the MLP in the context of socio-technical transitions. It demonstrates how each framework approaches the analysis of transitions, emphasising different levels and aspects.

Table 4-3 Comparison between the GIESTS Framework and traditional MLP

Dimension	**Multi-level Perspective**	**The GIESTS Framework**

Focus	It concentrates on a single system's niche, regime, and landscape interplay. Does not delve into inter-system or inter-market dynamics.	Broadens the analytical scope to encompass interactions within and across socio-technical systems and markets, including 'peer' and 'associated' dynamics.
Application	Primarily applied within a national or regional context.	Adapts flexibly for global market analyses, enhancing relevance for complex transitions in emerging markets.
Hierarchical Levels	• Niche: Incubation spaces for innovation • Regime: Dominant practices and technologies. • Landscape: Broader external trends and forces.	• Global: Wider global events and trends. • Internal: The target system with its niches, regime, and actors. • External: Influential systems outside the target system.
Spatial Dimension	Recognises spatial scales but does not integrate them as a core analytical element.	Explicitly incorporates spatial dimensions, distinguishing between locally and internationally associated systems for a refined spatial analysis.
Complexity	Established and straightforward, thus user-friendly.	It introduces greater complexity, necessitating more in-depth data and analysis, but provides richer insights into multifaceted transitions.

4.7.4 Summary

The GIESTS Framework, which encapsulates Global, Internal, and External Socio-technical Systems, offers a sophisticated and systematic approach to analysing socio-technical transitions. This multi-tiered framework is meticulously constructed to dissect the complexities of transitions across different levels:

- **Global Level**: At this stratum, the framework investigates the landscape, identifying forces that may accelerate, inhibit, or neutrally affect the socio-technical transition. It considers broad macroeconomic trends, global crises, and long-term shifts that influence the transition at a foundational level.
- **Internal Level**: Here, the focus shifts to the nuances of the internal socio-technical system, delving into the dynamics between niches—spaces for radical innovation—and regimes—the established systems with entrenched practices and technologies. The interactions within this level are critical in determining the pace and direction of

the transition.

- **External Level**: The external dimension brings peer and associated socio-technical systems that, while not directly part of the central transition, exert significant influence on it. These systems may provide comparative insights, competitive pressures, or collaborative opportunities that shape the transition's trajectory.

The GIESTS Framework is esteemed for its exceptional integrative capability, weaving diverse elements into a cohesive analytical narrative. Its design is inherently flexible, enabling adaptation to various research contexts. This adaptability renders it an essential tool for scholars and practitioners dedicated to understanding and facilitating socio-technical transitions across various domains, including energy, transportation, technology, and infrastructure. Beyond guiding empirical analysis, the proposed framework also contributes to theoretical progress. It provides a robust platform for the formulation of innovative strategies and the crafting of effective policy interventions.

Chapter 5. Case study

In this chapter, the outcomes of the case study are elucidated, incorporating both secondary and primary data sources. The chapter is structured as follows:

- **Section 5.1**: The scope of the case study is clearly defined to provide a concise understanding of its boundaries and aims. This initial section sets the stage for the following detailed examination, ensuring clarity and focus throughout the analysis.
- **Section 5.2**: Offers a comprehensive overview of the case study, delineating the socio-technical transition path towards automotive electrification. This transition is segmented into five distinct stages, drawing upon authoritative reports, scholarly articles, and insights gained from participatory observation. The division into stages facilitates a structured exploration of the complex transition process.
- **Sections 5.3 to 5.7**: Detail the findings from the secondary data analysis, enriched by participatory observation, within the GIESTS Framework. These sections meticulously unpack the dynamics of each transition stage, leveraging the GIESTS Framework to provide a systematic and in-depth understanding of the factors driving and influencing the shift towards electrification in the automotive industry.

The chapter concludes with a comparative analysis of the results, synthesising insights from secondary and primary data sources. It underscores the comprehensive nature of the study, providing a rich, multi-faceted understanding of the socio-technical transition towards automotive electrification.

5.1 Scope of the case study

In a broad context, China's NEV landscape encompasses three primary categories: fuel cell vehicles (FCV), PHEVs with range extenders, and BEVs. While there are other vehicle types with varying powertrains, such as mild-hybrid or hybrid electric vehicles, it is essential to note that these vehicles, despite their improved fuel economy, are typically not categorised as NEVs since they still rely on gasoline.

Another dimension for classifying vehicles involves distinguishing between passenger cars and commercial vehicles. Passenger cars encompass many vehicle types, including sedans, SUVs, sports cars, coupes, hatchbacks, multi-purpose vehicles (MPVs), and wagons, primarily designed for transporting individuals on public roads. In contrast, commercial vehicles serve specific commercial purposes, including transporting large numbers of people or cargo, with trucks, pickups, and buses as typical examples.

For this research project, the focus is directed toward the passenger car sector as the primary socio-technical system of interest. This choice is rooted in the sector's substantial influence on people's daily lives and its involvement with a multitude of socio-technical factors when compared to commercial vehicles. In the NEV sector, attention is paid to the socio-technical niche, particularly concerning BEV, PHEV, and range extension vehicles. Collectively, these categories constitute the majority of NEVs in China.

The main objective of this research endeavour is to investigate the transformation of the NEV sector, specifically how it evolves from a niche position to supplant the internal combustion vehicle sector and establish itself as the dominant regime or mainstream within the targeted socio-technical system. The blue-shaded columns in Table 5-1 are within the scope of the case study.

Table 5-1 Scope of the case study

Automotive sector in China	Passenger Car Sector (Targeted Socio-technical	Internal Combustion Engine Vehicle Sector	Pure Gas Strong Hybrid Mild Hybrid
		NEV Sector	Pure Electric

	System)		Plug-in Hybrid Range Extension Fuel Cell Other new energy
	Commercial Car Sector	Internal-combustion Engine Sector	Pure Electric Plug-in Hybrid Range Extension Fuel Cell Other new energy

Moreover, this case study primarily focuses on China from a spatial perspective. However, it is worth noting that one of the critical objectives of this research is to analyse the impact of diverse socio-technical systems. Therefore, the interaction with the automotive and NEV sectors in North America, Europe, and other countries within the Asia-Pacific (APAC) region will also be explored and deliberated upon. The research project will explore how these automotive and NEV sectors across different regions influence the trajectory of the targeted socio-technical system.

5.2 Overview

The automotive sector is renowned for its diversity and extensive value chain, which can influence other sectors (Orsato and Wells, 2007a). The introduction of vehicles has significantly improved the quality of human life, with personal consumption being a primary driver of sector growth (Liu et al., 2015). However, the proliferation of vehicles has led to a dramatic increase in energy consumption and environmental burdens, thereby creating substantial environmental pressures. This has emerged as a central challenge requiring resolution (Dargay et al., 2007, Orsato and Wells, 2007a, Orsato and Wells, 2007b). In response to these environmental pressures, electric vehicles have been recognised as a solution to ensure the sustainable development of the automotive industry by reducing energy consumption through higher energy efficiency and minimising greenhouse gas emissions (Faria et al., 2013).

Unlike Europe and the United States, which embarked on electric vehicle exploration and development as early as the late 20th century, China's foray into BEV began later and can be traced back to 2001. In 2001, China witnessed a significant transformation, particularly its accession to the World Trade Organization (WTO), leading to a more open market (Harwit, 2001). This compelled China to reevaluate its automotive strategy as foreign companies designed and manufactured the most popular cars. While the market was substantial, it lacked the strength and competitiveness required in this new exogenous environment (Jin et al., 2021, SCIO, 2018).

The Tenth Five-Year Plan (FYP), a primary national planning document, incorporated NEV into its '863 plan' (People's Daily, 2001). This plan established the initial technological roadmap for NEVs, referred to as the 'Three-by-Three Research and Development Strategy', forming the foundation for subsequent NEV development, as will be elaborated in later sections of this case study (Jin et al., 2021). One of the interviewees mentioned that '*Three-by-Three Research and Development Strategy provides automakers with a direction for making a long-term plan, and such direction is still valid today.*' Subsequently, the Chinese government employed a range of policy instruments to create a protective environment for the NEV niche and foster its development. These policies fall into seven categories: macroscopic, demonstration, subsidisation, preferential tax, technical support, industry management, and infrastructure (Li et al., 2016). Different policy tools have been applied at different stages of the socio-technical transition to promote the transition process effectively.

From 2001 to 2008, China has invested approximately 125 million USD in NEV development and facilitated collaboration between leading universities, governments, research institutions, and significant local automotive companies through numerous pilot projects based on the Three-by-Three Research and Development Strategy (Gong et al., 2013). The debut of 500 China-made NEVs during the Beijing Olympic Games marked a significant milestone for NEV development, boosting local automotive companies' confidence and accelerating their NEV research and development efforts (Jin et al., 2021). However, despite these achievements, the foundation of China's automotive industry remained fragile, with the supply chain heavily reliant on foreign companies. While China's passenger car market surpassed that of the United States and became the largest in 2008, it was still considered 'big but not strong', as demonstrated in Figure 5-1. International automotive OEMs have predominantly controlled vital technologies and know-how for the automotive sector. Local Chinese automakers were engaged in learning from these global leaders through joint ventures, collaborations with suppliers, and reverse engineering.

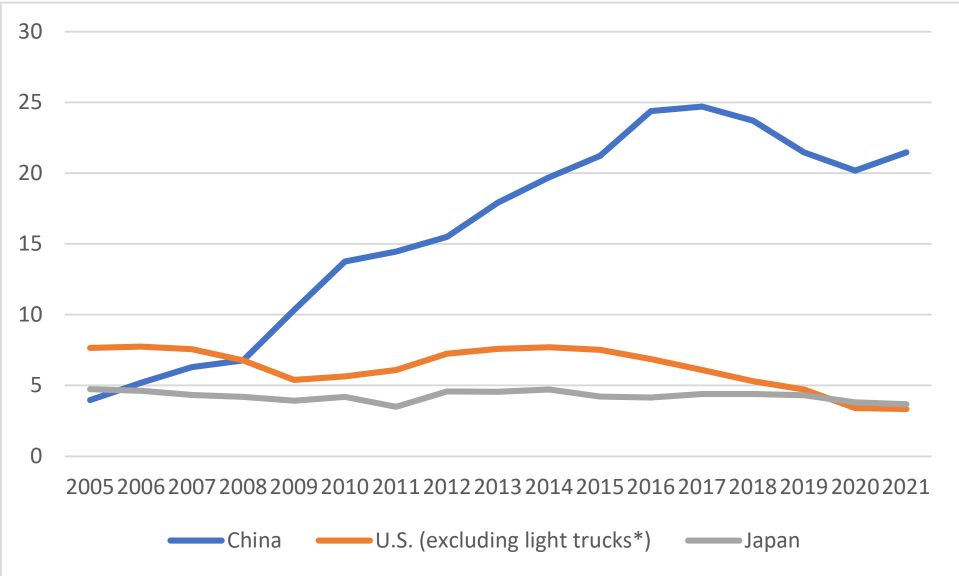

Figure 5-1 Sales of passenger cars in selected countries worldwide from 2005 to 2021 (in million units) (OICA, 2022)

2008, the global financial crisis erupted, causing a sharp increase in oil prices and significantly impacting China's economy due to its heavy reliance on foreign oil. Concurrently, the U.S. government introduced a massive economic stimulus plan to promote clean energy industries (Ball, 2019). These circumstances influenced China's decision to promote the NEV sector. In 2009, a new era of NEV development in China began when former President Jintao Hu announced during the annual speech to the National People's Congress that NEVs would become a part of China's national strategy. This announcement marked official central government support for NEV development (Jin et al., 2021).

From 2001 to 2009, the Chinese government has established a network comprising key stakeholders and sought the right direction for the NEV sector. This was done against the backdrop of a weak Chinese economy, necessitating efficient utilisation of limited resources for innovative sector outcomes.

Afterwards, from 2009 to 2013, large-scale projects promoting NEV development were launched in major Chinese cities. The 'Ten Cities, Thousand Cars' program, jointly initiated by China's science and finance ministries, aimed to deploy 10,000 NEVs across 25 cities over three years, primarily targeting government and state-owned company fleets (MOF, 2009). To stimulate consumer adoption, five of these cities were selected for pilot programs focused on private NEV usage (CATRC et al., 2015).

During this transformative period, the Chinese government employed various strategies to nurture the burgeoning NEV sector, deliberately creating protected sub-niches in select locales (Jin et al., 2021). An industry veteran with over a decade of experience with local automakers reflected on the competitive landscape of the early 2010s, noting, '*The local automakers were still competitive in the early 2010s, especially for products requiring technologies controlled by developed countries like BEV. The protection became extremely important for the survival of these innovations.'* This perspective highlights the significance of government interventions in safeguarding and promoting local innovation amidst a challenging competitive environment, underscoring the strategic role of policy in shaping the trajectory of China's NEV sector.

Since 2013, worsening environmental problems, such as the 2013 smog crisis in Beijing, have intensified pressure on the government to find solutions (Jin et al., 2021). Initially introduced to alleviate traffic congestion, the quota system in Beijing became a pivotal driver for consumers to switch from ICE vehicles to NEVs. This system limited the issuance of new license plates for ICE vehicles, requiring a lottery for customers seeking new car licenses (CATRC et al., 2015, Zhang and Qin, 2018). NEVs were given a higher probability of obtaining a license plate, leading to a surge in NEV adoption, especially BEVs (Xu, 2013, CATRC et al., 2018).

Concurrently, many other Chinese cities introduced policies such as license plate discounts and road access privileges to promote NEVs. The number of pilot cities for NEVs also expanded from 25 to 88 (CATRC et al., 2017, CATRC et al., 2022). Government incentives and subsidies at the central and local levels significantly stimulated the NEV transition. Production volumes of NEVs proliferated during this period, reaching 500,000 units by 2016, as illustrated in Figure 5-2.

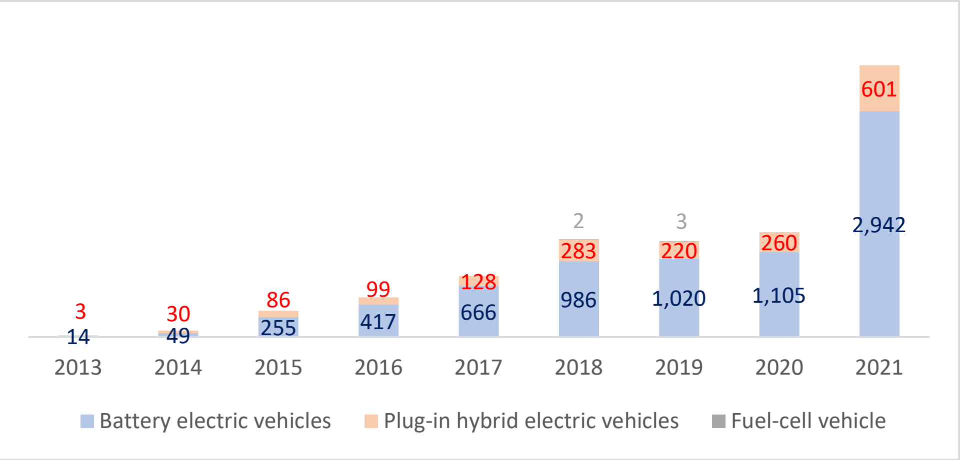

Figure 5-2 Annual production volume of new energy vehicles in China from 2013 to 2021, by type (in 1,000') (CAAM, 2022)

Despite rapid progress during this phase, several challenges emerged, including the NEV subsidy fraud scandal. Despite these obstacles, the market evolved from government to market-led, and NEVs gradually transitioned from niche products to mainstream alternatives. An interviewee stated, ' *Around mid-2015, we could see more than 300 start-ups that claim they could build NEVs; however, less than 5% of them could keep their promise to investors and the government.*'

In 2017, a new phase in the development of the NEV sector began. Direct subsidies for NEVs were reduced, and the Chinese government introduced the 'dual-credit system', requiring automakers to produce more NEVs and improve the fuel economy of ICE vehicles (Dong and Liu, 2020, CATRC et al., 2020). Companies failing to meet credit standards had to purchase credits from others to continue selling vehicles in the market. This policy shifted from subsidy-based promotion to mandatory requirements (Jin et al., 2021, Monika, 2020, Li et al., 2018b).

Reflecting on the impact of these policy changes, several interviewees with experience in multinational automakers and joint ventures observed, '*The launch of the dual-credit system in 2017 makes the multinational automakers firstly aware of the trend of electrification in China.*' This statement highlights the system's role in enforcing compliance and signalling the irreversible trend towards electrification within the Chinese market to the global automotive industry.

Infrastructure development became crucial due to long queues at public charging stations and the need to address range anxiety (Zhang and Qin, 2018, Yu et al., 2019, Dong and Liu, 2020). The government implemented policies to boost charging infrastructure, alleviating concerns among potential buyers (McKinsey, 2019). Infrastructure development can be found in Figures 5-3 and 5-4. At the same time, Tesla significantly influenced consumers and infrastructure development, spurring the growth of fast-charging stations. By the end of this stage, NEVs, especially BEVs, began to capture a significant market share from ICE vehicles.

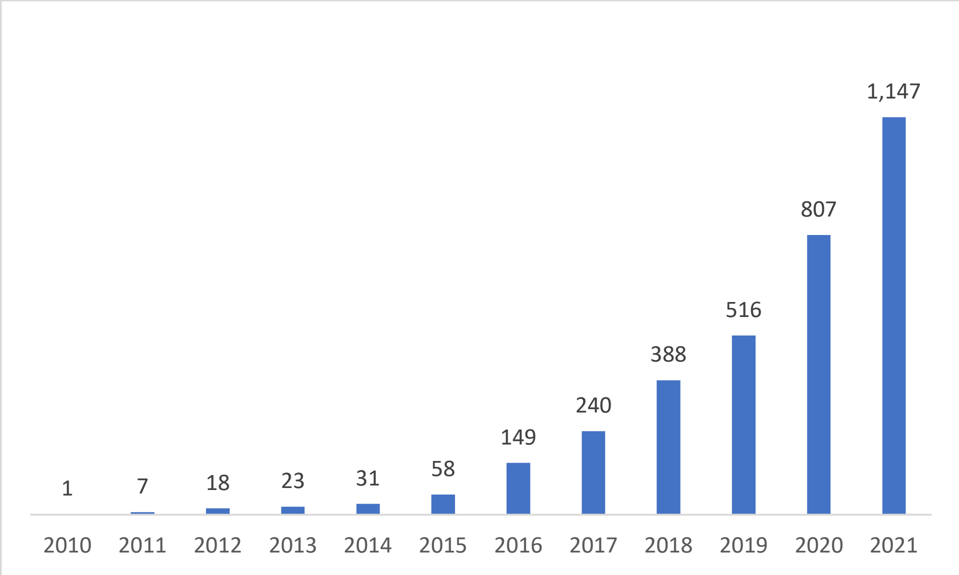

Figure 5-3 Total number of public electric vehicle charging piles in China from 2010 to 2021 (in 1,000s) (Eastmoney.com, 2022)

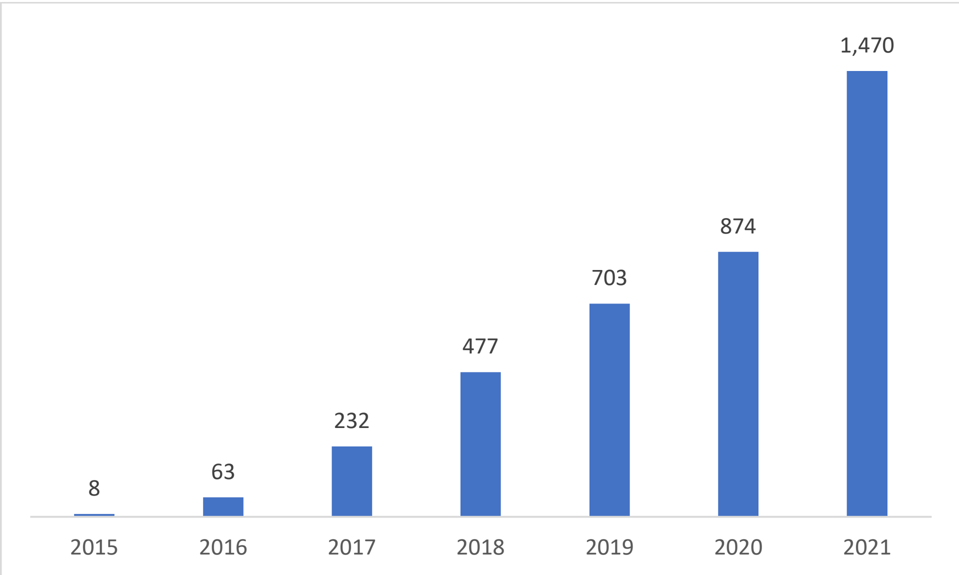

Figure 5-4 Total number of private electric vehicle charging piles in China from 2015 to 2021 (in 1,000s) (Forward Intelligence, 2022)

In the latter part of 2019, a new era dawned on the Chinese automotive market. Despite the significant disruptions caused by the global pandemic that began in late 2019, the automotive industry saw a substantial reduction in sales volume. Remarkably, even in these challenging circumstances, the sales of NEVs continued to grow in 2020, leading to an increased market share (CBIRC, 2023). This phenomenon signalled an accelerated transition from ICE vehicles to NEVs. During this same period, innovative local start-ups began to claim a larger market share from traditional automakers. BEVs gradually transitioned from niche products to becoming the mainstream choice for consumers. In 2021, Wei-Xiao-Li, comprising Nio, Li Auto, and XPeng Motors, the top three BEV start-ups, capitalised on this momentum, seizing market share. By the end of 2021, all three start-ups had collectively achieved around 100,000 total sales (CBIRC, 2022).

However, the landscape shifted again in 2022. Traditional automotive OEMs, particularly local companies, gained ground by offering increasingly competitive products with superior quality, craftsmanship, and healthier cost structures. This shift was underlined by an interviewee from a top local start-up, who observed, '*As demand increased, automakers without sufficient manufacturing capabilities, especially the local automakers, lost the leading position very soon.*' During this phase, market fluctuations became commonplace, and the industry underwent a process of reformation. Leading the market in one year did not guarantee the same position in the next, and leaders in the ICE vehicle sector gradually lost their foothold during this transformative period. Figure 5-5 illustrates this shift, with international automakers having limited exposure in the list of top sales while local automakers took the lead. In Chapter 7, I will delve into this diversified performance of different types of automakers through capabilities analysis.

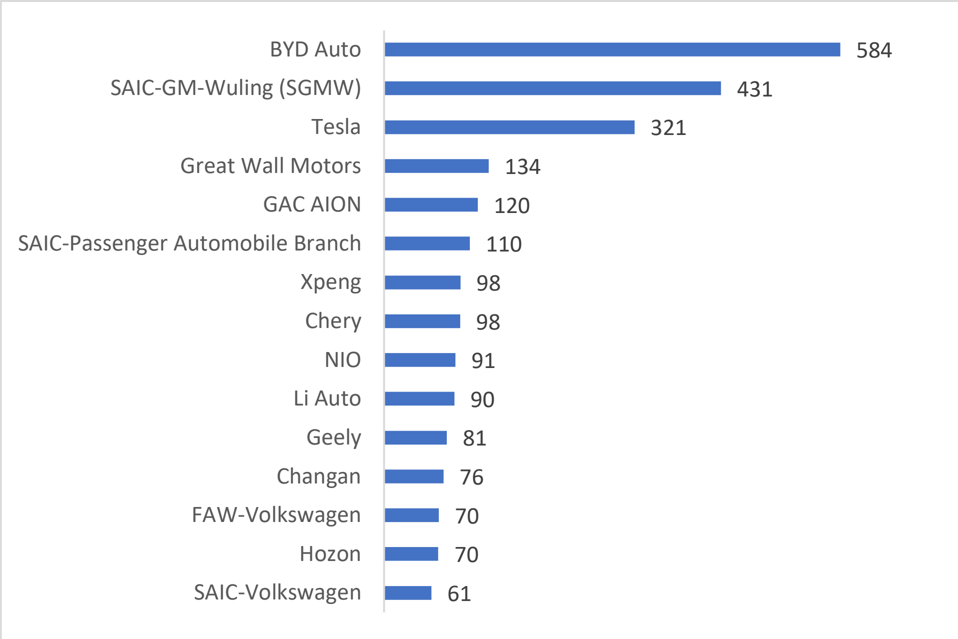

Figure 5-5 Top 15 new energy passenger car companies in China in 2021 (in 1,000 units) (Sina Auto, 2022)

Another notable trend in this stage was internationalisation. Starting in 2019, Chinese OEMs, both traditional players like SAIC and BYD and start-ups like XPeng Motors and Nio, began exploring opportunities for expansion overseas. Unlike previous strategies focusing on less developed or competitive markets in Southeast Asia or the Middle East, they set their sights on the European Union. The EU offered attractive policies to promote NEVs and a high penetration rate of such vehicles (Little, 2022). Additionally, the technological gap between ICE vehicles and NEVs was not as pronounced, making Chinese automakers' products more competitive in developed markets (CATRC et al., 2021).

An interviewee from the internationalisation department of a local automaker encapsulated this ambition, stating, '*Our leadership team believes that we could enter the developed markets with our prevailing intelligent features.*' This assertion underscores the confidence among Chinese automakers in their innovative capabilities and product offerings, positioning them as formidable competitors on the global stage. This shift toward internationalisation triggered more significant interaction between the socio-technical systems of the European Union's automotive sector and mainland China's automotive sector, impacting talent mobility, global supply chain development, and organisational structures. Figure 5-6 shows the average financial subsidies at purchase in major NEV markets in 2022.

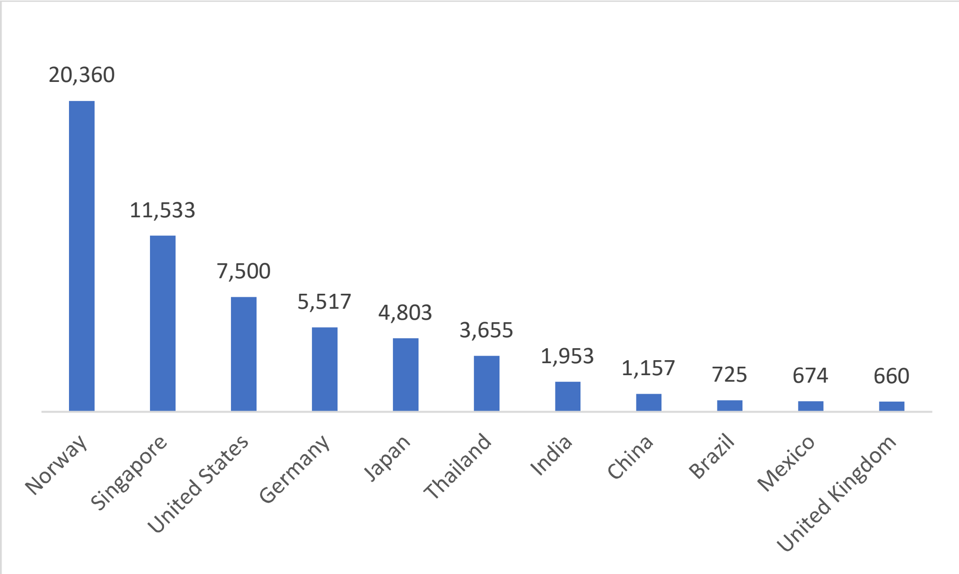

Figure 5-6 Average global EV financial subsidies at purchase in selected countries in 2022 (in U.S. dollars) (Little, 2022)

This section provides an overview of the socio-technical transition from ICE vehicles to NEVs in China and proposes dividing this transition into five distinct stages. These stages are characterised by different attributes and levels of niche development, including exploration, pilot programs, market formation, market maturation, and market reformation. A summary of these five stages is presented in Table 5-2, serving as the foundational structure for the subsequent case study.

Table 5-2 Summary of stages of the socio-technical transition of NEV in the automotive sector in China

Stage	Exploration	Pilot-run	Market Formation	Maturation of Market	Market Reformation
Period	2001-2009	2009-2013	2013-2017	2017-2019	2020-2022
Description	· An initial technology roadmap was developed, with significant support from academic institutions. · The quest for direction in the new energy vehicle sector and creating industry-academic networks have been pivotal.	· Goals have been established as guiding principles for subsequent action plans. · Pilot programs for NEV promotion and market testing have jumpstarted the NEV sector's value chain development.	· The market has experienced rapid growth, solidifying China's position as the world's largest NEV market. · Government policies and plans have matured due to valuable experiences gained during this period. · Numerous companies from various industries have entered the EV sector to access subsidies.	· Stricter requirements for OEMs to qualify for subsidies, based on technological levels, have been implemented. · Start-ups took the lead in the first round of selections to eliminate unqualified players. · Infrastructure construction progressed swiftly, with over 770,000 charging stations by 2018.	· Local OEMs, including State-Owned Enterprises (SOEs) and private firms, have outperformed local start-ups. Joint Ventures (JVs) have also introduced competitive products. · Fewer policies have been enacted to promote NEVs, resulting in a market-driven more by market forces than government policies.
Volume Driver	· Smaller-scale pilot programs	· Bigger-scale pilot programs	· Policies mainly	· Policies and Market	· Market mainly
Main Buyers	· Government, research institutions and universities	· Public fleet, including public service, government, and SOEs	· Private Customers	· Private Customers	· Private Customers
Starting Point	In 2001, China's tenth five-year plan introduced the 'Three-by-Three Research and Development Strategy' for NEVs, encompassing fuel cell, hybrid, and electric technologies, along with three	2009, during his annual National People's Congress speech, former President Hu Jintao officially declared NEV development as a national strategy aligning with the	In 2013, the 'Air Pollution Action Plan' (State Council of China, 2013) identified NEVs as critical in achieving clean energy goals, pressuring provincial and local governments to incorporate	In 2017, subsidies were reduced, and the dual-credit system was announced for implementation in 2019, marking a shift from incentives to mandatory standards for OEMs.	In 2020, BEV sales in China's passenger car market surpassed one million units for the first time, with private customers accounting for over 80% of total sales, a historic milestone (Jin et al., 2021). Additionally, Tesla's

	core component areas: powertrain control systems, driving motors, and batteries. (Jin et al., 2021).	nation's current conditions.	NEV targets into their clean air plans with central government guidance.		localised models have increased their production volume.
Key Events/ Projects	• 863 Program from 2001 (People's Daily, 2001) • Olympic demonstration in 2008 (Jin et al., 2021)	• 'Ten Cities, Thousand Cars' program	• 'Ten Cities, Thousand Cars' program has been finished, and more than 300 cities have proactively promoted NEVs compared to merely 88 cities in the original plan (Dong and Liu, 2020)	• Tesla's electric vehicle factory in Shanghai's newly approved Lingang free-trade zone • Competitive EV start-ups such as Nio and XPeng started to launch products	• Energy-saving and New Energy Vehicle Technology Roadmap 2.0 was released in 2020 (China SAE, 2020) • The State Council published the NEV Industry Development Plan (2021-2035) in 2020 (State Council of China, 2020)
Major Policies	• Management Rule of New Energy Vehicle Product Market Entrance (National Development and Reform Commission, 2007)	• The Notice on Implementing Energy Saving and New Energy Vehicle Pilot Program detailed vehicle eligibility, technical criteria, and subsidy amounts (State Council of China, 2012a)	• Guidance on Accelerating the Application of New Energy Vehicles (State Council of China, 2014) • Expanded central tax waiver (Yu et al., 2019) • NEV fleet procurement requirements (Heller, 2017) • Charging infrastructure subsidies at both central and local levels (Jin et al., 2021)	• The abolishment of the limitation of foreign ownership on local auto companies and the removal of the restrictions on NEV joint ventures (Cheng, 2021) • A dual-credit system for increasing the number of NEVs produced and enhance the fuel economy for ICE vehicles at the same time (Cui and He, 2016) • Free or cheap license plates for NEV in big cities which have high costs and limited quota of license plates (Dong	• The policies for subsidies have continued to reduce; it was announced in 2021 that the subsidies would be withdrawn in 2022 (in 2022, the target time was postponed to 2023) (Liu et al., 2022a) • Updated dual-credit system, including corporate average fuel consumption (CAFC) and NEV credit requirements (Monika, 2020) • Notice on Promoting the Participation of New Energy Storage Technologies in the Electricity Market and

				and Liu, 2020)	Dispatches (CNESA, 2022)
Key Challenges	· Lack of technological and industrial background	· Local protectionism · The government, instead of the market, triggers the technological roadmap · Products are not competitive enough to serve target customers	· NEV subsidy scandal of 2016, which stimulate the development of technological standards · Lack of charging stations to serve the increasing number of NEVs	· Lack of charging stations to serve the increasing number of NEVs	· Lack of plan for the recycling of retired battery · Shortage of chips and lack of capability to produce chips internally · Increasing cost of raw material of batteries

5.3 Stage 1: Exploration

5.3.1 Overview

In the early 2000s, China identified NEVs as a crucial strategic direction, viewing the transition from ICE vehicles to NEVs to reduce foreign fossil fuel dependency, combat worsening air pollution and CO2 emissions, and catch up with developed countries' technological prowess (CATRC et al., 2022). Despite lagging behind Western and Eastern countries in technological foundations and industry development for advanced technologies, the Chinese government believed this gap could be bridged through new technological sectors (Liu and Kokko, 2013, Jin et al., 2021). However, due to these initial shortcomings, China dedicated significant time and resources to the early stages of this socio-technical transition, which I term the ‘exploration stage’ in my research.

This stage’s origins can be traced to including the NEV sector in the 863 Program, or the National High Technology Research and Development Program, in 2001. This inclusion was pivotal for the nascent sector, as the program was the flagship for guiding strategic directions in advanced technology (People's Daily, 2001, Liu and Kokko, 2013, Gong et al., 2013). Throughout most of this stage, the primary focus within the niche was on research to identify the right technological direction and roadmap while establishing a robust foundation for future sector development.

Simultaneously, numerous networking activities between the government, academic institutions, and industry were initiated to better consolidate and utilise China’s limited resources during this period. The conclusion of this stage is marked as 2009, when the emphasis shifted from research to gradual commercialisation. The launch of BYD’s F3DM, the first mass-produced NEV by a local company in December 2008, represented the initial fruits of the socio-technical transition resulting from the efforts during this stage (Gong et al., 2013). In the following sections, we will delve into the various components of this stage based on the conceptual framework developed in the previous Chapter. Moreover, Table 5-3 in section 5.3.7 shows a summary of the analysis.

5.3.2 Global level

In 2001, China’s accession to WTO marked a pivotal shift, necessitating an elevation in market openness and exposing it to heightened global competition. This development compelled the country to reassess its strategies and plans for industrial development. Strategies that were initially designed for a protectionist environment were rendered obsolete in the face of these new global challenges. The impact of WTO accession extended beyond the automotive industry, affecting sectors such as agriculture, insurance, telecommunications, and banking (Harwit, 2001).

In the context of the socio-technical transition from ICE vehicles to NEVs, China’s WTO accession acted as a positive force for the transition. This force drove the nation to make strategic decisions and take action to enhance its competitiveness across various sectors, including the automotive industry (SCIO, 2018). It spurred the automotive sector to improve quality systems, cost competitiveness, and process management to compete globally. It compelled China to chart a new course to catch up with global leaders. This, in turn, created a window of opportunity for the NEV sector to flourish in China.

Simultaneously, global discussions surrounding climate change gained prominence. The escalating levels of carbon dioxide (CO2) have emerged as the primary driver of global warming, prompting industry, academia, and governments worldwide to address environmental concerns (Zhang and Cheng, 2009). Furthermore, China's rapid economic growth led to a substantial increase in energy consumption and carbon emissions. Between 1980 and 2007, during a period of 9% average annual GDP growth, energy consumption surged by 340%, while CO2 emissions rose by 352% (Zhang and Cheng, 2009, Liu et al., 2015). The Kyoto Protocol, which established legally binding emission reduction targets from 2008 to 2012 (Protocol, 1997), was considered by some scholars and experts to be flawed and insufficient in achieving its intended reductions (Böhringer, 2003). Nevertheless, imperfect as it may have been, the treaty provided impetus for the socio-technical transition to advance, especially after China's State Council linked the automotive industry to climate change concerns in 2007 (Bohnsack, 2018). These environmental challenges and events necessitated new solutions to mitigate environmental impact, with NEVs emerging as one solution due to their potential to reduce fuel consumption and address the environmental consequences of oil supply and demand imbalances (Zhang and Qin, 2018).

Additionally, the Beijing Olympics in 2008 played a pivotal role in accelerating economic growth in the host city and stimulating economic development at the regional level, thereby significantly impacting the national economic landscape (Huang, 2011, Giulianotti, 2015). During the Olympic Games, NEVs played a crucial role in facilitating the mobility of athletes. Despite product limitations, China introduced 500 domestically manufactured NEVs, including electric buses and passenger cars, through government procurement (Lane et al., 2013). This demonstration inspired local automotive companies, signalling the government's commitment to NEV development, and showcased China's determination to promote NEVs on the international stage (Jin et al., 2021).

5.3.3 Internal level: regime

During this stage, the traditional ICE vehicle dominated China's automotive sector. The period from 2000 to 2010 holds immense significance in the history of China's automotive sector. Annual car production surged from 2 million units in 2000 to over 10 million in 2009. This exponential production growth involved more than 200 OEMs, primarily state-owned ones, as well as joint ventures between foreign and local companies, such as FAW-VW (a joint venture between China's FAW and Germany's Volkswagen) (OICA, 2022, Liu and Kokko, 2013, CPCA, 2023).

As the market expanded and global brands gained significant market share, international automotive companies financially increased their investments in China by deploying human resources. The challenge of bridging language barriers and corporate cultures was notably highlighted by an interviewee with experience at Chang'an Ford, who remarked, '*Initially, finding individuals with strong English proficiency, the official working language of Ford, proved challenging. To address this, employees from Taiwan were relocated to Chang'an Ford as representatives of Ford Motor Company in the joint venture.*' This strategic move addressed immediate operational needs and fostered a unique blend of skills and expertise within the joint venture, contributing significantly to areas such as management processes, product development, design, quality control, and the establishment of aftersales systems.

Even though local automotive companies lagged behind global ones, their participation in joint ventures gave them opportunities to learn from leading global automotive firms. The sales volume of different types of automakers could be found in Figure 5-7. The experience gained through collaboration with these global companies laid the foundation for future growth. Since 1978, the Chinese government has been harnessing foreign direct investment (FDI) with a 'trade market for technology' strategy (He and Mu, 2012). Interviewees with joint venture experience have observed a palpable eagerness among local automaker representatives to assimilate new knowledge and practices. One noted, '*The employees who represented the local partner in the joint venture express high motivation to learn new knowledge to us, which could be one of the reasons for their quick catch-up.*'

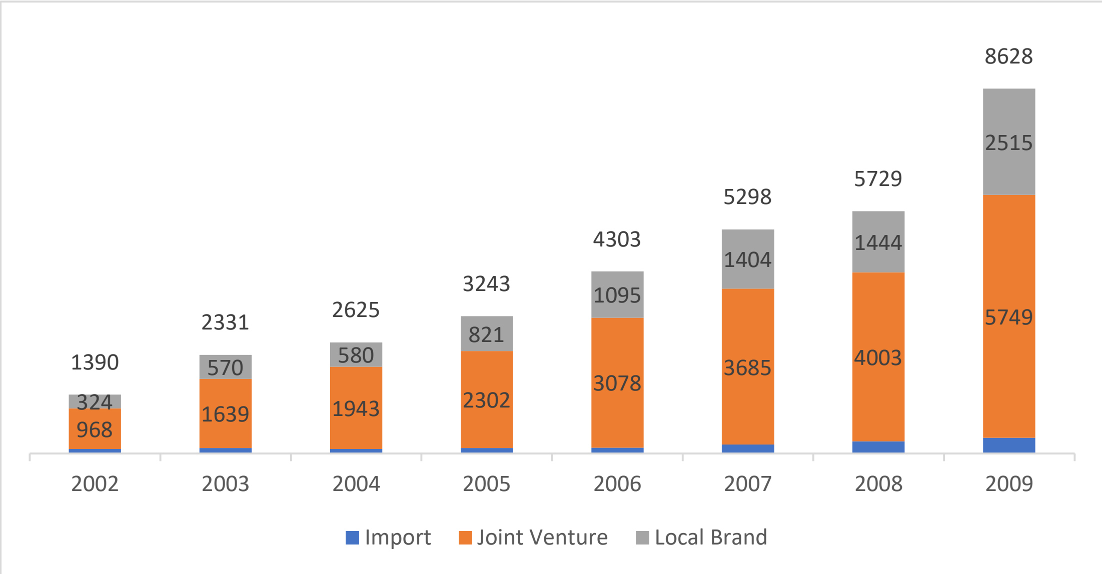

Figure 5-7 Passenger Car Market in China, 2002-2009 (in thousand) (CPCA, 2023)

As vehicle sales and ownership escalated rapidly in the early 21st century, the entire value chain of the automotive sector expanded, involving more participants. Business collaborations with joint ventures compelled automotive suppliers, traditionally focused on developing and manufacturing products based on aftermarket criteria and standards, to align with the production-level standards established by global automotive companies. Furthermore, when multinational automakers began localising their products in China, they brought their global suppliers into the market. This intensified competition, motivating local suppliers to enhance their capabilities, and facilitated knowledge transfer and human capital development through joint ventures and local localisation activities.

For instance, Bosch, in its pursuit of entering China’s automotive business, established various business units, subsidiaries, and joint ventures, encompassing powertrain, electric vehicle systems, platforms, and more. By 2021, Bosch Group operated 59 companies in China, generating revenues of 128 billion CNY (approximately 18-20 billion USD, depending on exchange rates) (Markline, 2021).

5.3.4 Internal level: niche

The 863 Program is a pivotal milestone in the initial stage of China’s transition toward NEVs. This program delineated the direction for NEV development over the next two decades, mainly through its ‘Three-by-Three Research and Development Strategy’. This strategy encompassed three NEV technologies: (1) fuel cells, (2) hybrid systems, and (3) electric vehicles, as well as three critical component technologies: (1) powertrain control systems, (2) drive motors, and (3) batteries (Jin et al., 2021, Ouyang et al., 2018, CATRC et al., 2022).

From 2001, the Program engaged scientists from over 200 universities and experts, and by 2005, it had already garnered an investment of 880 million CNY (approximately 125 million USD). Post-2006, investment increased further, culminating in 1.1 billion CNY (around 140 million USD) allocated to the program for the 11th five-year plan, lasting until 2010 (Bohnsack, 2018). The government played a pivotal role in driving the transition forward, fostering a unique industry-government-academic network under the central government’s leadership (Jin et al., 2021, Liu and Kokko, 2013).

Given local automotive companies' limited research and development capabilities at that time, academic institutions assumed pivotal roles in advancing NEV technologies. Leading Chinese universities cultivated relationships and collaborations with domestic automotive firms, establishing specialised research centres tailored to their respective capabilities and resources.

Throughout this period, the NEV market had yet to take full shape. The niche’s primary focus was determining technological directions, conducting research, establishing networks, and initiating smaller-scale projects. Nonetheless, the government tried to create space for NEV deployment, although not on the scale seen in the second stage. For instance, the Chinese government leveraged the opportunity presented by the Olympic Games to procure hundreds of domestically produced NEVs (Zhang et al., 2014).

5.3.5 External level: peer socio-technical systems

As China embarked on the journey to determine the future direction of NEV development, global automotive giants such as General Motors in the USA and Toyota in Japan were dedicating substantial resources to developing hybrid technology (Gong et al., 2013). These multinational OEMs introduced hybrid products to the Chinese market through their joint ventures, contributing technological expertise and know-how essential for the sector’s growth, encompassing engineering design, manufacturing, and operational processes.

Toyota, for instance, launched its highly successful Prius model in Japan in 1997 and in North America during the early 2000s, marking the first wave of mass-produced hybrid products in the global automotive industry. The Prius accumulated invaluable data through real-world usage and marked its introduction into the Chinese market via Toyota’s joint venture in 2005, becoming the market’s inaugural hybrid product. Beyond imparting expertise to local OEMs, it stimulated the entire value chain of the

NEV sector as localised parts production increased. Concurrently, these products helped Chinese consumers better understand NEV offerings (Zhang et al., 2014).

However, even though hybrid products were available in the global market before 2009, PHEVs and BEVs remained relatively rare in leading automotive markets. Most BEV programs were still considered advanced initiatives among global automakers rather than mass-production-focused ventures aiming for profitability. Nonetheless, despite the absence of breakthroughs, some smaller-scale projects and products were launched globally. For instance, Tesla introduced the Roadster in North America in 2008. Based on a platform supplied by Lotus, this all-electric coupe served as a pioneering effort and laid the groundwork for global BEV development, notably in areas such as the strategic deployment of charging stations to meet car owners' needs (Stringham et al., 2015).

As detailed in the previous section, a significant influx of international talent entered China's socio-technical system. Taiwan emerged as one of the primary sources of these talents. In the 1990s, Taiwan's automotive sector experienced rapid growth due to its robust economic expansion, earning it a place among the 'Four Asian Tigers' alongside South Korea, Hong Kong, and Singapore (Bloomenthal, 2021). By 1999, ten automotive OEMs in Taiwan produced vehicles for American, Japanese, French, and German automotive companies (DVMA, 2022).

Nonetheless, in the 2000s, Taiwan's automotive market began to contract. Annual production, hovering around 400 thousand units during the 1990s and early 2000s, declined to approximately 300 to 350 thousand units in the late 2000s, as illustrated in Figure 5-8. As the market contracted, so did the number of automotive OEMs. By 2009, only eight automotive OEMs remained, with just five producing over 10,000 vehicles annually (DVMA, 2022). Faced with this situation, professionals within the industry had to make choices and explore new opportunities. Many Taiwanese automotive experts and companies decided to move to China or invest in the Chinese market. Armed with more vital foreign language skills, extensive experience in cooperating with foreign firms, mature professional competencies, and Mandarin as their native language, these professionals brought valuable technological and managerial capabilities to China's automotive sector, serving as bridges between global automakers and local Chinese automakers.

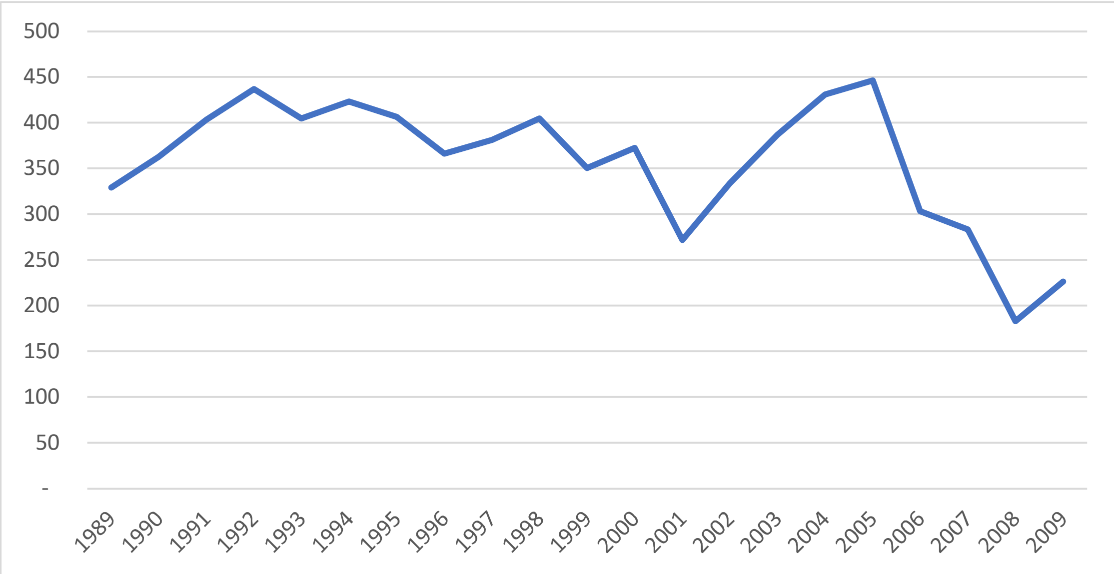

Figure 5-8 Local-built Car in Taiwan, 1989-2009 (in thousand) (DVMA, 2022)

Reflecting on this transition period, an interviewee who moved from Taiwan to China in the early 2000s shared, '*The local automakers and the subsidiaries of multinational automakers provided us with huge opportunities, offering unimaginably high salaries to invite us here. They wanted us to lay a foundation for them through our experience in a more mature Taiwanese automotive industry.*' This statement highlights the strategic importance attributed to these Taiwanese professionals by local and international automotive firms operating in China. Their expertise and experience were seen as invaluable assets in establishing a more competitive and globally integrated Chinese automotive sector, underpinning the industry's rapid development and internationalisation efforts.

The influence of these Taiwanese talents persisted into the late 2010s, with many occupying senior management positions in Chinese automotive firms. Examples include Jack Cheng, co-founder of Nio and the CFO of XPeng Motors from 2019 to 2023, who came from Ford Lio Ho and relocated from Taiwan to China in the early 2000s.

Moreover, in addition to automotive companies in Taiwan, Taiwanese suppliers saw tremendous potential in China due to challenging market conditions in Taiwan. With favourable policies, numerous Taiwanese companies, including many automotive suppliers, established subsidiaries or joint ventures in the Chinese market. Armed with extensive experience in collaborating with global automotive OEMs, these suppliers not only facilitated product localisation in the market but also enhanced the capabilities of local suppliers in terms of quality systems and process management, further strengthening its foundations for China's sectoral development. For instance, Tong Yang Group (TYG), one of Taiwan's largest parts suppliers based in Tainan City, Taiwan, began investing in China in the early 2000s, establishing numerous joint ventures to serve the market better (Tong Yang Group, 2022).

To sum up, at the onset of this stage, while some leading global automotive OEMs had initiated NEV products in select sectors in developed countries, there was limited cooperation and interaction regarding NEVs between China and other nations. However, as China's automotive market continued to expand, international automotive giants committed more resources, including funding, human capital, and technology, thereby enhancing the technological capabilities of the targeted socio-technical system (He and Mu, 2012). Furthermore, supported by policies encouraging talent mobility, the shrinking automotive market in Taiwan prompted both individuals and companies to seek opportunities in mainland China. This influx of talent and expertise indirectly expedited progress toward the targeted socio-technical transition.

5.3.6 External level: associated socio-technical systems

As previously discussed, the 863 Program was the primary driving force behind NEV development during this stage. It allocated government funding to various sectors crucial for NEV advancement. Among these sectors, the power battery sector was an integral component of the socio-technical system facilitating the transition. Battery performance emerged as a critical factor capable of reducing the environmental impact of electric vehicles throughout their entire lifecycle (Liu et al., 2015). Prominent power battery suppliers like Shenzhen Desay and Shanghai FuelCell Vehicle Powertrain participated in the program to develop power battery technologies (Gong et al., 2013). Notably, it wasn't solely power battery suppliers that played substantial roles within this sector; some local automotive OEMs also committed resources to power battery technology development, highlighting the multi-faceted roles actors could adopt across various socio-technical systems.

Moreover, as previously mentioned, the networking between government, industry, and academic institutions was systematically established under the government's purview. Actors from the academic sector played a pivotal role in driving the transition by providing essential human resources and leveraging their research capabilities to foster innovation, policy studies, technological advancements, and standardisation efforts (CATRC et al., 2022). Through these collaborative endeavours, national-level laboratories and engineering centres were established. Given that, during this period, most local automotive OEMs could not independently develop products, these academic institutions played a critical role in helping the targeted niche build a robust foundation for future development.

5.3.7 Summary of the stage

During the Exploration Stage of China's transition from ICE vehicles to NEVs, several vital factors converged to create a favourable 'window of opportunity' for this socio-technical transition:

- **WTO Entry and Global Competition**: China's entry into the World Trade Organization (WTO) in 2001 compelled the nation to seek solutions to enhance its automotive sector's global competitiveness. This external pressure acted as a catalyst for change.
- **Climate Change Imperative**: Heightened global awareness of climate change and the escalating levels of carbon dioxide emissions placed significant pressure on China to explore alternative energy solutions for its transportation needs, especially in response to growing environmental concerns.
- **Beijing Olympics 2008**: The Beijing Olympics served as a pivotal platform for the Chinese government to demonstrate its commitment to the NEV transition. It provided an opportunity to showcase the progress made in NEV development over the preceding eight years.

Internally, the regime was characterised by the dominance of ICE vehicles in the market. Despite substantial market growth—from approximately one million annual sales in 2001 to over eight million annual sales in 2009—China's automotive sector was viewed as 'big but not strong.' Leading brands were primarily international, highlighting the persistent gap between Chinese automakers and their global counterparts.

The NEV niche in China remained at an early stage, primarily focused on finding the right direction and establishing a robust foundation for future development. Key developments during this stage included:

- **Industry-Government-Academia Collaboration**: The Chinese government played a central role in establishing a collaborative network between industry, government, and academic institutions. This strategic collaboration aimed to lay the groundwork for the future growth of the NEV sector.
- **Pioneering Joint Ventures**: Joint ventures with international automotive OEMs became the dominant mode of interaction between China's automotive sector and global players. Increased investments by international automakers in China injected more resources into the automotive sector, aligning with the Chinese government's strategy of leveraging the market to gain access to advanced technologies. These joint ventures facilitated technology transfer and attracted talent to China, mainly from Taiwan, which was crucial in supporting local automotive development.
- **Taiwanese Talent and Supplier Influence**: Improved cross-strait relations between China and Taiwan led to an influx of Taiwanese talent into China's automotive industry. These professionals contributed significantly to the development of China's automotive sector, particularly in joint ventures. Furthermore, Taiwanese suppliers entering the Chinese market bolstered the automotive supply chain through subsidies and joint ventures, enhancing its capabilities.

In summary, the Exploration Stage witnessed favourable external factors aligning with a suitable environment for China's transition to NEVs. However, this stage primarily involved preliminary groundwork and direction-finding rather than substantial progress in the targeted socio-technical transition. The Chinese government was leading in facilitating this transition, establishing critical networks and providing crucial support for the nascent NEV sector. By the stage's conclusion, the foundations were in place, including a roadmap for NEV development and strong networks between academic institutions, industry players, and government entities, setting the stage for the subsequent stages of development. The summary is presented in Table 5-3.

Table 5-3 Summary of exploration stage

Landscape (Environment)	Positive Force	• China joined the WTO. • Climate change has become an important global topic. • The 2008 Beijing Olympics.
	Negative Force	• Not Applicable (N/A).
Internal Socio-technical System	Internal Regime	• ICE vehicles dominated the regime. • Joint ventures had a clear advantage over local automakers.
	Internal Niche	• The network between industry, government and academic institutions was formed • The initial technology development roadmap was available
External Socio-technical System	Peer Socio-technical System	• The joint ventures provided a gateway for interactions with other countries. • Taiwan's automotive sector influenced China's automotive sector mainly through talent mobility.
	Associated Socio-technical System	• The power battery sector still focuses on developing technologies, providing a foundation for future stages. • The academic sector provided talents and laboratories for technology development.

5.4 Stage 2: Pilot-run

5.4.1 Overview

With a foundation in research and development established during the exploration stage, the NEV sector in China began preparing to launch products suitable for market sale. However, lacking practical experience, local automakers faced challenges in determining the right direction and developing effective strategies. Confidence within the niche also needed boosting to sustain their NEV development efforts. Pilot programs were initiated in select cities to address these needs, marking a transition towards commercialisation. The analysis summary could be found in Table 5-4 in section 5.4.7.

5.4.2 Global level

During this period, China continued its remarkable economic growth momentum. However, this growth came with increasing energy demand, leading to concerns about oil supply and making it a critical national security issue. The energy dependency problem in other countries has been escalating since 2003, and to meet the rising demand, China had to import more crude oil. The percentage of oil dependency surged from 33.3% in 2003 to 59.6% in 2014 (Li et al., 2016). As car ownership in China continued to grow, experts anticipated an even more severe situation in the future (Sierzchula et al., 2014).

While the oil dependence issue compelled policymakers to focus on the country's energy security and make policy decisions accordingly (He and Guo, 2021), NEVs emerged as one of the solutions to reduce dependence on foreign countries, providing a positive impetus for the targeted socio-technical transition. One interviewee reflected on the national discourse surrounding energy dependency, stating, '*The energy dependency became a key issue for China; the media and government talked a lot about it, which provided an opportunity for NEVs as they became a solution to this issue.*' This perspective illustrates how the confluence of economic, environmental, and security concerns created a pivotal moment for the advancement of NEVs, aligning national policy objectives with the technological and environmental imperatives of reducing oil dependency.

Additionally, in 2008, the global financial crisis erupted. While China was not among the hardest-hit countries, it still experienced some adverse effects across various dimensions. For the automotive sector, the crisis resulted in increased stockpiles of vehicles for automotive OEMs and a sharp decline in car exports. Suppliers also lost a significant portion of their orders due to the rapidly shrinking global market, leading to some suppliers going bankrupt (Sina Auto, 2008). Even though the NEV sector had not yet become mainstream and had limited interactions with the market, the worsening financial situation was still negatively influenced. Under these economic circumstances, automotive OEMs and suppliers were compelled to adopt a more conservative approach and reduce their investments in innovative technologies, including NEVs.

5.4.3 Internal level: regime

During this stage, the Chinese automotive market experienced a second round of substantial growth from 2009 to 2013, following the earlier expansion in the 2000s. The total sales volume during this period surged from 13 million in 2009 to over 20 million in 2013, solidifying China's position as one of the world's leading automotive markets, as shown in Figure 5-9. Notably, this growth was predominantly driven by the passenger vehicle segment, signifying that passenger cars had become a standard mode of transportation for the general public, not just the affluent or government officials.

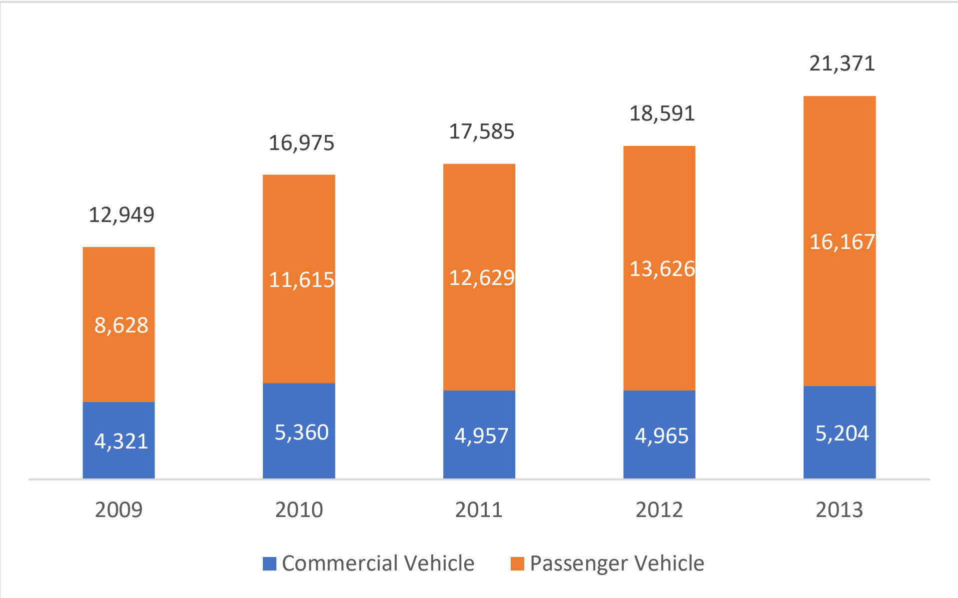

Figure 5-9 The sales volume of the car market in China from 2009-2013 (in thousands) (CPCA, 2023)

Concurrently, joint ventures continued to dominate a significant share of the passenger car market in China, accounting for around two-thirds of the total passenger car market. Local automakers struggled to compete effectively with joint ventures, capturing less than 30% of the total passenger car market, as presented in Figure 5-10. For instance, in 2013, while joint ventures exceeded 10 million in sales volume, local OEMs struggled to reach 5 million. This performance gap underscored the need for local automakers to enhance their competitiveness across various dimensions.

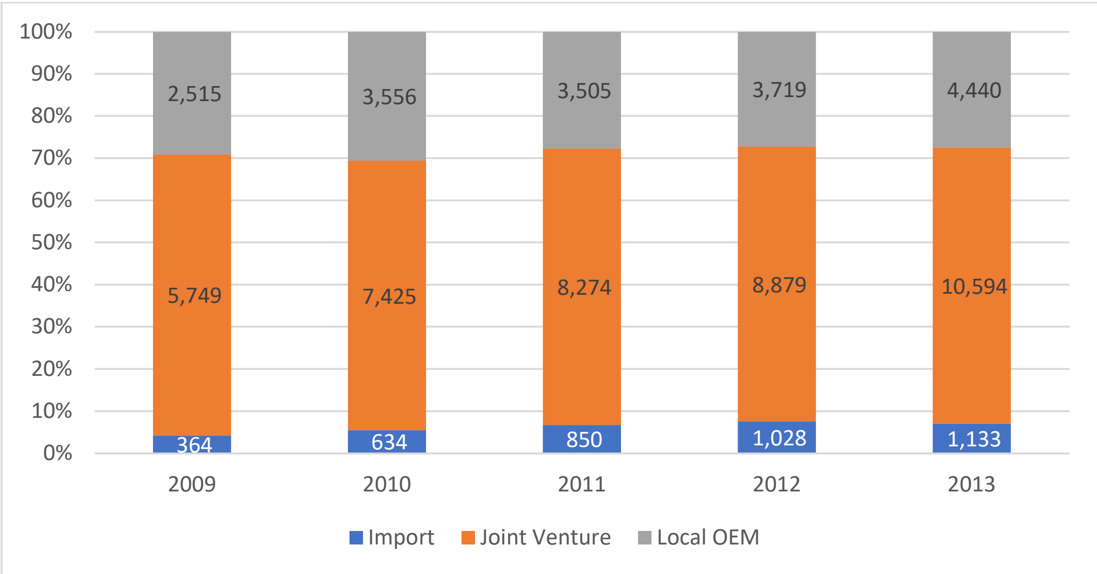

Figure 5-10 Volume distribution of passenger car market (in thousand units) (CPCA, 2023)

Among the leading local OEMs, the top three were privately owned, although they maintained strong ties with local governments to secure benefits (which will be discussed in later sections). Due to limited capabilities and experience in developing and producing competitive products, these local automakers heavily relied on technologies and know-how acquired from collaborations with foreign companies in joint ventures or through global suppliers. Lacking extensive design capabilities, some local automotive OEMs even attempted to replicate international automakers' vehicles, resulting in cars that closely resembled those offered by global automotive OEMs.

The tension between collaboration and competition in these joint ventures was palpable. An individual with experience in a joint venture highlighted the protective measures these partnerships necessitate, stating, '*Our local partner wants our data very bad. Thus, we need to follow lots of internal rules to prevent our data from being copied by them.*' This quote underscores the delicate balance between sharing enough to foster collaboration and protecting proprietary information to maintain competitive advantages.

Considering the market was saturated with numerous OEMs, consolidation was necessitated. In 2009, the 'Automotive Industry Readjustment and Revitalization Plan' was introduced, recommending a reduction in the total number of OEMs to 10 over the following years to consolidate and restructure the industry. The plan outlined two tiers of companies: Tier 1, owned by the central government, with an annual production capacity of 2 million, and Tier 2, owned by regional or provincial governments, with a capacity of 1 million. These tier 1 and tier 2 OEMs expanded their influence and business beyond their bases through mergers and acquisitions with smaller automakers. Additionally, some smaller private OEMs, such as Geely and BYD, remained independent in the industry (Liu and Kokko, 2013).

The plan aimed to create a more streamlined structure for China's automotive sector while balancing economic development across different regions nationally. The government anticipated that this consolidation would enable the automotive industry to integrate limited resources and invest in ICE vehicles and NEVs. This effort helped local automotive OEMs rapidly develop their capabilities, although a significant gap existed compared to global OEMs (Liu and Kokko, 2013).

Furthermore, demand for local suppliers grew with the increasing car sales and a higher rate of localisation of joint ventures. Collaborations with foreign suppliers, such as joint ventures or OEM/ODM arrangements for foreign companies, allowed local suppliers to develop their capabilities. Additionally, supplying parts to car manufacturers provided local suppliers with a better understanding of the requirements of automotive companies, including design verification plans, testing requirements, and development processes, which were notably more complex than aftermarket parts (the primary focus of many of these suppliers initially). One interviewee with experience from an American automaker has highlighted this point, stating, '*We have pushed the suppliers to provide higher-quality parts. To support them, quality experts have been dispatched to these suppliers to provide coaching.*'

For instance, Ford Motor Company and its joint venture, Chang'an Ford (CAF), implemented a rigorous process for suppliers to become part of Ford's supply chain, which could take several years. However, successful suppliers received support from Ford, including supplier technical assistant (STA) engineers who helped them meet Ford's requirements. Sometimes, Ford invested in suppliers to establish production lines and upgrade systems. These actions collectively supported the enhancement of local suppliers' capabilities in China and thus improved the capabilities of the automotive sector's supply chain.

5.4.4 Internal level: niche

Having laid the foundation for the NEV sector during the preceding years, the focus in this stage has shifted from research and development to commercialisation. Several programs and policy packages to establish a robust market foundation were introduced to achieve this new objective. The 'Automotive Industry Readjustment and Revitalization Plan' unveiled in 2009 encompassed four distinct components: (1)

increasing production capacity, (2) advancing technical expertise, (3) allocating resources for research and development, and (4) implementing measures to boost demand for NEVs. The plan set an ambitious target to raise the production capacity of NEVs to half a million units by 2011, capturing a 5% market share (Tang, 2009, Xian-Jun, 2011). This marked the first instance where a top-level document explicitly outlined the national-level direction for NEV sector development, with specific objectives for capacity building, market share, and enterprise capabilities (CATRC et al., 2022). The plan was pivotal in guiding local automotive companies in formulating their strategies and instilling confidence in investors (CATRC et al., 2015).

From a technological perspective, fuel cell technology received lower priority due to slower progress in the initial stage. The majority of resources were directed toward hybrid (including PHEV) and pure electric (BEV) technologies (Gong et al., 2013, Liu and Kokko, 2013). Approximately 10 billion CNY was allocated to develop key NEV components, including motors, batteries, and thermal management systems (Liu and Kokko, 2013). Specific goals were set for these critical technologies, such as achieving a battery density of 150 Wh/kg by 2015 and 300 Wh/kg by 2020 (CATRC et al., 2022).

Several significant pilot programs regarding market establishment were initiated in select cities across China. These programs were designed to promote NEV adoption, recognising that NEV technology was not yet competitive enough to challenge traditional gas-powered vehicles directly. These cities were considered niches created to provide a protective space for NEVs. In early 2009, the ‘Notice on New Energy Vehicle Demonstration and Extension Work’ was jointly issued by the Ministry of Science and Technology (MOST), the Ministry of Finance (MOF), the Ministry of Industry and Information Technology (MIIT), and the National Development and Reform Commission (NDRC), bearing the slogan ‘10 cities, thousand vehicles’ (Jin et al., 2021, Kokko and Liu, 2012, Liu and Kokko, 2013). Initially, 13 cities were selected, but the list expanded to 25. The central government subsidised these cities' local governments to encourage public sector adoption of NEVs in applications such as taxis, sanitation, logistics, and postal services, aiming to reduce air pollution and energy consumption (Liu and Kokko, 2013, Xinhua.com, 2009). Local governments also allocated budgets for local subsidies and associated infrastructure development, including charging stations. Furthermore, events like the 2010 Shanghai Expo were leveraged as opportunities to boost government purchases of NEVs, similar to the role played by the 2008 Olympics in the previous stage (Zhang et al., 2014).

Despite the low demand from the private market, the central government has initiated pilot projects to promote NEVs (primarily BEV and PHEV) to private consumers. In mid-2010, the 'Notice on Subsidies for Private Purchases of New Energy Vehicles' was jointly introduced by the Ministry of Finance, the Ministry of Science (MOS), the Ministry of Industry, and the NDRC (Jin et al., 2021, Gong et al., 2013, Xue et al., 2016). Five cities with competitive automotive companies were selected as pilot cities for NEV subsidies in the private sector: Shanghai (SAIC), Shenzhen (BYD), Hangzhou (Geely), Hefei (Chery), and Changchun (FAW). These cities offered subsidies of 50,000 CNY for PHEVs and 60,000 CNY for BEVs to private customers, supplemented by local subsidies from the respective city governments (Liu and Kokko, 2013).

Scholars have noted that in the early stages of the socio-technical transition from ICE vehicles to NEVs, government policies directly influenced purchasing decisions and moderated financial incentives, product performance, and environmental considerations (Zhang et al., 2013, Li et al., 2016). To promote NEVs and create a protective space for the sector, the Chinese government also introduced restrictions on private purchases of traditional ICE vehicles. Examples include implementing 'odd-even' traffic restrictions for ICE vehicles, lotteries for passenger car purchases in Beijing (with higher probabilities for NEVs to obtain license plates), high prices in license plate auctions (in 2012, the average auction price for conventional ICE vehicle license plates was around 60,000 CNY, while customers could purchase NEVs without auctions), and lane or area restrictions in certain cities such as Shenzhen (CAAM, 2012; X Zhang et al., 2014).

The stringent policies around license plate acquisition emerged as a significant driver for these manufacturers in China to pivot towards electrification. Interviews with executives from these traditional automakers revealed a strategic recalibration towards producing NEVs, motivated by the policies' influence on consumer preferences. One executive noted, '*Getting a license plate is extremely difficult in big cities like Shanghai and Shenzhen, making such policy a huge incentive for buyers to choose NEVs, even if it means accepting higher costs and lower performance.*'

However, despite the plethora of policies promoting NEV adoption, the outcomes fell short of expectations while witnessing rapidly increasing sales volumes. By 2015, the market size had not yet reached the goal set in the 2012 Industry Development Plan of Energy Saving and New Energy Vehicles, which aimed for 500,000 annual NEV sales (including PHEV and BEV) by 2015 (State Council of China, 2012a). This phenomenon was characterised as a 'cold market with hot policies', a challenge not unique to the Chinese market but also observed in European and American markets (Li et al., 2016).

The key actors of the internal niche and their interactions in this stage are described below:

- **Central Government**: During this period, the central government was crucial in guiding NEV sector development. Government policies and subsidies directed the niche's development trajectory and introduced associated regulations to organise further and structure the niche. Notably, the central government clarified its focus on PHEV and BEV technologies, reducing investment in fuel cell technology. Key government players included the Ministry of Science and Technology (MOST), responsible for coordinating NEV research programs since the 1990s; the National Development and Reform Commission (NDRC), responsible for strategic policy formulation and long-term investment; the Ministry of Industry and Information Technology (MIIT), tasked with setting NEV standards, quality control, and testing; and the Ministry of Finance (MOF), a key contributor to policy-making (Liu and Kokko, 2013).

- **Local Government**: Besides the central government, provincial-level local governments actively participated through local policies and subsidies. These local governments often had strong ties with or even ownership of local OEMs. Given the central government's concerns about excessive OEM numbers, local governments sought to ensure the survival of the OEMs they supported. Local governments, such as Shanghai and Chongqing, which had strong links to local OEMs, actively provided local subsidies and implemented policies to promote and protect these local OEMs (Liu and Kokko, 2013, Zhang et al., 2009).
- **Actors from the Internal Regime**: State-owned automakers, predominantly government-controlled, played a leading role in driving the transition processes. Cooperation between local governments and these state-owned automakers became a driving force propelling the transition forward. By the end of 2010, prominent local automakers had developed NEV products that could be mass-produced, including BYD, Chang'an, FAW, Cherry, SAIC, and Dongfeng, with several other local OEMs working on NEV development, including both pure electric and hybrid vehicles (Yang et al., 2010, Gong et al., 2013).
- **Cooperation and Competition Among the Actors**: Collaboration and

> competition were evident among the critical actors in the niche. Cooperation between the central and local governments was critical, with local governments actively participating in policy-making and sometimes influencing central government decisions. Various alliances were established with government support, such as the Electric Vehicle Industry Alliance (EVIA), which coordinated large state-owned automotive companies controlled by the central government. These alliances served as communication channels for niche actors to influence policymakers through lobbying and provided funding for their endeavours. However, these alliances favoured state-owned companies over private ones, as state-owned companies could join multiple alliances, while private companies could only join one (Yang et al., 2010, Gong et al., 2013).

Competition occurred on multiple levels, including local governments, state-owned automotive companies within the same province or city, and industry alliances. Local governments often supported local companies and preferred to select local brands for public sector purchases, such as taxis or buses. The competitive environment was particularly challenging for private companies, which had to compete for limited resources provided by local governments. Even within industry alliances, companies vied for leadership roles in funded R&D projects or the authority to set standards based on their technological strengths (Yingqi Liu & Kokko, 2013).

5.4.5 External level: peer socio-technical systems

As elucidated in prior sections, state-owned automotive giants like SAIC and BAIC primarily spearheaded the alliances formed within the Chinese automotive industry. These state-owned entities often engaged in multiple alliances to access additional resources and networking opportunities with other niche stakeholders, including research institutions and universities. In contrast, private automotive companies faced several challenges in their quest to develop niche products, as identified by Liu and Kokko (2013):

- **Limited Alliance Opportunities**: Private companies encountered restricted opportunities to participate in industry alliances, which constrained their access to vital resources and collaboration prospects.
- **Limited Participation in National-Level Projects**: Private companies had reduced access to major national-level projects, hindering their ability to contribute to significant industry initiatives.
- **Obstacles in Building Relationships**: Establishing relationships with key actors within China's socio-technical system, such as state-owned grid companies, proved more challenging for private companies, further hampering their technological capabilities.

These challenges collectively contributed to the limited technological capabilities of private automotive firms. To overcome these limitations, private companies needed to explore alternative avenues for nurturing their technological prowess (Liu and Kokko, 2013).

Traditionally, the dynamics of socio-technical systems in the global automotive sector have influenced China's automotive development through avenues such as exporting foreign products to China and establishing joint ventures with local companies. For private automotive enterprises struggling to access resources within local socio-technical systems, collaboration with peers from similar socio-technical systems became increasingly vital.

A noteworthy example of such collaboration is BYD's partnership with the Mercedes-Benz Group in creating Denza, a joint venture headquartered in Shenzhen, the same city as BYD (Stoklosa, 2012). BYD initially specialised in battery production when founded in 1995, becoming a pivotal player in China’s battery sector. In 2003, after merging with Xi’an Qinchun Auto, BYD entered the automotive sector. However, the company lacked experience in developing and manufacturing passenger vehicles, resulting in products that faced stiff market competition and criticism of resembling Japanese models, particularly those from Toyota, as illustrated in Figure 5-11.

Figure 5-11 Comparison between BYD F3 and Toyota Corolla (Fernando, 2010)

Given the need to enhance its competitiveness and high-end vehicle manufacturing proficiency, BYD’s collaboration with Mercedes-Benz Group through Denza was instrumental. Denza aimed to amalgamate BYD’s battery-related technologies with Mercedes-Benz Group’s advanced manufacturing capabilities, quality systems, car design and development expertise and tuning know-how to establish China’s first luxurious NEV brand (Stoklosa, 2012). Although Denza’s sales performance was modest in this period, the venture provided BYD with valuable insights into developing high-end products, management practices, and advanced manufacturing systems. Beyond product-related benefits, this partnership allowed BYD to attract top-tier talent to the city and bolster its image as a leader in China's NEV sector (Liu and Kokko, 2013). Figure 5-12 shows the concept car by Denza in 2012 Beijing Auto Show.

Figure 5-12 Concept car by Denza in 2012 Beijing Auto Show (Stoklosa, 2012)

Moreover, as the economic landscape improved, leading automotive companies gained the capacity for mergers and acquisitions (M&A) of foreign enterprises. Private companies also saw M&A as a viable strategy for acquiring technological capabilities from established automotive OEMs (Liu and Kokko, 2013). Additionally, Chinese automotive firms faced challenges regarding their innovation capabilities, defined as the capacity to enhance technological innovativeness and create novel business value propositions through acquiring, utilising, and developing valuable technological resources and knowledge (Burgelman et al., 1996).

Simultaneously, cross-border M&A activities offered several advantages, including establishing networks and relations between host and home countries for improved regional development. Through M&A deals, companies could enhance various facets of their capabilities, including intangible assets, human resources, facilities, branding, and managerial expertise (Chen et al., 2015). Additionally, these transactions provided access to otherwise challenging resources (Narula, 2006). Given these factors, it is understandable why knowledge-intensive countries became targets for emerging market companies seeking asset augmentation (Yiu et al., 2007). Lane and Lubatkin (1998) argue that higher inter-organizational learning occurs when the knowledge possessed by acquired firms aligns closely with the knowledge held by acquiring firms, resulting in greater absorptive capacity.

An exemplary instance of technology transfer through M&A is Geely's acquisition of Volvo in 2010, which facilitated significant technology transfer (Chen et al., 2015). Subsequently, in 2013, China-Euro Vehicle Technology (CEVT), owned by Geely Zhejiang Holding Group, established its R&D centre in Gothenburg, Sweden. This centre encompassed virtually all critical functions within the vehicle development value chain, including advanced planning, conceptual design, product strategy and planning, technology development, prototype development, vehicle testing and development, and support functions such as purchasing/sourcing and program financing (Yakob et al., 2018).

Reflecting on the impact of this collaboration, an interviewee with experience at both companies noted, '*Consequently, Geely bolstered its innovation capabilities and enhanced its vehicle development capabilities, especially for platform development and safety feature development, which were areas where knowledge was lacking at the time.*' This statement highlights the transformative effect of the Volvo acquisition on Geely's technological and development prowess, particularly in areas critical to automotive safety and platform efficiency.

While the M&A did not directly contribute to NEV development during this stage, it laid a solid foundation for Geely's future NEV endeavours by strengthening overall capabilities, attracting international talent, enhancing the group's brand image, introducing more capable suppliers, and improving management systems. Notably, Geely gained ownership of the performance brand Polestar, originally under Volvo's purview, which would play a pivotal role in Geely's expansion into the European NEV market.

Meanwhile, protectionist measures impeded the effectiveness of peer socio-technical systems in China. Key players in the United States and Europe encountered challenges in expanding their NEV markets in China, limiting their ability to introduce advanced technologies, products, and investments. In contrast to Europe and the United States, where subsidies were granted to models with lower or zero emissions, China primarily allocated subsidies to local companies (Gong et al., 2013). This made it arduous for foreign firms, such as the Nissan Leaf and Chevrolet Volt, popular NEV models in North America and Europe, to qualify for Chinese government subsidies during this period (Zhang et al., 2014).

5.4.6 External level: associated socio-technical systems

Within the context of China's socio-technical landscape, the energy sector has emerged as one of the most pivotal associated socio-technical systems during this stage of development. While the ownership of NEVs remained relatively low and the demand for energy-related products was not yet substantial, the competition among critical actors in the energy sector had already intensified. The anticipation of a significant expansion in the market for NEVs shortly drove this heightened competition. As NEV volumes grew, the significance of infrastructure also escalated, as it played a crucial role in enhancing the usability and competitiveness of NEVs compared to traditional ICE vehicles (CATRC et al., 2015).

In this stage, two prominent state-owned grid companies, namely the State Grid Company and the China Southern Power Grid Company, recognised the strategic imperative of developing and providing infrastructure to challenge the dominant position of oil companies in China's energy sector. Similar to the automotive sector, geographical boundaries also influenced the roles of critical actors in the energy sector. The State Grid Company held a dominant position in Northern China, while the China Southern Power Grid Company led the way in the South. Both companies enjoyed robust support from their respective local governments. State Grid Company initiated its transition by establishing standards for charging stations and inaugurating its first commercial charging station in Shanghai in 2009 (Liu and Kokko, 2013).

Unlike certain Western countries where traditional oil companies have acted as lock-in mechanisms, hindering the transition from gas-powered vehicles to NEVs (Klitkou et al., 2015), China's state-owned leading oil companies, including China Petrochemical Corporation and China National Offshore Oil Corporation, were keenly aware of the central government's directives. Consequently, these state-owned enterprises began investing in the requisite infrastructure.

Moreover, the power battery sector was pivotal in this socio-technical transition. Battery sector actors initiated their involvement in the transition during the first stage by focusing on battery technology development (Tollefson, 2008), and this trend persisted into this stage. Batteries constituted a significant proportion of NEV performance, particularly for BEVs, affecting driving range and electricity consumption. Higher energy density enabled NEVs to store more power for driving and vehicle operations.

Although energy density remained relatively low at this stage, it steadily increased, thus improving NEV performance and expanding their range of applications.

The cost of batteries represented a substantial portion of the Bill of Materials (BOM) for NEVs (Hsieh et al., 2019). Despite the persistently high costs, advancements in associated technologies had already initiated a rapid reduction in battery costs during this period. In just two years, from 2011 to 2013, the cost of a lithium-ion battery pack for electric vehicles plummeted from $579.8 to $324 per kilowatt of usable energy (EERE, 2021). This reduced battery costs made NEVs more affordable for consumers and heightened consumer interest in transitioning to electric mobility (Hsieh et al., 2019). Consequently, this development laid a solid foundation for forming the NEV market.

5.4.7 Summary of the stage

The global financial crisis 2008 had far-reaching implications, dampening market activity and inducing a climate of caution among industry players, initially challenging the targeted socio-technical transition. However, compared to the global downturn, China's relatively independent economy thrived, bolstered by sustained economic growth. This growth injected fresh capital into the market and generated heightened demand for energy resources. Importantly, it created a favourable environment for developing NEVs as a strategic means to reduce the nation's energy dependence.

As China's economy surged, the automotive market experienced explosive growth, culminating in registering 20 million vehicles by the end of this stage. Joint ventures remained dominant while local automakers diligently honed their capabilities to compete with global industry leaders. Despite the relative competitiveness of China's domestic automakers, numerous emerging local automakers entered the market and continued to expand, eager to seize opportunities within the burgeoning automotive landscape. To optimise resource utilisation, the government has initiated efforts to consolidate local carmakers and restructure the automotive sector, laying a stronger foundation for its future development. During this period, they also witnessed China's earnest pursuit of developing its autonomous automotive supply chain, reducing dependency on foreign suppliers, and fortifying the sector's resilience.

The NEV sector transitioned from a research and development-centric phase to one focused on commercialisation. Government intervention played a paramount role in ensuring the sustained progress of this socio-technical transition. Robust policies and comprehensive plans were unveiled to support NEV development, complemented by the launch of multiple pilot programs designed to carve out a niche for NEVs and provide a protective framework. Among these initiatives, the 'Ten Cities, Thousand Cars' program emerged as a linchpin, encompassing private and public markets. As government support poured into this niche, competition among industry players intensified, marking a critical test for local automakers vying for limited resources.

In parallel, the foreign automakers and suppliers remained pivotal in supplying essential elements such as knowledge and technologies to the evolving socio-technical system, akin to the exploration stage. However, as China's economy surged in strength, domestic automakers began to exhibit the capability to acquire global counterparts, exemplified by Geely's acquisition of Volvo. This shift towards mergers and acquisitions contributed significantly to acquiring crucial elements. Additionally, the socio-technical shift from ICE vehicles to NEVs spurred a concurrent transformation in grid companies as they aimed to challenge the hegemony of petroleum companies. These grid companies channelled resources into infrastructure development by reshaping the competitive landscape and creating windows of opportunity. Consequently, the energy sector ascended in importance as an associated socio-technical system, complementing the role of the power battery sector.

Despite the acceleration of the transition, notable challenges surfaced. The absence of standardised specifications for batteries and charging stations prompted vital actors to develop products based on proprietary standards, with an eye towards these becoming national standards in the future, to secure their sectoral leadership positions. Concurrently, as the NEV sector remained in its nascent stage, issues such as immature technology, a gradual market penetration trajectory, elevated product costs, and limited enterprise investments came to the forefront. However, thanks to government policies and pilot-run programs, the market garnered increased confidence in the prospects of NEVs, spurring more substantial resources into the sector. In summary, this stage laid a robust foundation for the future development of NEVs within China's socio-technical landscape. The summarised analysis could be found in Table 5-4.

Table 5-4 Summary of pilot-run stage

Landscape (Environment)	Positive Force	• Economic growth in China continued. • More considerable demand for energy stimulates more serious energy dependence issues.
	Negative Force	• Financial crisis in 2008 from subprime mortgage.
Internal Socio-technical System	Internal Regime	• The market size was proliferating; gas-powered cars were still the mainstream. • Joint ventures still led the market, and local automakers were still trying to catch up with these leaders; copying foreign products ('homage' products) was expected. • The government has started to consolidate and integrate local automakers. • The local supply chain has become more competitive.

	Internal Niche	• Focus transited from research and development to commercialisation. • The government set up goals for both market performance and technological targets. • The 'Ten Cities, Thousand Cars' pilot run program was launched for the customer (2C) and the government (2G) market. • The government played the most crucial role in propelling the development of the NEV sector and creating protective space. • Competitions between local automakers started to be fiercer.
External Socio-technical System	Peer Socio-technical System	• Foreign automakers provided required capabilities to local automakers through joint ventures (similar to the previous stage), especially for private local automakers, which received fewer resources than state-owned ones.
	Associated Socio-technical System	• The energy sector (especially grid companies and oil companies) to build infrastructure. • The power battery sector enhanced the competitiveness of NEVs by providing better battery technologies.

5.5 Stage 3: Market formation

5.5.1 Overview

In 2014, the development of NEVs achieved a significant milestone as it was prominently featured in the annual Government Work Report (CATRC et al., 2022). This recognition was paramount, given that the NEV sector had been initially designated as one of seven emerging industries by the State Council in 2010. During this stage, the development of NEVs assumed a pivotal role in addressing China's pressing energy and environmental challenges (Li et al., 2016, State Council of China, 2014).

Building upon the foundation laid during the preceding stages, the widespread promotion of NEVs commenced nationwide. Concurrently, developing comprehensive NEV-related policy frameworks gained momentum, encompassing vital aspects such as subsidies, tax exemptions, investment management, and infrastructure development (CATRC et al., 2022). During this period, we also witnessed a surge in private market growth, marked by local automakers' launch of numerous NEV products. Innovations in business models aimed at product promotion and increasing customer acceptance proliferated. Notably, foreign companies, particularly European entities, recognised the strategic significance of NEVs, especially PHEVs, within the Chinese market.

Consequently, the private passenger car market began to claim a larger share of the NEV market. Furthermore, as the importance of charging infrastructure for NEV adoption persisted, infrastructure construction accelerated, bolstered by novel business models and supportive policies. Consequently, by 2016, China boasted the most significant number of charging ports globally (CATRC et al., 2017).

This stage marked a transformative period for the automotive sector, characterised by heightened interactions with other industries, notably the internet and mobile sectors. This synergy gave rise to pioneering concepts such as ‘intelligent cars’ equipped with intelligent cockpits and autonomous driving features and the advent of the shared economy. The ‘A.C.E.S. concept’, denoting Autonomous driving, Connectivity, Electrification, and Shared mobility, began to disrupt the global automotive landscape (Hamid, 2022). Due to their structural advantages, BEVs emerged as the preferred vessels for implementing these transformative technologies, enhancing the overall competitiveness of NEV (CATRC et al., 2017).

Simultaneously, the NEV sector prepared for the forthcoming market expansion in subsequent stages. These preparations involved optimising policies to address persistent issues such as subsidy fraud and local protectionism. Additionally, significant industry players entered the NEV sector. Notably, ‘Wei Xiao Li’ (comprising Nio, XPeng, and Lixiang Auto), the top three NEV startups of the early 2020s, originated during this stage. Furthermore, as a telecommunications industry leader, Huawei has established a dedicated business unit focusing on automotive connectivity (Huawei Consumer, 2013).

This stage served as a crucial juncture for the government to evaluate policy effectiveness and devise strategies for a ‘post-subsidy era’ (Li et al., 2018b). It also allowed automotive companies to reevaluate their product portfolio strategies. It became increasingly evident to key players in China’s automotive sector that NEVs were the market’s future. Consequently, many traditional automakers, also influential stakeholders within the existing regime, started considering increasing their investments in NEVs and emerged as key players within this niche. The summary of the analysis could be found in Table 5-5 in section 5.5.7.

5.5.2 Global level

With robust economic growth since the early 2000s, the energy demand has experienced continuous escalation, contributing to a growing concern regarding oil supply, as previously discussed. In 2014, the external dependency on oil supply surged to 59.6%, compared to 33.3% in 2003 (Wu et al., 2018). By 2017, this figure had soared to 67%, prompting significant national security apprehensions within the Chinese government (Wu et al., 2018). This predicament persisted despite more than a decade of development in NEVs (Sierzchula et al., 2014, Li et al., 2016). Like previous stages, this energy dependency paradoxically maintained the ‘window of opportunity’ while necessitating continued government efforts to promote the transition from gas-powered vehicles to NEVs.

This period has, in turn, provided NEVs with an enhanced opportunity to compete against conventional vehicles, primarily due to their potential as platforms for integrating and showcasing advanced technologies (Adler et al., 2019). An interviewee highlighted the innovative edge of NEVs, stating, '*Lots of NEV makers started to try out new technologies and features on their NEV products as the structure of the NEVs is simpler, and lots of new concepts have been adopted on NEV as the low sales volume of NEV could reduce the associated risks for such concepts, which all offer new opportunities for the NEVs to capture people's attention.*' This observation points to a strategic advantage for NEVs, wherein their simpler architecture and lower initial sales volumes present a lower-risk environment for experimenting with and implementing groundbreaking technologies and features.

The unique position of NEVs as carriers of cutting-edge technologies catalyses consumer interest and reinforces the strategic importance of NEVs in China's broader socio-technical transition towards sustainable mobility. This dynamic, characterised by the interplay between technological innovation, market adaptation, and policy support, underscores the critical role of NEVs in addressing environmental concerns and energy security challenges. The forthcoming sections will delve deeper into the socio-technical systems associated with this transition, further exploring the implications of these developments for China's automotive industry and energy strategy.

5.5.3 Internal level: regime

The surge in car ownership posed challenges related to energy dependency and increased carbon emissions and prompted the Chinese government to promote NEVs as a solution. Consequently, during this phase, critical players in the automotive industry began participating in the NEV niche under government guidance (CATRC et al., 2018).

Nevertheless, due to the uncertainty surrounding the future of NEVs, there were extensive discussions within these automotive companies about the direction of their strategies. These players assumed significant roles both within the regime and the niche.

Simultaneously, the passenger car market underwent a transformation driven by increasing consumer purchasing power. The market saw a shift towards premium brands, which accounted for more than 10% of the market in 2017, compared to less than 6% in 2010, as demonstrated in Figure 5-13. To categorise these brands, a research project consolidated sales data from the China Passenger Car Association (CPCA) and incorporated expert perceptions from the automotive industry. The resulting brand categorisation included:

- Mainstream brands encompass local economic brands like Geely, Cherry, and Roewe and international brands such as Toyota, Chevrolet, and Hyundai.
- Premium brands targeting higher-value consumers, such as Mercedes-Benz, BMW, Alfa Romeo, Land Rover, and some BEV start-ups like Nio and Tesla.
- Luxury brands, comprising the highest-priced brands like Rolls-Royce and Ferrari, generally with a starting MSRP exceeding 2 million CNY (250,000 USD).

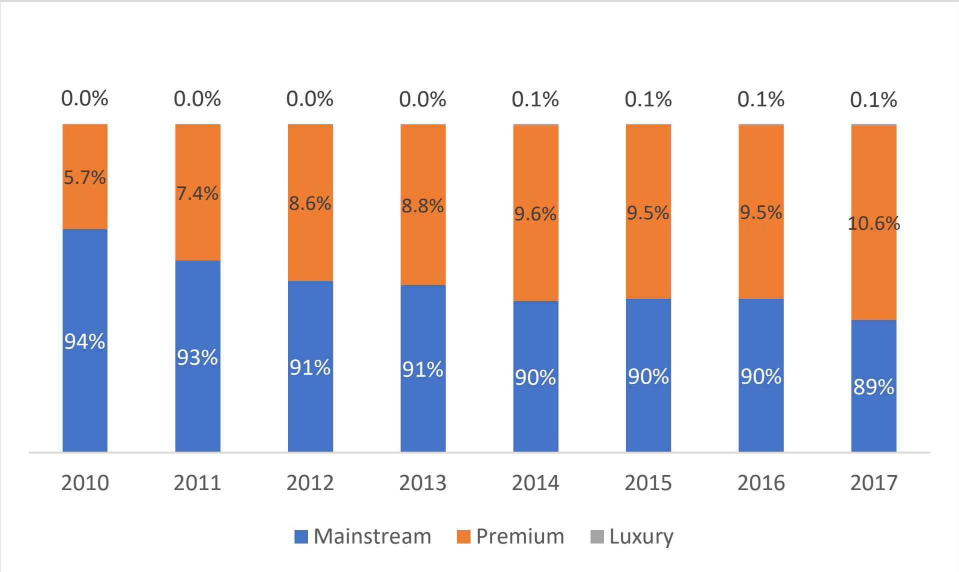

Figure 5-13 Brand distribution 2010-2017 (CPCA, 2023)

The segment distribution within the passenger car market also experienced shifts. In 2010, the mini and small segments held 6% and 14% market share, respectively. However, by 2017, these figures had decreased to 2% and 11%, respectively (CPCA, 2023). This transformation in the automotive sector led local companies to reconsider their product strategies. Some companies aimed to ‘upgrade’ their products to escape the image of inferior products and compete directly with global mainstream and premium brands. For instance, Geely announced a new brand, Link & Co., in collaboration with Volvo in 2016. This brand intended to share technology with Volvo and compete globally with a ‘born digital’ design concept (Savov, 2016).

Reflecting on this period of strategic realignment and brand evolution, an interviewee from a local automaker shared insights into the motivation and outcomes of these efforts: ‘*We were trying to utilise the technologies from multinational automakers and to launch products which could compete with mainstream global brands such as Toyota and Ford. This could be considered the first step in upgrading the brand position of local automakers. The result was not very impressive at the beginning, but it ended up in the booming of local premium brands after 2020.*’

This statement underscores local automakers' initial challenges in their quest to elevate brand perceptions and market positioning. However, it also highlights the eventual success of these efforts, culminating in the significant growth of local premium brands in the years following 2020. This evolution in product strategy and brand positioning reflects a broader trend within China’s automotive sector, where local companies increasingly focus on quality, innovation, and global competitiveness. Figure 5-14 demonstrates the ‘market upgrading’ trend in this period, which consumers have shifted their preferences to larger cars.

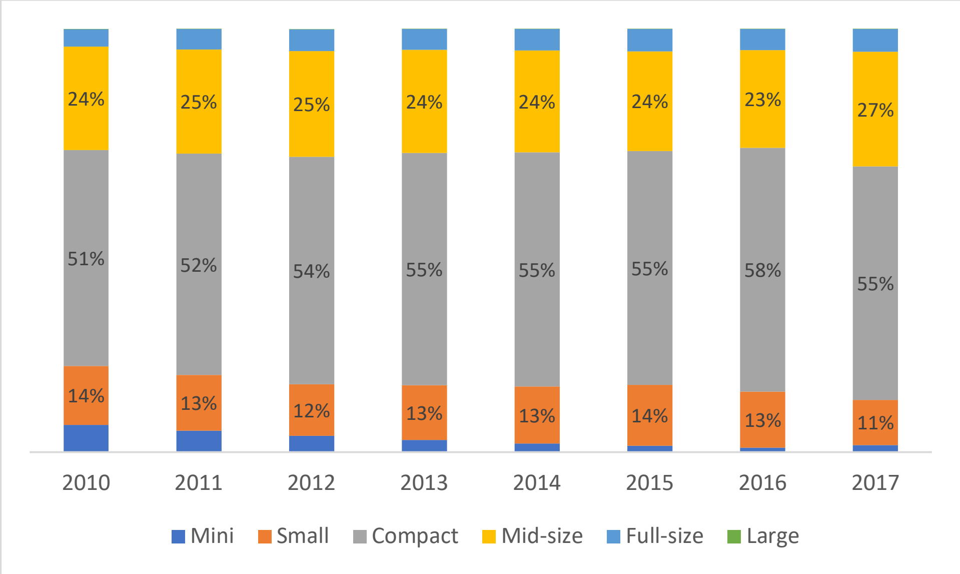

Figure 5-14 Segment distribution of passenger car market in China, 2010-2017 (CPCA, 2023)

In this phase, multinational companies, notably those manufacturing gas-powered vehicles, maintained an advantage in various dimensions such as quality systems, management systems, talent, technological capabilities, and design. Despite the shrinking gap between local and global companies, as illustrated in Figure 5-15, many leaders of local automotive companies perceived the difficulty of catching up with global leaders. This challenge prompted a search for alternative solutions. NEVs emerged as one such solution because they offered a more straightforward structure compared to the complex systems of internal combustion engine vehicles, making it easier for latecomers to compete.

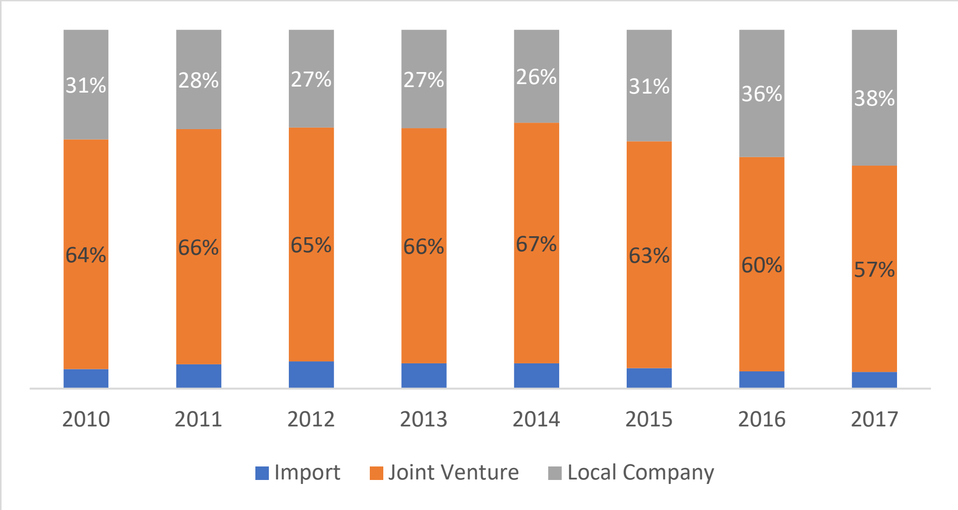

Figure 5-15 Sales distribution of passenger car market in China by company type, 2010-2017 (CPCA, 2023)

Throughout this phase, policies and regulations governing the automotive sector underwent optimisations. In 2016, qualifications for car production were revoked for 13 automotive companies categorised as ‘zombie companies’ by the Ministry of Industry and Information Technology (MIIT) (CATRC et al., 2017). This move aimed to upgrade and regulate the industry while eliminating unqualified players. Additionally, anti-monopoly rules were introduced to ensure fair trade, leading to penalties such as the 29 million USD fine imposed on General Motors in 2016 for rule violations (Gardner, 2016). Moreover, with a growing car parc and increased demand for vehicle replacement, policies for the secondary market were liberalised and improved. In 2016, the State Council issued recommendations and instructions to promote and regulate the secondary market, optimising registration processes and enhancing used car trading platforms (State Council of China, 2016).

Overall speaking, this phase marked a critical point for the regime. External pressures such as oil dependency and carbon emissions drove the shift from gas-powered vehicles to NEVs. Actors within the regime began adapting their strategies to this new environment. Concurrently, the market continued its growth, albeit with a slightly reduced pace in 2017, signalling potential market stagnation. Premium products gained traction, with market dominance remaining with joint ventures due to the technological gap between China and leading global automotive nations. NEVs presented an opportunity for local companies to bridge this gap, with some laggards attempting to secure sales volume through imitation. Policies, regulations, and rules were continually optimised to govern and foster sector development.

5.5.4 Internal level: niche

The development of the internal niche for NEVs in China accelerated during the period. Despite starting with modest figures of 84,000 NEV ownership and 12,000 production units in 2014 (Li et al., 2016), these numbers fell short of the ambitious target set by the Industry Development Plan of Energy Saving and New Energy Vehicles, which aimed for 500,000 NEVs by 2015 (State Council of China, 2012b). However, as the market matured and several factors, including increased acceptance among private customers, well-devised policies, infrastructure development, and improved product offerings, emerged, the transition toward NEVs gained momentum, as indicated by interviewees. Nevertheless, challenges persisted, as the initial years of this stage still grappled with the ‘hot policy and cold market’ scenario. Consequently, understanding customer perceptions of policies and enhancing policy effectiveness became imperative for the government (Li et al., 2016).

To address these challenges, the Chinese government undertook a strategic review of policy deployment during this stage. The 2015 edition of ‘The Blue Book of New Energy Vehicles’, published by CATRC et al. (2015), gathered key stakeholders from both the NEV niche and the automotive regime. This comprehensive review categorised policies into six distinct types: macroscopic policies regulating specific objectives, demonstration policies to accelerate NEV adoption and raise public awareness, preferential tax policies reducing purchase costs, technology innovation policies supporting incremental advancements in the vehicle, electronic control, and energy technology, industry management policies to reinforce sector regulation in China, and infrastructure policies.

Under the central government's leadership, the mechanisms for collaboration between central and local governments became clearer, optimising the use of limited resources. A structured policy system emerged in 2014, guided by the State Council's directive to accelerate NEV deployment (State Council of China, 2014). This policy framework addressed various aspects of NEV development, including removing local protectionism, fostering product innovation, and expediting infrastructure construction. Financial incentives, such as removing the vehicle purchase tax for NEVs in 2015, were implemented to encourage customer adoption (CATRC et al., 2022).

As a result of these efforts, the NEV market experienced exceptional growth, with more than 300% growth in 2015 and over 50% in 2016. NEVs achieved a 1% market share in 2015, a significant milestone acknowledged by Chinese automotive experts (CATRC et al., 2017). Concurrently, the market witnessed a surge in product offerings. In addition to traditional local automotive OEMs, newcomers, including foreign companies, have entered the market through joint ventures and start-ups. This influx heightened competition and led to cost reductions for NEVs, especially those designed to qualify for government support. The driving range of NEVs also improved during this period. This increased product competitiveness and public acceptance further matured the niche. Intense competition prompted automakers to expedite new product launches and invest more in product development to maintain or expand market share (CATRC et al., 2017).

Infrastructure development played a pivotal role in facilitating the growth of electric mobility. Inadequate charging stations would limit the usability of NEVs in intra-city scenarios. In China, infrastructure construction gained momentum to accommodate the increasing number of NEVs. Between 2012 and 2015, the number of charging pillars grew at an average rate of 40.5%, bolstered by government financial support (CATRC et al., 2017). By the end of 2016, there were over 150,000 charging pillars nationwide, a significant increase from around 49,000 in 2015 (EVCIPA, 2017).

Ownership of these charging stations became more concentrated in 2016 and early 2017, with the top four operators controlling over 80% of the market (CATRC et al., 2017). Notably, these operators began collaborating rather than engaging in sole competition—this cooperative approach aimed to share resources and promote infrastructure development. Business models also matured, fostering increased cooperation among stakeholders like charging operators, automotive OEMs, and real estate companies. Nevertheless, two critical challenges remained: the compatibility of charging stations with vehicles and the readiness of the grid infrastructure, particularly in older neighbourhoods, posing obstacles to NEV promotion (CATRC et al., 2017).

The rapid development of these companies demanded a significant recruitment drive to secure the necessary human resources to support their ambitious growth plans. However, the influx of newcomers also introduced challenges to the industry. Many of these entrants focused more on securing investment or government subsidies than vehicle design, production, and sale. This phenomenon led to a situation where, metaphorically, as noted by several interviewees, '*Newly-founded automakers in this period were building cars from PowerPoint presentations rather than tangible products.*'

Two interviewees who shared similar observations regarding the surge of NEV start-ups highlighted this issue. They remarked, '*The hugely increasing number of start-ups making NEVs was shocking. However, most had no long-term plan and faded away very soon. They just wanted to get money and run away, and only a few survived until today.*' These comments shed light on the transient nature of many of these ventures, which, despite the initial hype and investment, lacked the strategic planning, technological foundation, and operational capability necessary for sustainable growth and success in the competitive automotive market.

5.5.5 External level: peer socio-technical systems

The interactions between internal and external socio-technical systems have gained unprecedented momentum. In addition to the talent flow from international companies to local firms and joint ventures, as discussed earlier, local automotive OEMs have actively engaged with other socio-technical systems through various means. These include establishing design and research centres in other countries, close collaboration with global suppliers to access cutting-edge technologies, and developing networks with foreign dealers, governments, and ecosystems in preparation for exporting products manufactured in China (CATRC et al., 2017). The impetus for this internalisation strategy among local automakers was partially due to the slowing growth of the passenger car market in China, although still expanding. The foundation for such interactions has been firmly established during this period for the internationalisation action taken by Chinese automakers in later stages.

During the initial two stages, international companies and their subsidiaries and joint ventures operating in China were perceived as transition drivers. However, this dynamic shifted as China became the world's largest NEV market. The slower transition within the home countries of these global automotive OEMs led to more conservative decisions regarding NEVs. Consequently, many of these international companies lagged behind their local counterparts regarding technological capabilities. When these companies eventually announced their plans to enter the Chinese NEV market toward the end of this stage, they had already fallen behind local competitors.

In 2017, international brands held a significant share of the overall passenger car market, but they accounted for only a mere 6% of the NEV market in China (Roland Berger, 2020). Given that the joint ventures involving these international automotive OEMs played significant roles not only within the regime but also within the niche, they wielded considerable influence over consumer opinions regarding NEVs.

Meanwhile, despite the United States having a relatively low market share for NEVs during this period, it had already implemented well-designed policies that directly impacted NEV sales. For instance, the Corporate Average Fuel Economy (CAFE) regulations aimed to increase vehicle fuel efficiency, reduce emissions, and promote the production of NEVs. California’s Zero Emission Vehicle (ZEV) program, initiated in the 1990s, mandated automakers to include ZEVs as part of their total sales in the region, thereby directly influencing NEV sales (Li et al., 2018b, Long et al., 2020, Jenn et al., 2013). The Chinese government used these policies as references in crafting its own NEV credit systems and existing corporate average fuel consumption regulations (Hao et al., 2016). While the new credit system was not yet launched during this period (introduced in 2018), discussions surrounding it compelled automotive OEMs to make early preparations (Roland Berger, 2020).

5.5.6 External level: associated socio-technical systems

The internet and mobile sector experienced significant growth during this stage, with major players such as Baidu, Alibaba, and Tencent (the ‘BAT’ trio) expanding even more than in previous stages. These companies have recognised the suitability of electric vehicles for integrating connectivity-related and intelligent features (CATRC et al., 2017), including in-car infotainment systems and virtual personal assistants powered by voice recognition technology. Fuelled by the increasing market size of NEVs and government support, these tech giants decided to increase their investments in automotive business units, particularly in the NEV sector.

The unique characteristics of NEVs, such as their potential to serve as intelligent carriers (Modi et al., 2018), coupled with the innovative technologies brought by internet and mobile sector companies, shifted the focus of NEV product strategy towards greater ‘smartness’ compared to traditional internal combustion engine vehicles. Concepts like autonomous driving and intelligent cockpits have become prevalent in China and other countries, such as the United States.

Several NEV manufacturers capitalised on these advantages to promote their products. For instance, Tesla’s Model 3, launched in 2016 in the United States, claimed to support Autopilot for autonomous driving functions. Similarly, SAIC partnered with Alibaba in China to launch the ‘connected car’ RX5 in the same year (Wong, 2016). This shift in strategy was instrumental in enhancing the competitiveness of NEV products, differentiating them from traditional vehicles by focusing on intelligence and technological advancements.

This trend towards embracing cutting-edge features has differentiated NEV products from their traditional counterparts and influenced the broader automotive industry’s innovation and technology integration approach. An interviewee highlighted the impact of these shifts, stating, "*Multinational automakers are very conservative and would not adopt the innovative features any time soon. These local automakers, especially SAIC and Chang'an, provided opportunities for the 'outsiders' and some examples for the multinational automakers, thus pulling the participation of these technological sectors.*"

Integrating the Internet and other sectors also began to influence the NEV sector. Developing new in-car apps and connected car technologies improved the end-to-end charging experience for NEV users. This integration could address issues such as finding available and compatible charging stations, thus reducing the idle rate of charging pillars, which was only 5% in China in 2016 (CATRC et al., 2017).

The power battery sector also played a pivotal role, establishing development hubs in critical regions and attracting significant investments during this period. These regions included the Pearl River Delta, Yangtze River Delta, central plain region, and Yangtze River Delta, with substantial investments exceeding 100 billion CNY, resulting in a production capacity of 100 billion Wh annually (CATRC et al., 2017). This also saw the involvement of major global battery companies like Samsung, which established production facilities in China. A complete value chain was formed from materials to development and production, marking a significant milestone for future accelerated transitions. The infusion of resources into battery development led to a significant reduction in battery costs, as indicated in Figure 5-16, with prices dropping to as low as 40% of 2011 levels by the end of this stage (CATRC et al., 2022). However, battery reliability, system integration, and battery management challenges still require attention, as outlined by battery experts such as Chengwei Xiao (CATRC et al., 2017).

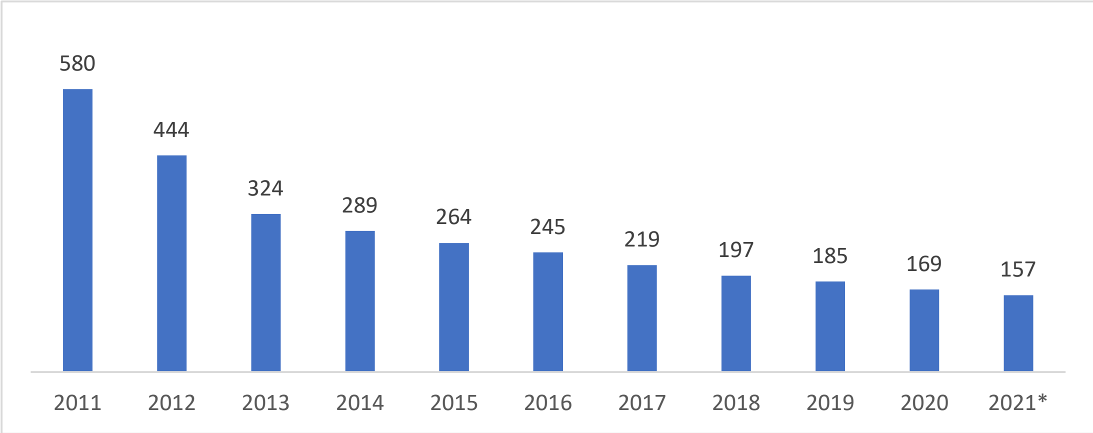

Figure 5-16 Cost of a lithium-ion battery pack for electric vehicles in the United States between 2011 and 2021 (in U.S. dollars per kilowatt of usable energy) (EERE, 2021)

Cooperation models between vehicle battery companies and automotive OEMs diversified during this stage. In addition to the traditional model of OEMs purchasing batteries as regular parts, strategic alliances, joint ventures, and partnerships were formed to enhance cooperation in innovative business models, product development, and market expansion. For example, CATL and Dongfeng collaborated to develop more compatible, safer, and cost-competitive products. This multifaceted cooperation aimed to strengthen the capabilities of the value chain (CATRC et al., 2017).

Furthermore, the internet sector has experienced explosive growth since the 2010s, coinciding with the ascent of BAT (Baidu, Alibaba, and Tencent), China's three foremost internet companies. This surge has ushered in new technologies into the consumer market, including Artificial Intelligence (AI) and Virtual Reality (VR) (Su and Flew, 2021). A product manager from a multinational automaker reflected on this period, noting, '*In the mid-2010s, we saw an influx of presentations from BAT showcasing their innovative products. It was eye-opening, though we were initially sceptical about integrating these technologies into cars.*'

While the internet sector's direct impact on NEVs was still nascent, its rapid growth laid the foundation for future technological integrations in the automotive industry. Internet applications had already permeated various aspects of Chinese consumer life, from payment systems to entertainment, by the early 2010s. With China emerging as the world's largest online market by early 2018 (Shen, 2020), the stage was set for these digital innovations to eventually cross over into the automotive realm, hinting at a future where vehicles could serve as platforms for a broad range of digital services and experiences.

Meanwhile, local automotive OEMs that primarily produced passenger cars continued to focus on the domestic market and emerging markets in regions like the Middle East and Southeast Asia (CATRC et al., 2018). However, the electric bus market began expanding into European and North American markets. BYD has extended its European presence since establishing its EU headquarters in 1999. The company announced plans to build a new bus plant in Hungary in 2016 and invested an additional 10 million Euros in 2017 to establish a secondary plant in France to cater to the European market (sohu.com, 2017).

Beyond Europe, BYD initiated operations in the United States, with solid support from the California government, and delivered its first batch of electric buses to a transportation company in the state in 2017 (People's Daily, 2017). These efforts laid the groundwork for the internationalisation of battery-powered NEVs in subsequent stages.

Moreover, employees involved in these internationalisation projects were expected to transfer their expertise to the passenger car department or other companies seeking to expand abroad. '*Most of my friends working in the internationalisation team of passenger cars today were responsible for electric bus projects,*' said an interviewee. Furthermore, networks and organisations established in these advanced markets could be adopted by NEV products, mainly passenger cars, and the knowledge gained would be invaluable for future growth and expansion.

In summary, the stage witnessed the dynamic growth of the internet and mobile sector's influence on the NEV industry, transforming NEVs into intelligent and technologically advanced vehicles. The power battery sector made significant strides, addressing cost reduction challenges and establishing complete value chains. Low-speed EVs found niche markets but raised questions about their role in the transition. Finally, the electric bus sector's market expanded into advanced markets, laying the groundwork for future internalisation efforts in the NEV sector.

5.5.7 Summary of the stage

The passenger car market in China displayed consistent growth during this period, albeit at a slower pace. However, the surge in car ownership brought forth a pressing concern – carbon emissions. This compelled the government to expedite the transition to low-emission vehicles, which can be seen as a positive force driving the transition. Despite the slowdown in growth rate, rising economic prosperity empowered consumers with increased purchasing power, making them more inclined to invest in pricier cars, further bolstering the transition. Nonetheless, international brands continued to dominate the market. At the same time, local automotive OEMs, the primary providers of NEV products, held a smaller portion of the passenger car market, potentially impeding the transition.

The nascent niche market began to exert influence during this period. While NEVs were still less competitive than gas-powered vehicles in cost, performance, and infrastructure, they began carving out their identity. This included features like connectivity and autonomous capabilities, supported by government incentives to attract private customers, positively impacting the transition. Two thousand sixteen private customers accounted for over half of the market share (CATRC et al., 2017). However, joint ventures, primarily led by international companies, remained somewhat passive due to slower transition paths in their home countries. Under pressure from competition and government directives, these companies eventually announced electrification plans in China, primarily focused on PHEVs, which were seen as a more conservative approach that could hinder the transition.

Moreover, newcomers from other sectors, particularly the internet sector, such as Nio and XPeng, injected new energy into the NEV sector. These fresh talents introduced innovative thinking and accelerated development processes, transforming the entire Chinese automotive industry and offering local automotive OEMs an opportunity to differentiate themselves from international competitors.

Despite China becoming the largest NEV market during this period and international automotive OEMs making limited contributions to the transition, well-designed policies of other developed markets, such as the United States and the European Union, remained essential references for the Chinese government. Additionally, widespread subsidy abuse among automotive companies forced the government to reevaluate policy effectiveness. These factors positively contributed to optimising policy systems and laying the foundation for further niche development. However, infrastructure struggled to keep up with the growing demand for NEV charging, with some incompatible with different vehicle types and specific older neighbourhoods lacking the necessary grid infrastructure for charging installations – all of which negatively impacted the transition.

The flourishing internet sector emerged as another opportunity for NEVs. In addition to powertrains, some advanced NEVs were positioned as smart cars, symbolising technology providers rather than just transportation tools. Collaboration between local automakers and leading internet companies like BAT (Baidu, Alibaba, and Tencent) became more active, providing connectivity and autonomous-related features to NEVs. Huawei, a future leader in smart cars, also made substantial investments in its automotive-related business during this period.

However, technological limitations at the time meant that these products were not as ‘smart’ as automotive OEMs claimed, with the true potential of NEVs as ‘smart cars’ expected in later stages. Furthermore, the growth of the battery sector in China increased the supply and reduced the cost of batteries, ensuring a steady supply of NEVs while lowering their cost. The electric bus sector laid the foundation for the future internationalisation of actors in the targeted socio-technical system. Overall, the growth of these sectors during this stage provided positive forces for the transition.

As the NEV market took shape and the niche rapidly gained a significant market share, it was time for the government to consider scaling back policies. Issues related to the increasing number of NEV ownership, such as battery recycling and infrastructure deficiencies, became crucial for the niche’s progress. Devising strategies to improve the existing policy system based on existing foundations and addressing challenges such as preventing subsidy abuse while transitioning from a policy-driven to a market-driven approach became essential topics that will be further explored in subsequent sections. The summary of this stage can be found in Table 5-5.

Table 5-5 Summary of the market formation stage

Landscape (Environment)	Positive Force	• China’s increasing energy dependency on other countries. • China’s economy maintained a high

		growth rate.
	Negative Force	• N/A (Not Applicable)
Internal Socio-technical System	Internal Regime	• Gas-powered vehicles still dominated internal combustion engines, but NEVs started to increase their share. • The market enjoyed significant car volume, size, and brand-level growth. • Joint ventures still maintained an advantage over local automakers, but the advantage reduced quickly. • The reduced growth speed at the end of the stage encouraged local automotive OEMs to 'go abroad.'
	Internal Niche	• The policy systems have been upgraded and optimised in different dimensions. • The leadership of the central government was confirmed to utilise limited resources better. • The market performance of NEVs has improved quickly, and China has become the leading NEV market globally. • The government encouraged infrastructure building and continued accelerating with innovative business models. • International automakers have increased their investment in NEVs in China through joint ventures. • With more newcomers, issues such as local protectionism and cheating for subsidies have become more serious.
External Socio-technical System	Peer Socio-technical System	• More interactions between the targeted and peer socio-technical systems have been found to prepare for internationalisation, which could stimulate the transformation of the targeted one. • Due to slower progress in their home countries, international automakers have slower movement in developing NEVs than local automakers in China, which could be a lock-in mechanism. • The more comprehensive policies and regulations of NEVs in developing countries have become a reference for the Chinese government.
	Associated Socio-technical System	• The internet and telecom sector have provided new features and concepts to

		the automotive sector, especially for NEVs, which were better carriers for such features. • There are increasing partnerships between actors in the automotive sector and the internet/telecom sector. • The power battery sector's value chain was built with participation from foreign companies. • The internet sector has gradually changed consumer behaviours

5.6 Stage 4: Maturation

5.6.1 Overview

Upon this point, industrialising the NEV sector has exhibited continuous acceleration. The level of NEV-related technologies has surged, costs have decreased in tandem with the expanding market share, and the Chinese government has remained steadfast in optimising the policy framework across various dimensions to more effectively allocate resources in support of the leading local automakers driving NEV marketisation (CATRC et al., 2022). The burgeoning market's value chain has matured, with numerous industrial clusters emerging across various country regions.

Furthermore, the NEV market has become more competitive than in the preceding stages. As the competitive landscape matured and automakers discerned substantial market potential in China, many new entrants threw their hats into the ring. This diverse array of participants includes Tesla, local startup automotive OEMs, and some previously conservative international and domestic automakers who had hesitated to engage in the transition before this period. Infrastructural development proceeded apace to support the burgeoning market, and the management system for NEVs underwent comprehensive optimisation.

In the face of heightened competition, automakers were compelled to furnish more competitive and distinctive products. Consequently, this led to increased collaborations and interactions with other sectors, including telecommunications, the Internet, and the battery industry. These sectors have transitioned from mere component suppliers for conventional gas-powered vehicles to actively engaging in the development processes of NEVs. Furthermore, many automakers, encompassing startups and traditional manufacturers alike, sought to expand into global markets, further transforming the landscape of the NEV sector in China.

In a nutshell, despite NEVs not matching the performance level of gas-powered vehicles, their unique features and product images have begun attracting a growing number of consumers. This shift has been bolstered by financial and policy support from both central and local governments. The NEV sector is gradually evolving from a niche industry, heavily reliant on government protection, into a mainstream entity or regime. The analysis summary could be found in Table 5-8 in section 5.6.7.

5.6.2 Global level

In this stage, the macroeconomic landscape was less optimistic than in the previous three decades, primarily due to the intensifying trade war between China and the United States. Beginning in 2018, trade disputes escalated both in frequency and scale. During this year, the United States initiated several anti-dumping duties and tariffs on products imported from China. In March 2018, the United States launched the ‘section 301 Investigation’, which specifically targeted intellectual property practices and led to further tariffs on Chinese imports (Lau, 2019). The Chinese government responded with countermeasures. Negotiations between these superpowers commenced in May; however, by the end of 2018, notable progress had not been achieved (Chong and Li, 2019). Scholars have suggested that China may experience more significant impacts than the United States (Itakura, 2020, Chong and Li, 2019, Li et al., 2018a).

Despite a perceived 'truce' in the trade war following the G-20 summit 2019, some experts contended that the repercussions would persist and further hinder China's technological catch-up to the United States (Lau, 2019). The International Monetary Fund (IMF) projected that the trade war would result in a 0.6% reduction in China's GDP (IMF, 2018). By the end of this stage, the trade war had caused China's growth rate 2018 to drop to 6.6%, the lowest in three decades. Moreover, the IMF's forecast for 2019, the first quarter, predicted a further decrease to 6.2% (McKinsey, 2019). The adverse economic conditions stemming from the trade war could be considered an opposing force, potentially impacting automotive OEMs through fund shortages and increased conservatism in investment decisions.

The social structure of China also underwent significant changes. Due to the country's population policies, the number of individuals in the 25-30 age group decreased from 2016 onwards, and the number of newlywed couples also declined from 2013 (McKinsey, 2019). These two demographic groups have traditionally been significant drivers of market growth. With their diminishing numbers, the potential pool of car buyers may have shrunk. This trend could be viewed as an opposing force for the transition due to the reduced pool of potential car buyers and the decreasing number of younger consumers who tend to be more inclined to embrace new products like NEVs. The internal regime section will present more extensive discussions on this matter.

The P2P (peer-to-peer) lending market collapse in China was significant. In the first half of 2018, over 300 P2P platforms announced shutdowns. In just the first half of July, more than 50 platforms defaulted, resulting in an estimated loss of 35-40 billion RMB

(Ngai, 2018). Before 2018, P2P lending had played a crucial role in driving the automotive market in lower-tier cities. However, the stricter licensing requirements that led to the fall of the P2P market caused customers in these lower-tier cities, who heavily relied on P2P financing to purchase cars, to reduce their demand for car purchases (McKinsey, 2019). Thus, what could have been considered a positive force for the transition, P2P lending, turned into an opposing force in this stage.

Furthermore, the sharing economy emerged as a significant economic trend in the 2000s and gained prominence after the 2008 financial crisis. The sharing economy gained a robust foundation with the proliferation of information and communication technology, especially the increased smartphone penetration rate. In European and American markets, 70% and 72% of the population participated in the sharing economy, respectively (Liu et al., 2020). Compared to developing countries, the sharing economy in China experienced rapid growth from 2016 to 2019, owing to the swift adoption of smartphones and greater consumer willingness to embrace innovation. In 2019, online car-hailing accounted for 37.1% of the total taxi market revenue, with nearly half of China's internet users utilising these services (State Information Center (PRC), 2020). More discussion will be presented in later sections. This trend positively impacted the NEV sector's development, especially in major cities, where most cars used for ride-hailing services, notably in tier 1 cities, were NEVs. This preference stemmed from policy advantages, such as easier license plate acquisition and superior infrastructure in these urban areas. Additionally, using NEVs allowed professional drivers to save on operational costs.

Lastly, environmental protection gained prominence during the 19th National Congress of the CPC. Developing an ecological civilisation system was deemed essential to address climate change concerns. Initiatives, including forest restoration, establishing a national park system, and resource conservation, were highlighted by the central government as strategies for combating climate change (Xi, 2017). Gas-powered vehicles, significant contributors to China's carbon emissions, were prioritised for government intervention. Consequently, the Chinese government introduced a series of policies that emphasised compelling automotive OEMs to allocate resources to NEVs (CATRC et al., 2018). This direction from the government, consistent with previous stages, supported the socio-technical transition path positively.

5.6.3 Internal level: regime

After years of sustained growth, China's passenger car market encountered a pivotal moment in 2018 when sales volumes began to decline, following a peak in 2017. This shift signalled a transition from a market characterised by rapid expansion to one focused on stock and replacement, intensifying competition among automakers. The changing dynamics prompted domestic and multinational automotive OEMs to reassess their market strategies and competitive positioning. During the interview, an industry insider reflected on this period, stating, '*We have seen a decreasing growth rate of the market but more intensive competition within the market, which caused the awareness of many multinational automakers to reconsider their strategy in the market.*' This observation underscores the strategic recalibration companies had to undertake in response to the evolving market landscape, emphasising the need for innovation and adaptability in a more mature and contested market environment.'

Several factors contributed to this shrinking passenger car market, including the social changes discussed in the landscape section of this thesis. Additionally, China's GDP growth rate slowed down during this period. Historically, the growth of the passenger car market in China had a positive correlation with GDP growth until the fourth quarter of 2015 (McKinsey, 2019). However, due to the influence of preferential tax policies aimed at supporting the passenger car market, consumer behaviour deviated from GDP growth for two years before realigning with it in 2018 (McKinsey, 2019). The deceleration in GDP growth had a noticeable impact on the market performance of passenger cars.

As discussed in the global landscape, there was a decrease in demand among young, first-time buyers. In China, first-time buyers were typically between 25 and 30 years old, and their numbers began declining in 2017. According to McKinsey's forecast, this trend is expected to persist (McKinsey, 2019). Furthermore, the number of newlywed couples also declined after reaching its peak in 2013 (McKinsey, 2019). Given that owning a car is a standard prerequisite for marriage in many Chinese families, the decrease in the number of newlyweds also hurt the car market performance.

The transformation of the car market from an incremental market to a stock market was reflected in the composition of car buyers, especially after 2017. In 2017, a significant 90% of car buyers were first-time buyers. However, by 2019, this percentage had decreased to 70%, with 23% of buyers purchasing cars to replace old ones or solely adding additional cars (McKinsey, 2019). This trend meant that automotive OEMs needed to enhance their competitiveness to maintain sales performance, as these consumers had become more mature through their experience of driving and purchasing cars. Furthermore, more automotive OEMs were now competing for a fixed market size rather than for a continuously expanding market.

Over the past three decades, the market's rapid growth allowed some unqualified or less competitive automotive OEMs to survive as demand exceeded supply. However, with market growth stalled and oversupply becoming prevalent, these companies found it increasingly difficult to attract customers. According to a survey by McKinsey (2019), customer loyalty increased from 12% in 2017 to 31% in 2019. This indicated that if an automotive OEM's brand position were not competitive enough, customers would not consider it in their purchasing decisions. For instance, automotive OEMs that initially gained market share by copying the designs of global luxury brands, such as Zotye and Land Wind, gradually lost their market share; Zotye's annual sales volume dropped from around 300,000 units in 2017 to a mere 11,500 units in 2019 (CPCA, 2023).

Moreover, the emerging connectivity and intelligent cockpit technology trend rapidly transformed the market. In 2019, over half of potential car buyers expressed interest in autonomous driving-related features such as collision warning, lane-keeping assist, adaptive cruise control, and parking assist. About 40% of potential car buyers were interested in connectivity-related features such as voice recognition, in-car payment, remote control, and others (McKinsey, 2019).

The development of these new technologies followed a different trajectory than that of traditional car development. For example, agile management, a concept widely adopted by internet companies, was rarely seen in traditional OEMs despite being suitable for developing these new technologies. Implementing this new concept within traditional processes presented a necessary but challenging task for these automotive OEMs. Additionally, strategic talent management, production systems, and supply chain management were crucial to this transformation.

Dynamic capabilities, including integration, reconfiguration, and developing external and internal competencies, became essential for adapting to rapidly changing customer demands (Teece et al., 1997). Some traditional OEMs, especially joint ventures, reacted more slowly due to a lack of dynamic capabilities in fast-changing environments, losing market share in China. For instance, Ford's sales volume in China dropped significantly from around 1 million units in 2016 to only 237,000 units in 2019, representing a 68% loss (CPCA, 2023). I will elaborate more on this topic in Chapter 7.

Despite the shift to a stock market and declining GDP growth rate, high-end products began to capture a larger market share. In 2013, 60% of the market was occupied by compact and smaller cars, but by the stage under consideration, more than 60% was taken up by mid-size and full-size cars, as illustrated in Figure 5-17. Changes in the composition of car buyers contributed to this trend, as fewer consumers were first-time buyers and more sought cars to accommodate growing families.

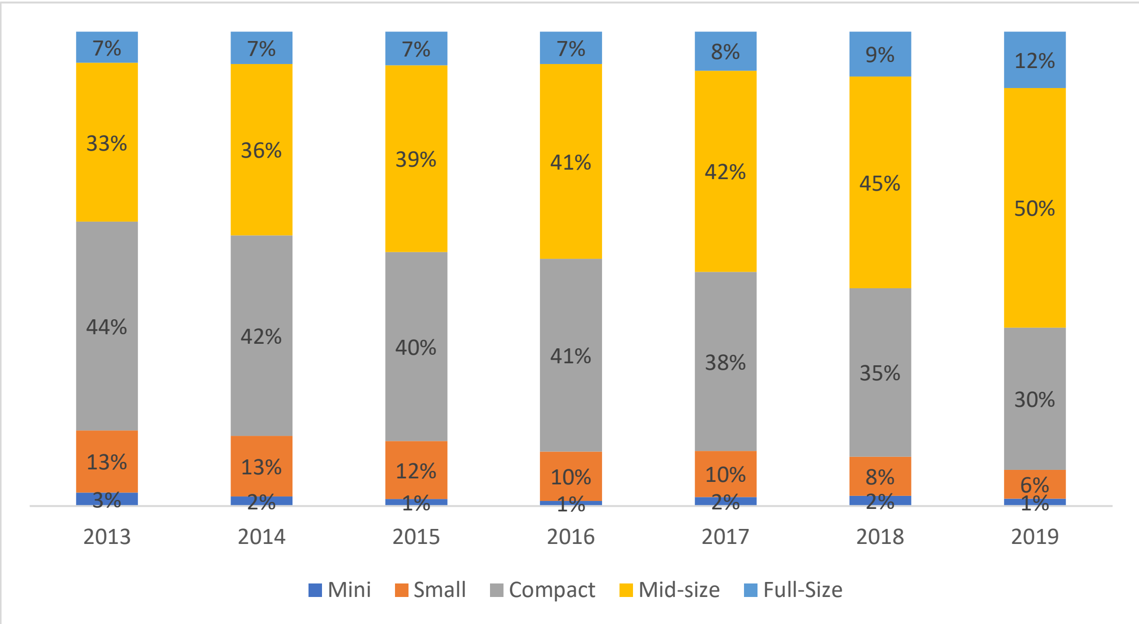

Figure 5-17 Segment distribution of passenger car market 2013-2019 (CPCA, 2023)

Moreover, premium brands (e.g., BMW, Mercedes-Benz, Audi, Jaguar) and luxury brands (e.g., Bentley) experienced significant sales growth. In 2013, these brands had a total volume of only 1.4 million units. However, Figure 5-18 shows that their annual sales reached approximately 3 million units and continued to increase yearly, even as the total passenger car market shrank.

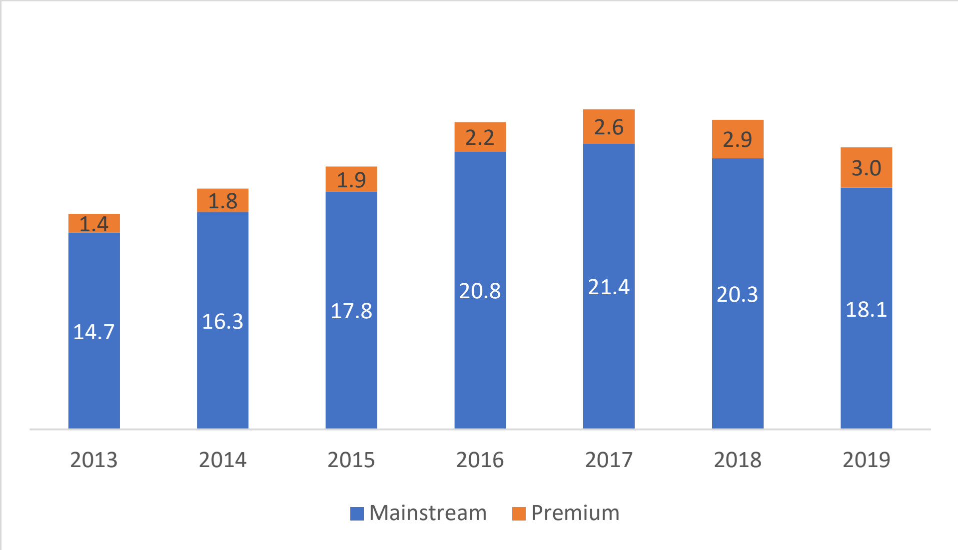

Figure 5-18 Passenger car market in China by brand level, 2013 to 2019 (in million) (CPCA, 2023)

One reason for this growth was the effort to increase the affordability of entry-level models while maintaining brand image through mid-range and high-end products (McKinsey, 2019). Models such as the BMW X1, Mercedes-Benz A-Class, and Audi A3/Q2 exemplify this strategy. This approach improved the sales performance of these premium brands and attracted younger consumers to become owners. Unlike more conservative middle-aged consumers, these younger buyers demanded innovative features like intelligent cockpits and autonomous driving, prompting these OEMs to invest more in developing these features rather than concentrating solely on colour and trim, craftsmanship, powertrains, etc. As a product expert stated during an interview, '*The younger generation imposes new requirements on automakers, pushing them to adapt and address these emerging challenges.*'

Furthermore, thanks to their quicker adaptation to market changes (Teece, 2018b, 2019), local brands steadily increased their market share. This increase began in 2016 when their market share exceeded 35%, marking a significant growth compared to previous years. One of the primary reasons for this surge in market share was the changing landscape, which provided a 'window of opportunity' for local automotive OEMs. With the emergence of the A.C.E.S. trend, local OEMs, considered to have better dynamic capabilities and fewer internal constraints compared to foreign automotive companies, were able to seize this window to catch up with international automotive OEMs that had previously dominated the market.

Reflecting on this industry-wide shift, an interviewee with experience in local start-ups and multinational automakers observed, '*The traditional automakers, especially the multinational ones, reacted very slowly to the changing environment. There were too many roadblocks within their companies, thus providing the newcomers and laggards a chance to catch up.*' This perspective underscores the challenges established automakers face in adapting to technological advancements and changing consumer preferences, highlighting the opportunities this opened up for more agile and innovative players in the market.

These local automotive OEMs demonstrated a deeper understanding of changing customer demands than their joint venture counterparts. This heightened awareness stemmed from stronger connections between their headquarters and the local market. Additionally, the senior management teams of local automakers possessed more extensive experience and superior knowledge of the market dynamics. Moreover, local automotive OEMs have forged robust relationships with local governments, particularly state-owned entities. This enabled them to understand the government's policy directions better and respond proactively to these new directives.

Furthermore, these local OEMs had cultivated strong partnerships with other sectors within the automotive market, including internet companies such as Tencent and Alibaba. These alliances provided them with a more flexible approach to supplier selection, enabling them to integrate advantages from various sectors swiftly. They also embraced innovative management concepts like those employed by internet companies, such as agile management. For example, SAIC collaborated with Alibaba to launch an in-car entertainment system between 2016 and 2017, showcasing their ability to adapt and innovate quickly (Wong, 2016). In contrast, Fiat-Chrysler could only introduce similar products through cooperation with Tencent in 2019-2020 (Monika, 2018). These factors collectively laid a solid foundation for building innovation capabilities. The innovation capabilities developed during this stage would soon become the driving force behind the success of local companies in the subsequent phase. More details are discussed in the associated socio-technical system subsection.

Furthermore, local automotive OEMs responded to increased competitiveness by repositioning their brand image, focusing on offering higher-quality products rather than solely emphasising mini, small, and compact cars. This shift was driven by the growing willingness of Chinese consumers, particularly younger demographics, to explore and invest in new, innovative products (McKinsey, 2019). By 2019, mid-size and full-size models had accounted for more than 50% of overall sales for local brands (CPCA, 2023).

These market shifts compelled foreign companies to adapt to maintain their dominant position. For instance, Ford entered a partnership with Volkswagen to develop autonomous driving capabilities and electric vehicles, while Mercedes-Benz and BMW collaborated to tackle next-generation mobility solutions (McKinsey, 2019).

In summary, the period under study for this thesis marked a new epoch in China’s automotive sector, characterised by:

- A market shift to a stock market model, amplifying competition.

- Consumer preferences are evolving, even amidst a static overall market size, with a tilt towards premium brands and larger vehicles.
- The emergence of A.C.E.S. as a pivotal factor in consumer decision-making.
- Joint ventures' market share erosion due to slower adaptation rates.
- The rising significance of dynamic capabilities for automotive OEMs to succeed in a rapidly changing market landscape.

This analysis reveals that while the market's shift could be perceived as a challenge due to the reduced demand for new cars, it also presents opportunities for growth and transformation within the industry, particularly for local automotive OEMs poised to leverage their agility and innovative capacity.

5.6.4 Internal level: niche

In 2017, the Chinese NEV market experienced remarkable growth, achieving an annual sales volume of approximately 0.8 million, as demonstrated in Figure 5-19. This positive trend continued into 2018, with the annual volume surging to around 1.26 million units, as illustrated in Figure 5-19. These sales accounted for more than 60% of the total global NEV sales, including both passenger vehicles and commercial vehicles, firmly establishing China as the world's leading NEV market for four consecutive years (China Automotive Technology and Research Center et al., 2019, CATRC et al., 2018).

A notable transformation occurred during this period as the NEV market expanded beyond the confines of tier-1 cities. Starting from 2017, tier 2 and tier 3 cities embraced NEVs, leading to significant growth. This marked a fundamental shift from a policy-driven market to one characterised by consumer demand. BEVs emerged as the dominant force, claiming most NEV sales. In 2017, 560,000 NEVs were sold, with over half of them going to private consumers, and out of these, 450,000 were BEVs (CATRC et al., 2017). McKinsey's survey data in 2017 indicated that only 20% of consumers considered NEVs their next vehicle. However, by 2019, this figure had risen dramatically to 55% (McKinsey, 2019).

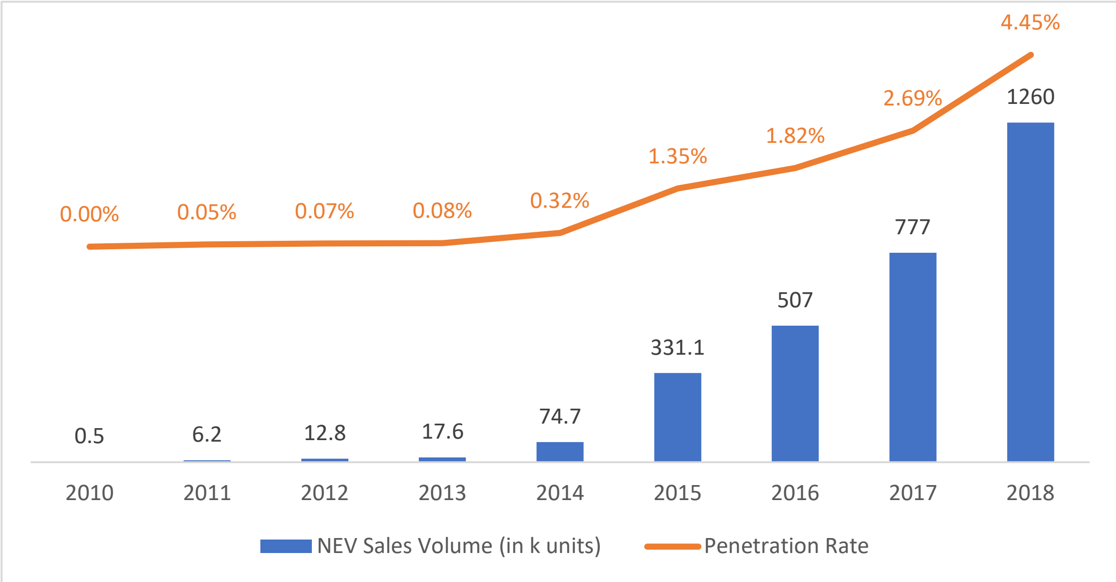

Figure 5-19 NEV Sales volume and penetration rate 2010-2018 (CPCA, 2023)

As the NEV market expanded, it became evident that it was no longer the exclusive domain of pioneers like BYD and BAIC. Almost all major local automotive OEMs announced their electrification plans, while foreign automotive OEMs introduced electrified models through imports. Some foreign automotive OEMs recognised the irreversible trend toward replacing gasoline-powered vehicles with NEVs, leading to increased investments in the Chinese NEV market (McKinsey, 2019). In addition to importing vehicles, these companies forged partnerships with other foreign or local automotive OEMs. Some examples of these collaborations are detailed in the table below. These cooperative ventures aimed to leverage each participant's strengths, striving to achieve maximum benefits for all parties involved (CATRC et al., 2018).

Furthermore, in response to the pressures of the dual-credit system, even automotive OEMs previously considered 'laggards' in the NEV space, such as Fiat-Chrysler

Automotive, Mitsubishi, and Toyota, contemplated the production of local NEV models to meet the system's credit requirements. An interviewee responsible for developing product strategy at a multinational automaker reflected on the company's response to the changing regulatory landscape, stating, '*Our company finally became aware of the trend of electrification in 2017 or 2018, especially after the launch of the dual-credit system, which allowed us to allocate some resources for early study. However, we were still short on funds for developing products that could be sold. We did more talking than doing, but it was a start anyway.*' Table 5-6 shows some cases of cooperation between local and foreign automotive automakers.

Table 5-6 Examples of cooperation between local and foreign automotive OEMs (CATRC et al., 2018)

Time	Companies	Content
Jun-17	Volkswagen Group Anhui Jianghuai Automobile Group	• Planned to invest 5.6 billion CNY to establish a new 50-50 joint venture for the development, production, and sales of NEV • Associated businesses such as mobility would also be included
Jul-17	Daimler-Benz Group Beijing Automotive Group	• Invested 5 billion CNY to establish a production centre and power battery plant in the existing joint venture between the two companies for launching and producing NEVs for the Chinese market
Jul-17	Volvo Cars Geely Group	• Established a 50-50 joint venture for developing next-generation platform technologies for NEV products
Aug-17	Renault-Nissan Alliance Dongfeng Motor Group	• Planned to establish a joint venture in China to develop BEV products; Dongfeng would take 50% of the shares, and Renault and Nissan would take 25% shares, respectively.

Meanwhile, the NEV sector in China has evolved over more than 15 years, maturing significantly and establishing its competitive edge to challenge the dominance of traditional ICE vehicles that continue to prevail directly in the automotive market. Collaboration and integration with other sectors, such as the internet and telecom sector, have presented new opportunities to bridge the gap between NEVs and traditional gas-powered vehicles. This collaboration will be further explored in the forthcoming subsections.

Within this context, Intelligent Connectivity Vehicles (ICVs) have garnered substantial attention within the market. These ICVs are perceived as a unique advantage of NEVs over ICE vehicles, owing to their distinctive structural features. Local automotive OEMs and startups that launched NEVs began incorporating numerous ICV-related features to attract consumers and actively engage in government initiatives, often with governmental support. This trend not only bolstered the innovation capabilities of local automotive OEMs but also enhanced the capabilities of foreign companies. These foreign entities benefited from improved knowledge of end consumers and stronger government relationships, enabling them to develop products more attuned to the market's demands.

An ICV is a vehicle equipped with advanced technologies, including cameras, advanced sensors, actuators, and high-efficiency systems, providing the vehicle with intelligence and cooperative driving capabilities (Modi et al., 2018, Yang et al., 2018). ICVs are envisioned as solutions to address various traffic-related challenges by enhancing traffic efficiency, driving safety, and fuel economy and potentially relieving humans from direct vehicle control (Yang et al., 2018). The Society of Automotive Engineers (SAE) has classified autonomous driving into five levels, as Figure 5-20 outlines.

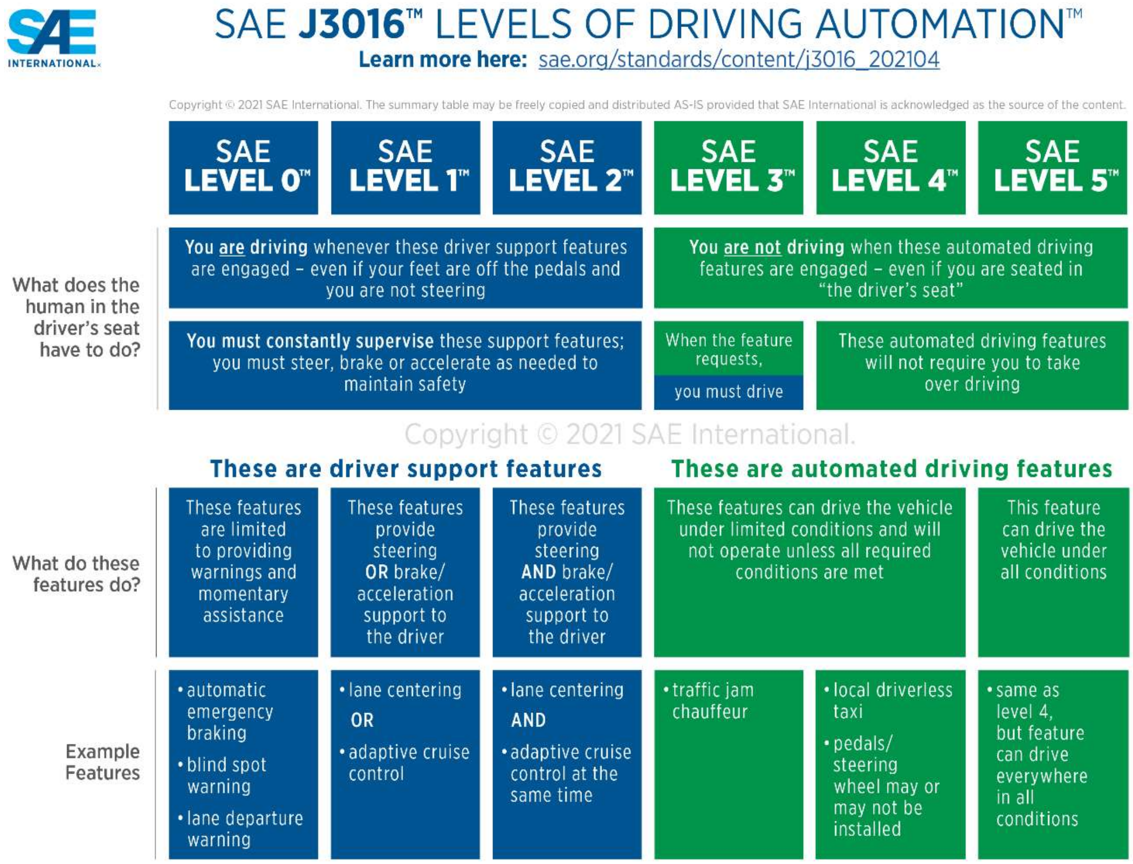

Figure 5-20 SAE J3016 visual chart (SAE International, 2021)

To this point, levels 3, 4, or 5 of autonomous driving remained elusive for mass production. Although many automotive OEMs announced aggressive plans to develop Level 3+ autonomous driving capabilities, Levels 3 and 4 were primarily found in select pilot projects. Towards the end of this stage, specific models equipped with Level 1 autonomy emerged, with some high-end models featuring Level 2 autonomy. To align with government directives, leading automotive OEMs, including local OEMs, startups, and global OEMs, unveiled their autonomous driving roadmaps tailored to the Chinese market (Pizzuto et al., 2019).

Following the proliferation of numerous startups during earlier stages, approximately ten survived into this fourth stage. However, as indicated by interviewees working in local start-ups, it became evident that these startups might struggle to catch up with traditional automotive OEMs concerning product competitiveness, particularly in cost control and technological advancement. The ability of these companies across various dimensions became critical for launching competitive automotive products. These dimensions included market knowledge, human resources, quality systems, supply chain management, production capabilities, product development expertise, internal and external processes, and more.

During this period, startups were in their nascent stages, and industrial experts identified several significant weaknesses: (1) technology reserves were not competitive compared to traditional automotive OEMs, and their products had not undergone market testing; (2) startups were unable to exercise control over core power battery technologies, which remained under the purview of suppliers and a select few traditional automotive OEMs, such as BYD; and (3) due to the absence of a robust supply chain and engineering capabilities, the operational costs of startups were notably higher than those of traditional OEMs (CATRC et al., 2018).

An interviewee from a local startup encapsulated this transformation, arguing, '*The traditions of automotive companies have been broken; these outsiders brought new processes, new business models, new concepts, and most importantly, new talents, into the old industry, which did make differentiation for them from other traditional automakers.*' This statement reflects the significant impact that startups have had on the automotive sector, challenging the status quo and introducing innovative approaches that differentiate them from established players.

Post-2018, these startups embarked on product launches and created distinctive brand identities, primarily driven by innovative business models and an aggressive strategy of adopting cutting-edge technologies. For instance, Nio introduced the ES8, a luxurious and intelligent SUV, in 2018, complete with industry-leading services tailored to car owners (Kader, 2022). XPeng Motor launched the G3, a compact SUV featuring a state-of-the-art intelligent cockpit and autonomous driving capabilities (Song and Suzuki, 2019). These novel features attracted a different demographic of consumers driven by diverse purchase motivations. Such characteristics also acted as a catalyst for potential buyers to opt for NEVs. According to a 2019 survey conducted by McKinsey, 69% of respondents have expressed a willingness to consider car brands due to improved connectivity experiences, a figure significantly higher than that observed in the United States (34%) and Germany (19%) (McKinsey, 2022).

This period marked a pivotal shift in the automotive sector’s landscape, with startups leveraging their agility and innovative capabilities to carve out a competitive stance. By integrating advanced technologies and adopting new business strategies, these companies have begun to redefine the automotive sector, setting new standards for vehicle connectivity, autonomy, and sustainability.

Concurrently, most traditional automotive OEMs, particularly foreign ones, maintained a conservative stance and continued to outsource infotainment systems to internet giants like Tencent, Baidu, and Alibaba due to a lack of expertise in this domain. Interviewees have highlighted that even though the local start-ups might have appeared as relatively small and less influential players within the niche during this stage, these startups, especially the leading ones, held the potential to be game-changers for the entire automotive industry as they transitioned into the fifth stage.

Regarding the current state of NEV development, industrial policies shifted from fostering stability, upgrades, compliance, openness, and environmental friendliness before 2017—aimed at nurturing capabilities and creating a protective space for the niche—to a top-level design approach that emphasised fairness, openness, and survival of the fittest. In other words, previous stages saw the government using policies to steer the market due to the sector's immaturity and the market's unpreparedness for new product types. However, starting from this stage, the market matured, and the targeted sector had developed sufficient competitiveness to challenge traditional gas-powered vehicles directly and the established regime. Consequently, the government gradually retreats from its protective stance, allowing market forces to guide the socio-technical transition (CATRC et al., 2018).

Reflecting on this transition, an interviewee observed, '*The customers in China have gradually accepted NEV as one of their options, and the technologies of NEV have become more mature, so the government determined to gradually reduce financial support and put more regulation for creating a better environment. I think it is the first time the market has embraced the new form of product (the NEV).*' This statement underscores the significant strides made in NEV acceptance and technological advancement, enabling a shift in policy focus from direct support to regulatory measures to foster a competitive and sustainable NEV market. The gradual reduction of financial incentives and the introduction of more stringent regulations reflect the government's confidence in the sector's ability to stand independently, marking a new era where NEVs are considered a viable and competitive alternative to traditional vehicles.

The rapid expansion of infrastructure was another prominent development. By the end of 2018, public charging stations exceeded 330,000, while private charging stations reached 477,000. China maintained its global leadership in infrastructure growth. However, despite increased infrastructure, the ratio of cars to charging stations remained relatively consistent due to the concurrent growth in car ownership. Notably, in terms of public charging station distribution, the three major metropolitan areas—Pearl River Delta (94,086), Beijing-Tianjin-Hebei Region (73,806), and Yangtze River Delta (36,009)—accounted for more than 200,000 of the 330,000 public charging stations nationwide (CATRC et al., 2019).

Beyond the sheer quantity of public charging stations, the quality of charging services witnessed improvement, with charging service operators better aligning themselves with market demand. Additionally, the growing trend of A.C.E.S. further enhanced charging services. As the NEV market experienced rapid growth, the Chinese government began redirecting subsidies from NEV purchases towards the operation of charging-related services, aiming to alleviate the burden on charging infrastructure operators (CATRC et al., 2018). Figure 5-21 shows how the quantity of public charging pillars increased in this period.

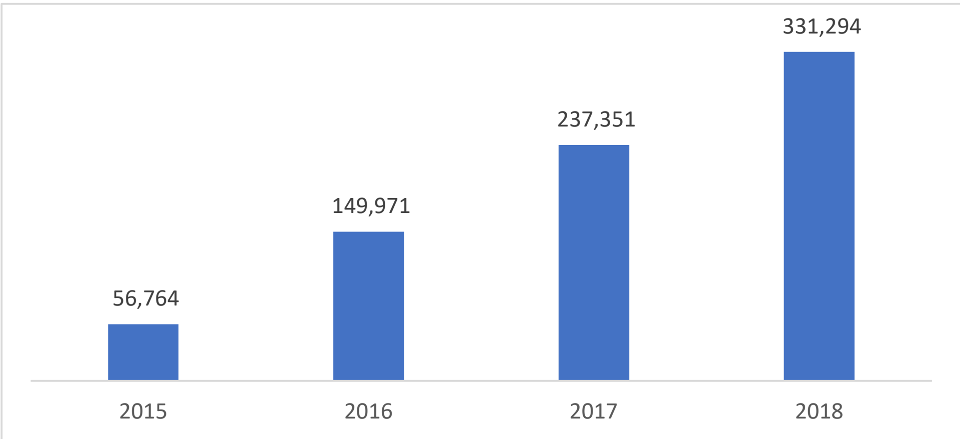

Figure 5-21 Number of public charging pillars 2015-2018 (CATRC et al., 2019)

After 2018, a series of policies were introduced to enhance the management mechanism within the NEV sector. These policies encompassed several facets, including maintaining consistency, promoting industry upgrades, monitoring the entire lifecycle of NEVs, ensuring the market's steady growth, and preventing potential risks (CATRC et al., 2019). These policy initiatives underscored the critical need for an improved management system to effectively address the burgeoning number of vehicles and associated challenges in this period, such as battery recycling and infrastructure deficiencies. Moreover, I contend that some of these policies have also bolstered the innovation capabilities of automotive OEMs. For instance, policies focused on ICV have incentivised automotive OEMs to allocate resources and recruit new talents to develop related products and engineering capabilities. Additionally, the heightened requirements for inclusion in the NEV catalogue to qualify for license plates or subsidies have compelled these automotive OEMs to enhance the competitiveness of their products.

In summary, the NEV niche has experienced rapid growth during this period, driven by several key factors. These include the augmentation of dynamic capabilities among key industry players, the improved competitiveness of NEV products, and the introduction of innovative business models. Furthermore, the widespread deployment of infrastructure, coupled with supportive government policies, has significantly contributed to this growth. Over two decades of development, local companies have cultivated their dynamic capabilities, adapting to the evolving landscape and gaining a deeper understanding of their customer base. Consequently, they have leveraged the advantages of NEVs, particularly their seamless integration with features associated with A.C.E.S. technologies, to develop and produce products tailored to the Chinese market. Additionally, introducing new business models tailored to the Chinese market has played a pivotal role in bolstering NEV sales. Lastly, supportive policies, such as dual credit systems, license plate limitations, and substantial infrastructure development, have incentivised consumers to opt for NEVs over traditional gas-powered vehicles.

Nevertheless, despite the overall optimism and positive trajectory of niche development, certain potential risks persist and warrant consideration as they could challenge the ongoing transition. Firstly, core battery technologies remain primarily controlled by battery suppliers rather than automotive OEMs. Secondly, connectivity-related features such as online stores, operating systems, and ecosystems are predominantly controlled by internet giants like Tencent, Alibaba, and Baidu, resulting in limited customisation for different automotive OEMs. Thirdly, data monetisation remains a topic of ongoing discussion and has yet to yield immediate profits for these OEMs (McKinsey, 2019).

Reflecting on these challenges, an interviewee with experience across multiple automakers shared, '*The period posted lots of challenges for the automakers; the environment changed so fast that we could not catch up and modify our plans. Where we should put our resources should determine the outcome.*' This statement underscores the rapid pace of change in the automotive sector, emphasising the need for automotive OEMs to allocate resources and adapt quickly to maintain competitiveness strategically.

As the automotive industry continues to navigate these challenges, defining the value chain and identifying key segments for investment emerge as crucial strategies. The subsequent section will delve deeper into these issues, exploring their implications for the transition path and the broader automotive ecosystem's evolution.

5.6.5 External level: peer socio-technical systems

While the Chinese NEV sector was actively enhancing and optimising its management systems, including homologation requirements and standards development, it was concurrently experiencing a significant increase in communication and collaboration across various global NEV markets. An illustrative example of this is the establishment of EVS-GTR (Electric Vehicle Safety - Global Technical Regulation) in May 2018, which represents the technical regulations for NEVs and addresses power battery safety under the purview of UNECE (United Nations Economic Commission for Europe) (CATRC et al., 2019). This project involved China taking on a leadership role, transitioning from a follower to a global leader within the NEV sector (CATRC et al., 2019). Furthermore, China actively engaged in numerous standardisation projects and hosted and participated in various conferences and seminars. These endeavours bolstered China's global influence and laid a foundation for internationalising the Chinese NEV sector.

From a market perspective, although China dominated the global NEV market, smaller markets such as the Netherlands and Norway, with annual passenger car sales of approximately 0.5 and 0.2 million, respectively, demonstrated remarkably high NEV penetration rates, as presented in Figure 5-22. Norway, for instance, boasted a 37.5% NEV penetration rate, while Sweden recorded a 6.5% NEV penetration rate in 2018 (CATRC et al., 2019). The attractive policy landscape was the primary driver behind these high market penetration rates. Using Norway as a case in point, scholars argue that national policies effectively accelerated NEV adoption while constructing an environmentally friendly image for BEVs. These Norwegian government policies offered economic and symbolic value to end customers (Ingeborgrud and Ryghaug, 2019, Orlov and Kallbekken, 2019).

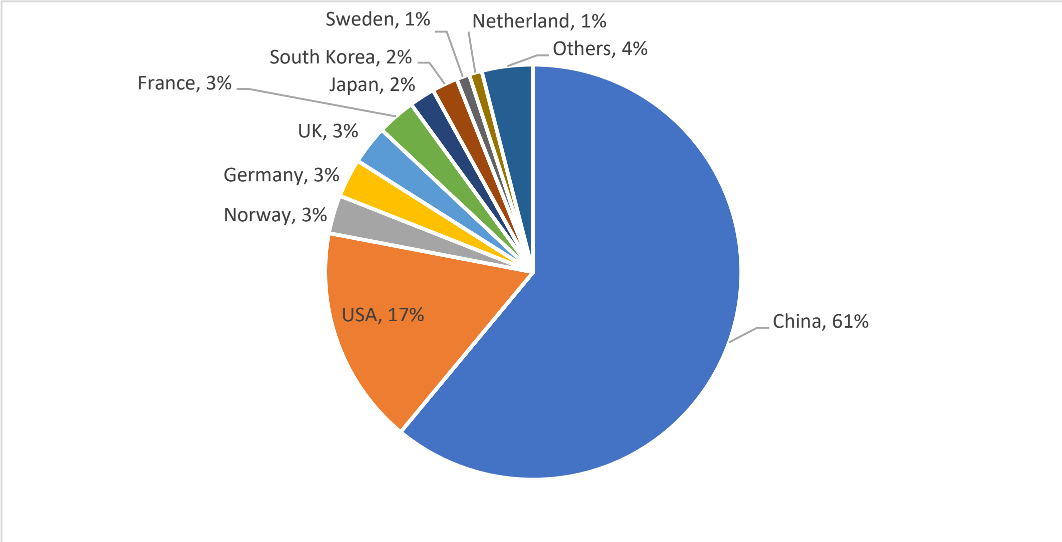

Figure 5-22 2018 NEV sales distribution among different markets (passenger car only) (CATRC et al., 2019)

In this context, Chinese automotive companies recognised European markets, notably Norway, as attractive opportunities for expanding their NEV market presence beyond their domestic borders. In 2017 and 2018, traditional automotive companies like Geely and SAIC and startups like Nio, XPeng, and Ai-Ways began considering European markets as their next destination. For example, Nio established NIO GmbH in Germany, serving as the company's design centre (Nio Inc., 2019a) and its preparation hub for entering the European market. This included building relationships with local governments and institutions and nurturing a talent pool tailored to the European market.

According to interviewees with experience in internationalisation, Norway was especially appealing to these Chinese automakers for several reasons: (1) it lacked a local automotive OEM, reducing the risk of local government or institution resistance to protect local companies; (2) it was not an EU member, thus avoiding strict EU homologation requirements with only minor modifications needed for local model compliance, (3) it boasted robust policy support and the highest NEV penetration rate, and (4) the market's relatively tiny size minimised the risk of failure, with Chinese

OEMs concerned that failure in Europe might impact their performance in China. For instance, XPeng's senior management team visited the European market in 2018 and 2019, officially entering it in late 2020.

Reflecting on this decision, an interviewee from a local start-up's internationalisation team remarked, '*We understood we were not going to take the market in one night, so we decided to find a low-risk market to build our capabilities first. Norway was the most suitable due to its favourable policies without a local automaker.*' This comment highlights the calculated strategy of Chinese automakers to use Norway as a testing ground for their international expansion efforts, leveraging the country's unique market dynamics to gradually build their capabilities and brand presence in Europe.

For local automakers, expanding overseas was essential for achieving global recognition. Initially, Chinese automakers predominantly entered developing markets, where product standards were lower and competition was less intense. However, targeting developed markets like Europe required a significant reallocation of resources towards product development, market research, strategy formulation, and supply chain management. The recruitment of international talent, exemplified by Nio's design centre in Germany, played a crucial role in enhancing the capabilities of Chinese OEMs. While these developed markets were not fully penetrated at this stage, the groundwork laid through these preparatory efforts positively influenced China's NEV sector. This 'going abroad' trend is argued to have benefitted the socio-technical transition of NEVs within China, marking a significant step in the industry's evolution.

The emergence of Tesla also played a significant role in shaping the focal transition. Tesla's renowned three-step master plan, 'build a sports car to enter the high-end market, then use this money to build a more affordable sporty family car, then keep decreasing the price and seize the mass market', propelled Tesla's substantial growth in the late 2010s, as demonstrated in Figure 5-23. Starting in 2016, Tesla's global sales exceeded 50,000 and surged to 195,000 in 2018 with the introduction of the Model 3 (Markline). Tesla possessed several clear advantages, including advanced technologies, vertical integration capabilities, an extensive Supercharger station network, and innovative business models like the subscription-based Autopilot feature.

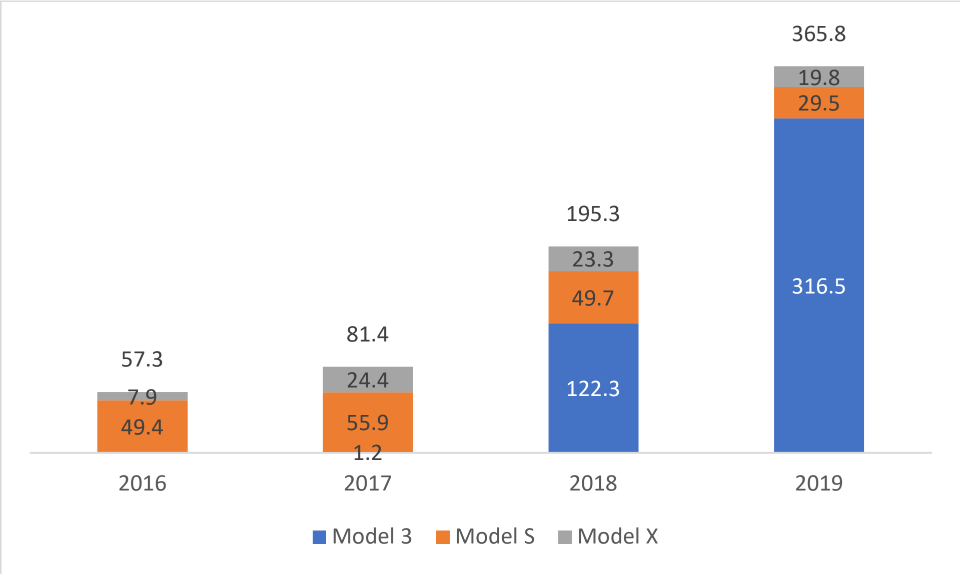

Figure 5-23 Sales volume of Tesla (in thousands) by model (Markline)

Establishing a robust charging network was crucial for overcoming range anxiety, a primary barrier to BEV adoption (vestedfinance.com, 2020). Instead of waiting for government or third-party operators to construct charging infrastructure, Tesla took the initiative to build its charging stations, covering key routes to alleviate concerns about finding charging stations during long-distance journeys. Despite the significant initial investment, Figure 5-24 shows that Tesla had already invested USD 1.5 billion in constructing these charging stations by the end of 2019. These actions positioned Tesla as a global pioneer in the NEV niche.

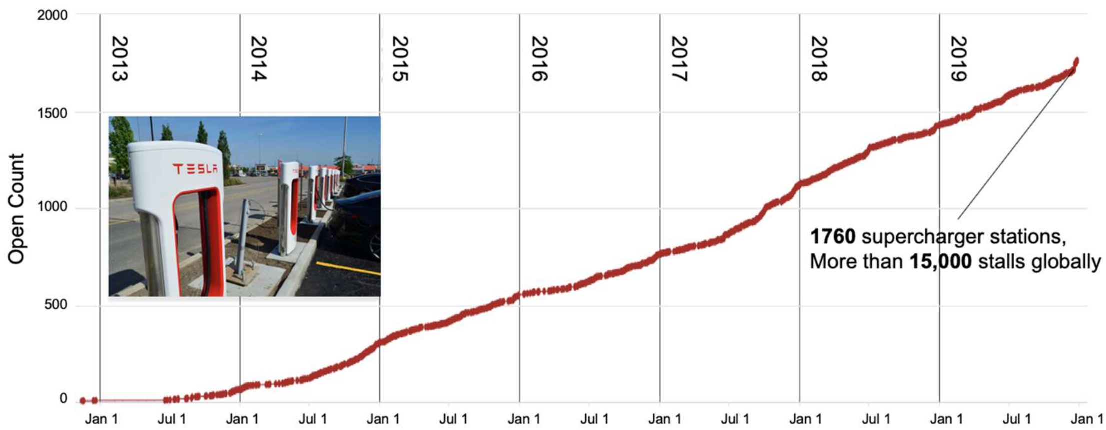

Figure 5-24 Tesla's global supercharger network (vestedfinance.com, 2020)

The Tesla effect was evident in China, particularly among local automotive OEMs and startups. The influence extended across various dimensions: first, Tesla's brand strategy was adopted by several Chinese automakers. For instance, Nio initially launched the high-end and limited sports car EP9 to enhance its brand image before introducing the high-end family SUV ES8. Second, Tesla's approach to creating uniqueness influenced not only NEV products but also gas-powered vehicles in China. Startups like Nio and XPeng emphasised autonomous driving capabilities and intelligent cockpit features such as personalisation and voice recognition. Third, while not directly copied, Tesla's business models inspired Chinese companies. Examples include Nio's Battery-as-a-Service (BAAS) concept and XPeng's construction of proprietary charging stations to address range anxiety. Fourth, Tesla's design principles prompted the 'Chinese Tesla' concept, widely discussed on the Chinese internet. Lastly, several local OEMs, particularly startups, adopted Tesla's marketing and sales strategies directly or with modifications. This encompassed strategies such as fixed pricing, direct sales, and showroom presence in shopping centres.

An interviewee from a local startup candidly expressed the widespread ambition within the industry: '*Everyone wants to be Tesla. If we can, we want to copy everything from Tesla to mimic its success.*' This sentiment underscores the profound impact of Tesla's strategies on shaping the aspirations and approaches of Chinese automotive companies as they navigate the competitive landscape and seek to establish themselves both domestically and globally.

Undoubtedly, Tesla's influence on the Chinese automotive industry extended far beyond a mere enumeration of examples. Interviewees have mentioned that it encompassed many areas, from adopting use-case-based product planning techniques to innovative approaches to leveraging social media for product promotion, vertical integration, feature subscription models, and even the internationalisation strategies deployed by Tesla. These elements collectively contributed to what can be described as 'the shadow of Tesla', permeating various facets of the Chinese automotive landscape. In summary, during this transitional stage, the Tesla effect can be unequivocally characterised as overwhelmingly positive. It introduced many transformative ideas, reshaped the perception of NEVs from primary products to premium offerings, addressed critical issues related to BEVs, such as range anxiety, and provided a benchmark for critical players within the NEV niche. More discussion will be presented in Chapter 8.

A significant increase in interactions with external socio-technical systems can characterise this transition stage. It represents a crucial phase where Chinese automotive OEMs positioned themselves for entry into developed markets, bolstered by the enhanced capabilities of these companies, which imbued them with the confidence to compete beyond China's borders. Notably, the linkages between China's internal socio-technical system and its global peer socio-technical systems grew stronger, departing from the more independent trajectories observed in earlier stages. These interactions injected substantial energy into niche development and proved conducive to the transition path.

Moreover, despite Tesla's models not being localised in China at this juncture, the far-reaching influence of the 'Tesla effect' had already commenced, compelling local companies to bolster their innovation capabilities in areas such as management systems, strategy development, and new business models. This effect can also be unequivocally regarded as positive, contributing to the advancement of the NEV niche and expediting the acceptance of NEV products among end customers.

5.6.6 External level: associated socio-technical systems

The 2019 KPMG China Leading AutoTech 50 report highlighted four automotive technology categories: intelligent connectivity, aftersales service, manufacturing technology, and mobility services (KPMG, 2020). These categories underscore the comprehensive impact of technology on the automotive industry, reshaping business models and consumer behaviours. NEVs have become a key platform for these technological advances, reducing the competitive gap with ICE vehicles.

In this context, five associated socio-technical systems were identified as influential: power battery, internet, telecom, grid, and shared economy sectors. These sectors have significantly shaped the development of A.C.E.S. For instance, autonomous driving advancements are linked to the internet and telecom sectors, while electrification is tied to the power battery and grid sectors. All five sectors influence shared mobility, as Table 5-7 demonstrates.

Table 5-7 The relation between socio-technical systems and A.C.E.S.

Socio-technical System	**Power Battery**	**Internet**	**Telecom**	**Energy (Grid)**	**Shared Mobility**
Autonomous Driving		V	V		V
Connectivity		V	V		
Electrification	V			V	
Shared Mobility	V	V	V	V	V

The power battery sector has grown significantly, with Chinese companies dominating over 60% of the global market by 2017 (CATRC et al., 2018, CATRC et al., 2019). Despite technological gaps compared to global leaders, China's power battery sector remains a crucial driver of NEV development domestically and globally (CATRC et al., 2019). Moreover, the Chinese power battery sector emerged as a critical driver of NEV development within China and as an influencer on a global scale.

Advancements in the power battery sector contributed to an extended driving range for NEVs. The increased power density and technological improvements like battery management systems and new materials propelled NEVs from intra-city mobility solutions to viable options for inter-city travel. Moreover, battery costs decreased as manufacturing processes improved and economies of scale kicked in. This reduction further narrowed the price gap between NEVs and traditional gasoline-powered vehicles. Nevertheless, challenges persisted, including management system shortcomings for monitoring and testing BEVs, inadequate battery recycling systems, and shortages of rare metals like cobalt and nickel (CATRC et al., 2019). The power battery sector positively impacted the focal socio-technical transition.

The consolidation of the power battery sector, internet sector, telecom sector, and grid sector led to resource integration in the charging services domain. Unlike previous stages, where disparate operators made it challenging to consolidate information about charging stations, alliances formed among key players, leading to the development of mobile applications containing data from various operators. This shift spared consumers from the inconvenience of having to download multiple apps. As more charging stations were built, operators shifted their focus from construction to improving operations and business models. While challenges like poor operation and outdated equipment remained, significant progress in charging services was achieved, positively impacting niche development (CATRC et al., 2019, McKinsey, 2019).

In the meantime, ICV technologies were still evolving, requiring extensive road testing to accumulate data, enhance technological capabilities, and ensure safety, reliability, and stability (CATRC et al., 2019). To advance ICV development, the government endeavoured to integrate resources from various sectors, including the internet, telecom, and shared mobility, as well as collaboration with universities and state-owned research institutions—both central and local governments pilot projects to evaluate products and explore new business models through sectoral integration. The market's value reached USD 55 billion in 2017 and was projected to grow by 20% over the following three years (CATRC et al., 2018).

Automakers ventured into the sector with innovative business models as the market grew. For instance, Tesla began constructing its charging stations, while Nio and BAIC introduced battery-swap stations, embracing the concept of battery-as-a-service (Qiao, 2023, Ibold and Xia, 2022, Kader, 2022). These approaches diverged from traditional charging station operators, who primarily aimed to profit from charging services to NEV users. In contrast, automakers focused on bolstering the sales of their NEVs. Tesla's investment in supercharging stations demonstrated its capability to provide super-fast charging services, enhancing the overall user experience, especially for Tesla owners.

Nio and BAIC recognised that challenges like battery depreciation, extended charging times, and high costs were significant barriers for end-users when considering BEVs. They introduced battery-swap services to address these pain points, enabling car owners to purchase vehicles without a battery, significantly reducing the initial purchase cost (Ibold and Xia, 2022). Subsequently, users could opt for a battery-renting package tailored to their driving needs, with lower-cost options for customers with lower mileage requirements.

In 2019, Nio took a step further by offering a ‘moving power bank’ service through its Nio Power department (Nio Inc., 2019b). This service involved trucks with substantial power banks driving to locations designated by car users to provide charging services for all-electric cars. Nio’s customers received cost advantages and priority service, making this initiative particularly well-received in areas lacking charging stations (Prenzler, 2019). It’s important to note that, according to interviewees’ insights, these services did not generate profits for the automotive OEMs; instead, they incurred significant costs for maintaining service quality. Other issues, such as high construction costs, limited coverage of battery-swap stations, and standardisation challenges, contributed to a low penetration rate of this service. Furthermore, mobile charging services raised environmental concerns due to their higher carbon emissions than regular charging services. Nevertheless, these initiatives enhanced the user experience of BEVs and can be considered positive contributions to the transition.

Shared mobility, led by actors from the NEV, internet, grid, and power battery sectors, played a pivotal role in the transition. Xiaomin Wang, an expert at the Research Centre of National Development, emphasised shared mobility as an ideal platform for integrating resources for NEV development. This integration encompassed aspects like autonomous driving, intelligence, electrification, digitalisation, cross-industry collaboration, and cross-company integration (CATRC et al., 2018).

Shared mobility served as a solution to address the rising car ownership in the market. Didi emerged as a critical player, collaborating with numerous local automotive OEMs and procuring significant numbers of NEVs, particularly in cities with NEV license plate policies. For example, NEVs from SAIC's Roewe brand were prevalent in Shanghai, while BAIC's NEVs dominated Didi's Beijing fleet. By 2018, Didi boasted 500 million users in China and provided services more than 10 billion times, surpassing Uber's 5.2 billion service instances in the same year (McKinsey, 2019). While shared mobility companies played a crucial role in the sector, automotive OEMs also actively participated in promoting their NEV products. Geely, for instance, established its own shared mobility company, Caocaokeji, and BAIC partnered with Foxconn to create GreenGo (CATRC et al., 2018).

The impact of socio-technical systems on the automotive industry has been profound and transformative, reshaping conventional business models and technological approaches. An interviewee encapsulated this shift, noting, '*All of the sudden, even the most conventional automotive company started to talk about smart tech and the concept of A.C.E.S., even though they might not know what they were talking about.*' This observation highlights the widespread influence of advancements in A.C.E.S. on the sector, driving even traditional automakers to explore and integrate these innovative technologies and concepts into their strategies, regardless of their prior experience or understanding.

To recap, the socio-technical systems related to A.C.E.S. technologies played vital roles in the transition path. Key actors within these socio-technical systems significantly contributed to the development of the target socio-technical system, enhancing NEV competitiveness through features like extended driving range, autonomous driving, intelligent cockpits, and connectivity services.

5.6.7 Summary of the stage

During this phase, the prevailing environment was marked by less optimism than in previous stages due to challenging macroeconomic conditions and the trade tensions between China and the United States. Significant shifts in social structures, including a reduction in potential buyers and the collapse of the P2P industry in China, also introduced hostile forces that impacted the transition. However, some positive factors emerged during this period, including the rise of the shared economy and the Chinese government's commitment to addressing environmental issues, which counterbalanced the negative influences on the transition.

The internal dynamics of this phase underwent substantial changes. Firstly, the market ceased its prolonged growth trajectory and entered a phase of stagnation and transformation towards a more stock market-oriented landscape. Moreover, the composition of consumers evolved, with a shift from first-time buyers to consumers seeking vehicle upgrades or replacements. This change in consumer demographics influenced their preferences, favouring more extensive and premium products, emphasising the importance of intelligence as a product characteristic, and leading more potential car buyers to consider NEVs due to their advanced intelligent features. Furthermore, the dominance of joint ventures in the market for decades began to wane, paving the way for local automakers to assert themselves. These transformations posed challenges for automakers, with uncompetitive ones facing the risk of elimination.

The market expanded rapidly beyond tier 1 and 2 cities, including lower-tier cities adopting NEVs. Consequently, the NEV sector became increasingly competitive and crowded during this stage. With a growing market size and clear government support, nearly all automakers formulated plans for electrification. Start-ups established in earlier stages also introduced their products, often incorporating innovative features such as advanced driver assistance systems or intelligent cockpit technologies.

Infrastructure development, including the construction of charging stations, accelerated to support the burgeoning market. Some automakers even took the initiative to build their charging networks. As the niche matured, the government initiated policy updates, gradually reducing protective measures.

China's emergence as the global leader in the NEV market opened opportunities for participation in international organisations and formulating international standards. These engagements laid the groundwork for local automakers to explore and enter international markets, subsequently influencing the NEV sector in China. Moreover, Tesla's localisation efforts in China significantly imprinted local automotive OEMs, including start-ups. The influence of Tesla was evident across various dimensions of these Chinese brands.

The concept of A.C.E.S. gained paramount importance in the automotive sector during this period. As mentioned, it was a critical driver for interactions and collaborations among different sectors. Innovative features and business models, such as battery swapping, were introduced and adopted by NEVs, as they were considered superior carriers of these features. These innovations further enhanced the competitiveness of NEVs and set them apart from traditional ICE vehicles. The Chinese government continuously optimised associated policies, regulations, and plans, creating an additional window of opportunity for the NEV sector's development.

This phase represents a critical juncture in the socio-technical transition of the NEV sector. The analysis reveals several key developments that collectively signify a profound shift in the industry's landscape.

- **Market Evolution and New Entrants**: The period under examination saw a significant influx of new entrants into the NEV sector, enriching the market with diverse product offerings. This influx heightened competition and expanded consumer choice, signalling a dynamic shift in the industry. The introduction of Tesla emerged as a catalyst for transformation, exerting a considerable influence on established and emerging players in the sector. The impact of Tesla's innovative strategies and models can be seen in the adaptations and responses of other key industry participants.

- **Policy Adaptation and Regulatory Frameworks**: There was a noticeable evolution in the regulatory landscape during this phase. Policymakers shifted from merely developing the market to fostering a high-quality, sustainable sector. This transition in policy underscores a deeper understanding of the sector's evolving needs and a commitment to supporting long-term, qualitative growth rather than mere quantitative expansion.
- **Sector Interaction and the A.C.E.S. Trend**: The widespread adoption of the A.C.E.S. features marked a significant development. It facilitated deeper integration and collaboration between the NEV sector and associated industries such as power batteries, telecommunications, internet services, the shared economy, and energy sectors. This interconnectedness highlights the multi-dimensional nature of the NEV sector's evolution and the importance of cross-sectoral synergies in driving innovation and growth.
- **Peer Socio-technical System and International Involvement**: The NEV sector's engagement with international NEV-related organisations and its contributions to developing international standards reflect its expanding role in the global arena. Additionally, the foray of local automakers into international markets indicates a strategic shift and an aspiration to compete on a global scale. This internationalisation of the sector not only diversifies the market but also enhances the global competitiveness of local manufacturers.

- **Intensified Competition between NEV and Traditional Gas-Powered Vehicles**: A crucial aspect of this phase is the positioning of the NEV sector to compete directly with conventional gas-powered vehicles. Despite the prevailing dominance of traditional vehicles, the stage was set for a gradual shift in market preference, with NEVs beginning to challenge the status quo.

In summary, this phase is pivotal in the ongoing socio-technical transition of the NEV sector. It encapsulates significant shifts in market dynamics, policy frameworks, sector interactions, and international involvement, collectively steering the sector toward a future where it can effectively compete with and potentially supersede traditional gas-powered vehicles. This comprehensive analysis forms an integral part of understanding the evolution and future trajectory of the NEV sector, as summarised in Table 5-8.

Table 5-8 Summary of maturation stage

Landscape (Environment)	Positive Force	• The shared economy boomed. • The Chinese government has determined to allocate more resources to environmental protection projects to improve the environment.
	Negative Force	• Macroeconomics were not as optimistic as in the previous 30 years. • The US-China trade war. • Changes in social structure. • The P2P lending market crashed.
Internal Socio-technical System	Internal Regime	• Gas-powered vehicles dominated the market, but NEVs gradually took market share. • The market has started to stagnate, transitioning from a growing market to a stock market. • The portion of first-time buyers decreased sharply, and buyers had a better knowledge of cars. • Intelligent features such as autonomous driving and an intelligent cockpit became popular. • Consumers tended to buy more significant and more premium cars. • Joint ventures began losing market share to local automakers.

	Internal Niche	• The NEV market extended from tier 1 and tier 2 to lower-tier cities. • More new actors entered the NEV sector. • Cooperation and interaction between automakers became the norm. • NEVs adopted intelligent features to enhance competitiveness and differentiation (the concept of ICV). • Protective policies were gradually removed. • Infrastructure construction accelerated.
External Socio-technical System	Peer Socio-technical System	• Interactions between countries became more frequent, and China participated in international standard-making processes. • Many Chinese automakers have entered or are prepared to enter the European market. • Tesla significantly impacted the development of the NEV sector in China.
	Associated Socio-technical System	• The power battery, internet, telecom, energy, and shared mobility sectors influenced the progress of A.C.E.S., which are considered critical features of NEVs. • Interactions and integrations between these sectors brought new business models and innovations to the NEV sector.

5.7 Stage 5: Market reformation

5.7.1 Overview

Over approximately two decades of development, the NEV sector, once considered a niche market with a limited market share, has gradually evolved into an integral component of the automotive sector in China. By 2021 and 2022, the penetration rate of NEVs had reached 14% and 26%, respectively, encompassing passenger and commercial vehicles (A.M.A and Oceanegine.com, 2023).

Conversely, traditional gas-powered vehicles, which had long dominated the Chinese automotive sector, began to experience a decline in momentum and influence following the emergence of the NEV sector. This environmental shift compelled industry leaders in gas-powered vehicles to revise their strategies to secure their market share in an era of rapid change. Furthermore, this transition saw the involvement of diverse sectors, transforming the formerly linear value chain into a complex network (CATRC et al., 2022). These new participating sectors, conceptualised as associated socio-technical systems in our research project model, introduced various uncertainties into the transition path.

Beyond the business landscape, numerous significant events unfolded during this period. Chip shortages disrupted production volumes, the Russo-Ukrainian War in 2022 impacted energy supplies, the COVID-19 pandemic brought the world to a standstill for over two years, and the UN Climate Change Conference in Glasgow (COP26) established carbon emission reduction goals for participants, all of which influenced the trajectory of this socio-technical transition. The evolving landscape presented challenges for critical actors in China seeking to advance the transition. It offered ‘windows of opportunity’ to enhance the competitiveness of niche markets and expedite the transition process (CATRC et al., 2022, CATRC et al., 2021). Additionally, China’s commitment to achieving carbon neutrality, as set by the government, acted as a significant catalyst for accelerating the transition (Mallapaty, 2020).

Amid this shifting environment, some former key actors with outdated strategies and limited dynamic capabilities, such as Stellantis, were phased out from the targeted socio-technical system. Meanwhile, minor players like BYD and GAC emerged as influential elements in the socio-technical transition path. Notably, there were instances where early entrants with a first-mover advantage struggled to sustain their success and quickly faded from prominence, as seen with Weltmeister and AiWays. The intensifying competition within the Chinese market prompted certain automotive OEMs to explore international expansion, even though their performance abroad was often suboptimal. This trend fostered more extensive interactions and communications between the targeted and peer socio-technical systems.

This section of the analysis will primarily focus on the period between the second half of 2019 and 2022, with occasional references to developments in the first half of 2023. However, these will not be the central focus of the analysis.

5.7.2 Global level

Since 2019, significant events have unfolded, affecting both the targeted socio-technical transition within the automotive industry and people's everyday lives. While this research project aims to encompass as many of these events as possible, it is essential to acknowledge that covering all significant occurrences within this section is impossible. Thus, I will primarily focus on four key events: the impact of the COVID-19 pandemic, the Russo-Ukraine war's influence on energy supply and government strategy, the consequences of the U.S.-China dispute and subsequent supply chain disruptions, and the ramifications of the global chip shortage. Experts in the automotive industry consider these events the most significant factors influencing the targeted socio-technical transition. The following context will elaborate on the impact of these environmental changes on the socio-technical transition.

The COVID-19 pandemic, originating in Wuhan, China, in late 2019, had far-reaching global effects in 2020. Numerous researchers have conducted projects to assess its impact across various dimensions, revealing significant effects on the economy and society, politics, legal conditions, and the environment (Korneta and Rostek, 2021). In 2020, the world faced threats to health and life, prompting strict lockdown policies in different countries. Social distancing measures were enforced to curb the virus's spread, leading to the closure of financial institutions and corporate offices and a halt in business and financial activities (Ozili and Arun, 2023).

The unpredictable nature of the crisis prompted a conservative approach among consumers, investors, and international trade partners, resulting in negative economic impacts such as a high unemployment rate, low GDP growth, and increased energy costs (Ozili and Arun, 2023, Korneta and Rostek, 2021, Bagchi et al., 2020). UNCTAD initially projected a 2% global economic growth rate in 2020 (United Nations, 2020), but the actual outcome was a staggering -2.8% decline in global GDP growth, as shown in Figure 5-25.

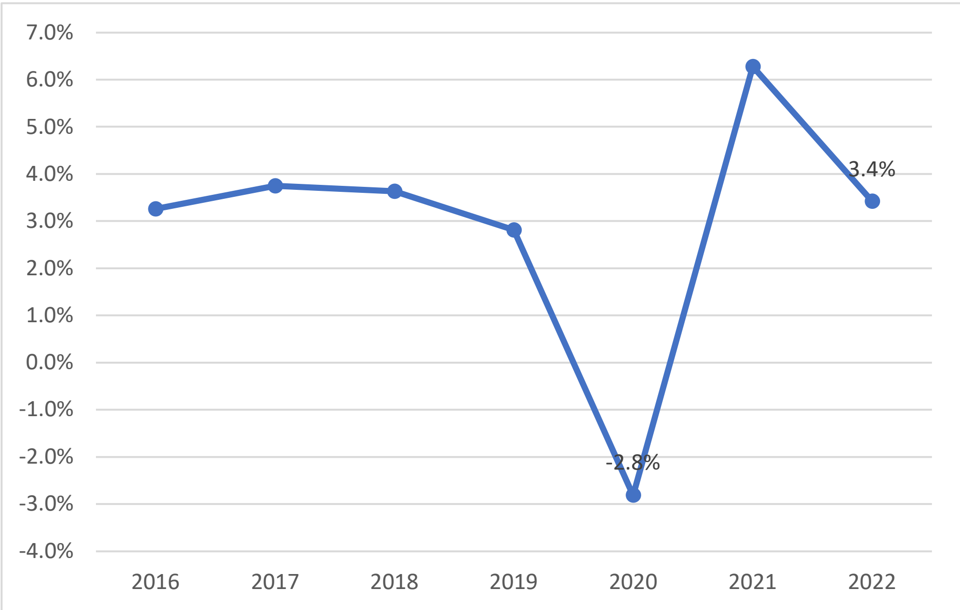

Figure 5-25 Global GDP 2016-2022 (IMF, 2023)

China experienced a similar trend, with economic activities halted for a substantial part of 2020. Many employees worked remotely, and manufacturing plants remained closed for months. Financial markets also faced challenges, with reduced financial activities and poor market performance (Sansa, 2020), China's GDP growth rate saw a significant decline in 2020 (2.2%) and 2022 (3.0%) during periods of stricter lockdowns, as demonstrated in Figure 5-26.

The automotive sector, in particular, felt these economic pressures acutely. An interviewee from a local start-up observed, '*Even before the outbreak of COVID-19 in 2020, we have seen the economy start to stagnate; however, the pandemic worsened the issue, and most automakers started to reduce their investment and cut human resources.*' This sentiment was echoed by several other interviewees, highlighting a widespread recognition of the pandemic's exacerbating effect on pre-existing economic slowdowns, prompting automotive companies to reassess their operational and financial strategies critically.

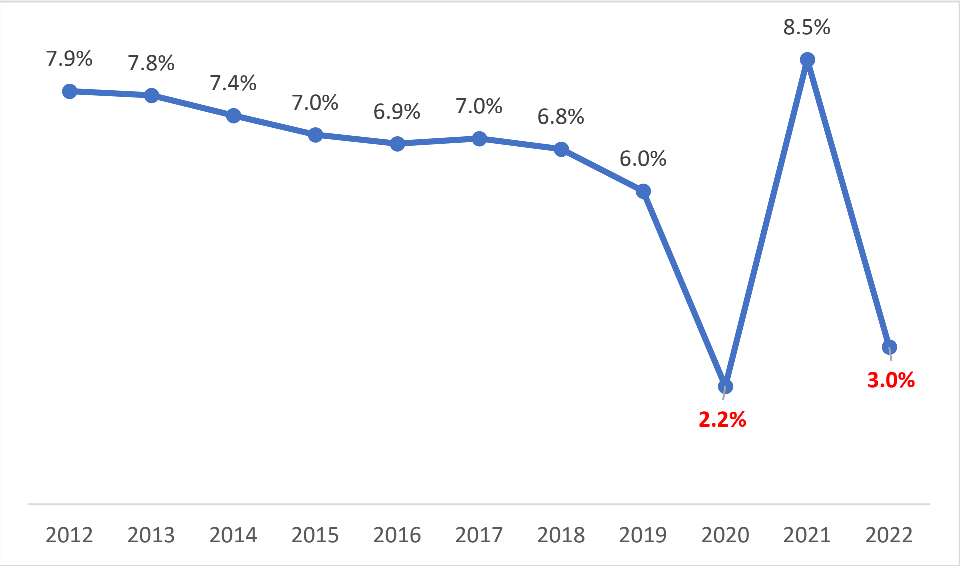

Figure 5-26 China's GDP growth rate 2012-2022 (National Bureau of Statistics of China)

The impact of COVID-19 on the automotive industry of China can be categorised into supply and demand. Supply-side disruptions led to reduced production capacity for automotive OEMs and suppliers, resulting in product shortages. On the demand side, lockdowns and income reductions decreased consumer demand. The overall market performance suffered, with passenger car sales volume declining from 21.2 million units in 2019 to 19.8 million units in 2020 (CBIRC, 2023). Additionally, it is noteworthy that decreasing economic growth had begun before the COVID-19 outbreak. In 2019, China experienced GDP growth rates of around 6%, and disposable income per capita in cities and townships decreased to 5%, lower than in the past decade, affecting consumer purchasing power (CATRC et al., 2020).

The Russo-Ukraine war, which began on February 24th, 2022, with Russia's invasion of Ukraine, had far-reaching consequences, especially for countries highly dependent on Russia for energy and commodities (Lo et al., 2022). This resulted in high inflation rates, energy and food shortages, shifting international relationships, and other consequences. The global GDP decreased from over 6% in 2021 to 3.4% in 2022, illustrating the war's impact. Developed countries, in particular, experienced adverse effects from the conflict.

The war disrupted the automotive industry's supply chain, potentially resulting in a one-million-unit decrease in production volume. Automotive OEMs with operations in Europe and Eastern Europe were forced to pause production because Ukrainian suppliers, mainly wiring harness suppliers, could not provide auto parts (ResearchAndMarkets.com, 2022). This impacted the production of NEVs and gas-powered vehicles (Vijayakumar et al., 2022, Ewing and Gandel, 2022, Silberg, 2022). The prices of these raw materials surged, further increasing costs (Silberg, 2022).

The Russo-Ukraine conflict has had a complex impact, both negative and positive. The conflict disrupted the automotive value chain, particularly for European automakers, by affecting the supply of essential components for ICE vehicles. This disruption, however, has inadvertently accelerated the transition to NEVs.

An interviewee from a European automaker elaborated on the dual nature of the impact: '*The war impacts the European automakers in two ways: firstly, it increased the oil price, which increases the cost of driving gas-powered vehicles, thus increasing the demand for NEVs. Secondly, it cuts the supply of some critical parts of ICE vehicles. Thus, the automakers are forced to change their strategy to NEVs, which don't require those parts.*' This shift is not limited to European markets but extends to subsidiaries and joint ventures in China, propelling a broader move towards electrification.

The interviewee further commented, 'Such *changes have also impacted their subsidiaries and joint ventures in China, which also move toward electrification. So, I think it's positive to the path of electrification.*' This perspective suggests that, despite the immediate disruptions caused by the conflict, the long-term effect could significantly accelerate the global automotive industry's transition towards electric vehicles. This shift towards electrification is seen as a silver lining, fostering innovation and adaptation in response to unforeseen global events.

Moreover, the ongoing trade dispute between the United States and China, which commenced in 2018, continued to exert a significant influence during the period under examination. Despite a temporary truce reached in 2020, during which China committed to increasing imports from the USA to $200 billion over two years, this target remained unmet. Notably, while the volume of agricultural goods imported from the United States to China reached a record high in 2022, the primary driver behind this increase was the soaring prices of agricultural commodities, a phenomenon attributed to the Russo-Ukrainian conflict. Indications emerged that the two nations were gradually drifting apart, signalling a gradual decoupling of their trade ties (Bown and Wang, 2023).

Throughout this trade dispute, the United States government employed various tools, including sanctions against prominent Chinese companies such as Huawei and imposing additional tariffs on bilateral international trade. In response, the Chinese government adopted similar measures in retaliation. Additionally, the White House announced the 'disruption of the supply chain' initiative in 2021, aimed at addressing vulnerabilities in critical product supply chains, fostering equitable and sustainable industrial foundations, and enhancing supply chain resilience in the United States (The White House, 2021). Notably, this initiative included sectors such as semiconductors and large-capacity batteries, which are closely associated with the targeted socio-technical sector.

The implications of this trade conflict on China's automotive sector were multifaceted. As indicated by interviewees, it introduced more significant obstacles for Chinese automakers seeking to expand their presence in North American markets. For instance, some American companies, like Ford, had plans to export vehicles manufactured in China back to the United States or move to Mexico.

Reflecting on the trade war's impact, an American automaker interviewee shared insights into their company's response: '*Our company started to reduce the investment in China after the trade war started. We don't know whether our company will retain operations in China if the situation worsens.*' This statement underscores the uncertainty and strategic reassessment faced by American automotive firms in China during the trade conflict. The recalibration of investment and operational strategies highlights the broader ramifications of the trade war on the global automotive industry, influencing not just trade dynamics but also the future of manufacturing and market strategies for international firms in China.

Furthermore, the intricacies of supply chain management became exceptionally convoluted under the burden of high tariffs and the relocation of some foreign suppliers' production lines from China to other countries. This necessitated a reorganisation of supply chains and the sourcing of specific components and services from alternative locations. Managing distributed facilities across different countries added complexity to suppliers' operations. Additionally, restrictions the United States and its allies imposed on exporting high-tech technology, talent, and products to China, particularly in fields like advanced semiconductors, created hurdles for China's access to cutting-edge technologies, marking a departure from China's traditionally technology-receiving role.

Consequently, China was compelled to bolster its Indigenous capabilities, although for some strategic areas, notably semiconductors, China lagged and required substantial resource allocation. The US-China trade dispute and the resulting disruption in the supply chain could be considered hostile forces impeding progress in the targeted socio-technical transition.

Another critical factor influencing the transition process was the global shortage of semiconductor chips. Semiconductors have assumed increasing importance as essential components in modern vehicles, especially in an era of heightened vehicle intelligence (Krolikowski and Naggert, 2021). Modern cars rely extensively on semiconductor technology with their driving assistance systems, safety features, and in-vehicle entertainment systems. The chip shortage in 2021 led to a reduction in automobile production exceeding 10 million units globally. China accounted for approximately 2 million of these units, while the European Union and North America contributed around 3 million units each. Moreover, chip costs escalated by 20-30%, and lead times extended to 25.8 weeks by the end of 2021, an increase of 82 days from the beginning of the year (CATRC et al., 2022).

The impact of the chip shortage was exacerbated by the disruptions caused by the

COVID-19 pandemic and its associated infection control measures. These measures severely curtailed production activities and disrupted global supply chains, including flight and port restrictions, quarantine requirements, and personnel isolation. Resource allocation and infection control measures resulted in a short-term supply-demand imbalance for automotive chips, contributing to the chip shortage. Moreover, during the first half of 2020, the demand for automotive chips sharply declined due to pandemic-related policies. This prompted a reallocation of production capacity towards consumer electronics to meet the surging demand for personal entertainment, distance learning, and remote work. Less capacity was allocated to automotive chips, complicating the recovery of the automotive market (Wu et al., 2021a, Attinasi et al., 2021).

The US-China trade friction also played a significant role in exacerbating the chip shortage. The semiconductor industry, particularly in the automotive domain, relies heavily on global cooperation and is extremely sensitive to geopolitical factors. The trade friction between the world's two largest economies introduced volatility and unpredictability into this intricate and lengthy industrial chain. China's dependence on chip imports and the United States' substantial influence over the semiconductor industry, where semiconductors are regarded as a strategic resource, heightened the chip crisis in China. Notably, the 'chip suspension' policies profoundly impacted Chinese enterprises (CATRC et al., 2022, CATRC et al., 2021).

As a result of the chip shortage, Chinese automotive OEMs began prioritising chips for higher-end vehicle models over entry-level models. An example of this strategic allocation was observed within Ford's operations, where the production volumes of models like the Focus and Escort were notably reduced. An interviewee highlighted this strategy: '*It was widely believed that the reduced production volume of models like the Focus and Escort was primarily attributed to Ford's allocation of chips to higher-priced* *models such as the Mondeo and Edge in the early 2020s.'* This strategy not only underscores the impact of the chip shortage on production decisions but also highlights the broader implications for market dynamics and product strategy within the automotive sector. We could find Ford's sales volume, divided by model, in Figure 5-27.

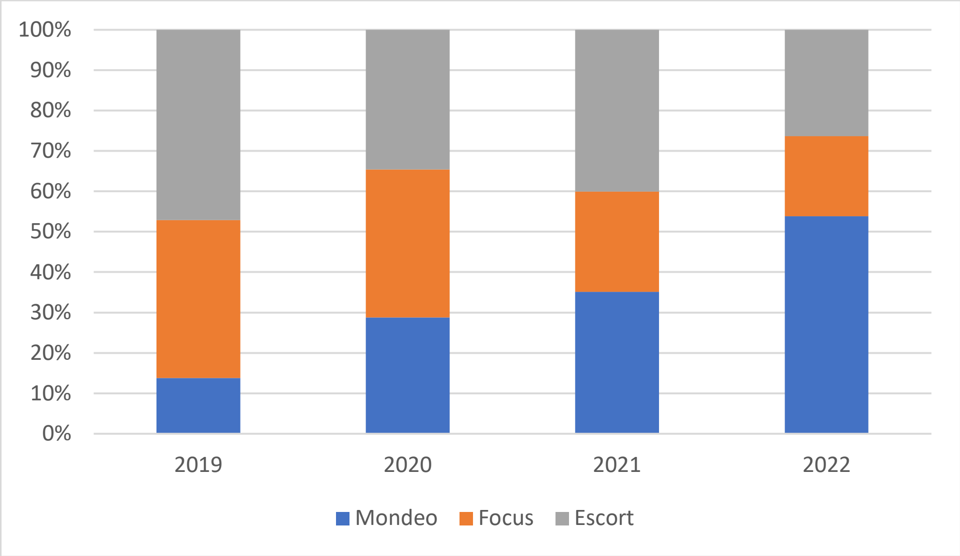

Figure 5-27 The sales share of Ford's sedan product in China, 2019-2022 (CBIRC, 2023)

The global chip shortage presented a formidable challenge to the niche market for NEVs, particularly affecting those models touted for their 'intelligence' features. These advanced vehicles, which prioritise intelligent cockpit functionalities such as voice recognition, in-vehicle entertainment, and autonomous driving capabilities, require more semiconductor chips to support their sophisticated systems. As a result, the chip shortage disproportionately impacted NEV production, with start-up companies feeling the brunt of this crisis.

In response to these unprecedented challenges, leading NEV manufacturers like XPeng, Nio, and Li Auto took proactive steps by establishing dedicated teams focused on navigating the chip shortage. These teams prioritised securing a stable supply of semiconductor chips to minimise production disruptions. An interviewee from a local start-up elaborated on their strategy, stating, '*Our company has urgently established a new department to handle the chip crisis, as do other automakers, especially local automakers, which have lower connections to foreign semiconductor companies. This forced us to increase the lead time for delivery and use lower-performance chips for selected models.*' By limiting production capacities and affecting NEVs more acutely than ICE vehicles, the chip shortage poses a critical challenge to the automotive industry's efforts to embrace electrification and intelligent vehicle technologies.

Amidst the predominantly adverse events during this period, a beacon of positivity emerged with the Chinese government's announcement of a carbon-neutral target for 2060. This pivotal declaration at the United Nations General Assembly in 2020 can potentially significantly bolster the socio-technical transition. Notably, NEVs have been identified as a cornerstone solution in achieving this ambitious goal (Mallapaty, 2020). Strategic actions and policies must be executed to realise this carbon-neutral target successfully. These encompass measures related to emissions reduction and technological enhancements (Liu et al., 2022b). Such policies and initiatives could collectively serve as catalysts, expediting the socio-technical transition towards cleaner and more sustainable transportation systems.

It is imperative to recognise that the factors discussed herein are intricately interwoven, rendering them incapable of isolated analysis. For instance, the decline in economic growth rates may primarily stem from the disruptions caused by the COVID-19 pandemic. Simultaneously, while exacerbated by the pandemic, the chip shortage is directly connected to the ongoing trade tensions between the United States and China.

Moreover, China's stance on the Russo-Ukrainian conflict could further strain its relationship with the United States, potentially escalating the trade war. This, in turn, could exacerbate China's economic conditions and possibly coerce a shift in its strategy towards a 'dual circulation' model, emphasising domestic market focus and self-reliance. In essence, the confluence of these factors paints a complex and multifaceted picture of the socio-technical transition landscape (Javed et al., 2021).

These factors have shaped an environment that may not be conducive to the targeted socio-technical transition. Their interplay could potentially impede the pace of this transition, posing considerable challenges and uncertainties on the path towards a sustainable and technologically advanced transportation system.

5.7.3 Internal level: regime

The automotive sector in China experienced a significant decline in sales volume in 2020 following the outbreak of COVID-19. The sales volume of passenger cars fell to less than 20 million units for the first time since 2016 (CBIRC, 2023, CPCA, 2023). However, despite not reaching the peak levels seen in 2017, the market made a rapid recovery in 2021, thanks to effective control of the COVID-19 pandemic. During this period, while the size of the passenger car market stabilised at around 20-21 million units annually, market dynamics continued to evolve.

In 2020, amidst a downturn in the overall passenger car market, premium automotive brands like Mercedes-Benz, BMW, and Audi experienced an uptick in market performance relative to 2019 (CBIRC, 2023). This trend continued into 2021 and 2022, as Figure 5-28 indicates. This shift posed significant challenges for mainstream automotive brands, which struggled to maintain sales volumes under the changing market dynamics.

An interviewee from a local automaker commented on the situation, highlighting the socio-economic undercurrents influencing consumer behaviour: ‘*It is a difficult time for mainstream brands, due to the enlarged gap between rich and poor of this market, the middle class is dying, who are targeted customers of mainstream brands. Now, these brands need to reconsider their strategy, that’s why lots of them have started to launch premium brands, such as localised Lotus by Geely and higher-positioned NEV brands by other automakers, such as VYOAH by Dongfeng, which has further propelled the path of electrification.*’

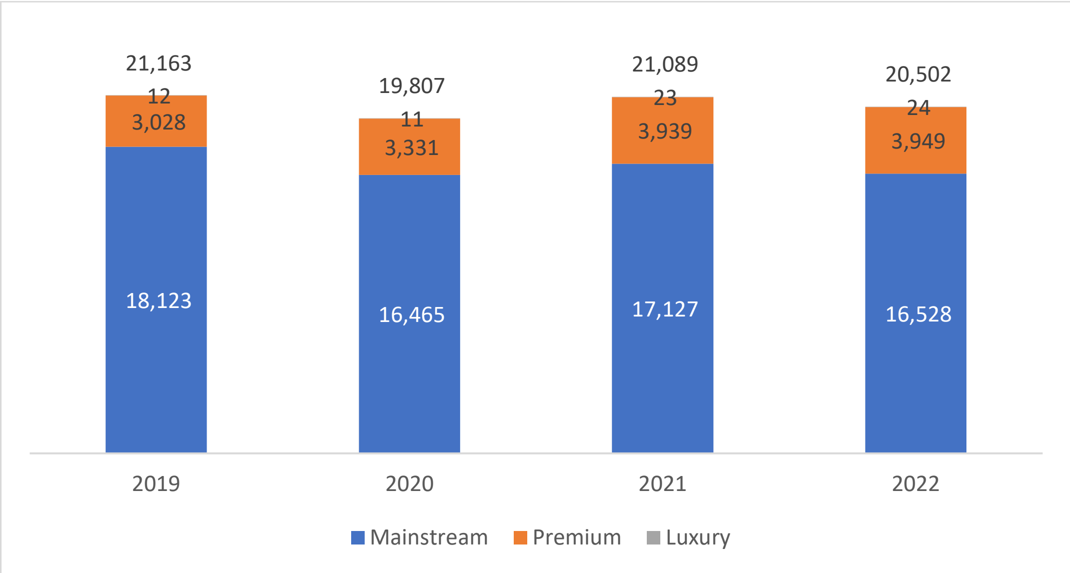

Figure 5-28 Passenger car sales volume in China, by brand level (in thousands), 2019-2022 (CBIRC, 2023, CPCA, 2023)

As international OEMs faced eroding price premiums, especially in the NEV segment, many local automakers adopted a ‘go premium’ strategy. They launched sub-brands for NEV products positioned above their leading brands. Local startups also introduced high-end products targeting the segment traditionally dominated by international premium brands like Mercedes-Benz, BMW, or Audi (collectively known as BBA in China). These actions were driven by changing consumer priorities, emphasising ownership cost, environmental friendliness, and intelligent features such as autonomous driving capabilities rather than brand reputation (McKinsey, 2022). Table 5-9 summarises the price range of selected models of local traditional automakers' sub-brands of traditional local automotive. Table 5-9 demonstrates some cases of price positioning of sub-brands of traditional local automotive OEMs until the end of 2021.

Table 5-9 Summary of NEV sub-brands of traditional local automotive OEMs until the end of 2021

Brand	**Parent Company**	**Partner(s)**	**Found Year**	**Approximate Pricing Range (CNY)**
iM Motors	SAIC	Alibaba Shanghai Zhang Jiang Hi-Tech Park	2020	300K - 500K
Voyah	Dongfeng	NA	2018	300K - 700K
ARCFOX	BAIC	Huawei Magna	2018	180K - 320K
Zeeker	Geely	Mobileye	2021	200K - 600K

Given the exceptional nature of 2020 with the pandemic issue, which may not fully represent market trends, the subsequent sections will focus primarily on market conditions in 2021 and 2022. Notably, Chinese consumers preferred larger vehicles, indicating that their purchasing power continued to grow, even as economic growth remained moderate. As demonstrated in Figure 5-29, in 2021, small and compact cars accounted for 56% of China's passenger car market. However, by 2022, this share had dropped to less than 50%, with mid-size and full-size cars enjoying a 7% growth to represent 44% of the market.

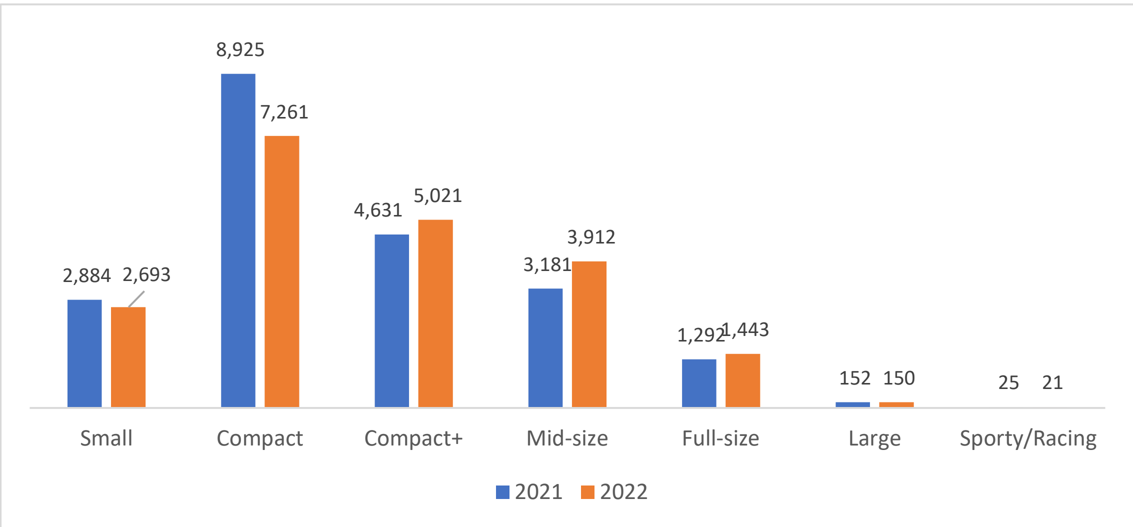

Figure 5-29 Comparison of passenger car sales performance in China between 2021 and 2022 (in thousands) by car size (CBIRC, 2023)

Moreover, unlike consumers in more mature markets, Chinese consumers were more willing to 'upgrade' their vehicles, making this a key driver for purchasing higher-end products (McKinsey, 2022). Consumers favoured more prominent and premium cars, whether in car size, brand level, or purchasing cost. However, it's worth noting that these consumers also became more discerning, having matured and gained exposure to high-value products in the market (McKinsey, 2022). These trends opened windows of opportunity for NEVs to capture market share through their value proposition and product competitiveness.

Brand recognition in China's automotive sector has seen considerable shifts, particularly with the rise of NEVs. Once perceived as inferior, local brands have gained significant ground, challenging the dominance of international premium brands, especially in the gas-powered vehicle domain. The changing consumer perceptions are evidenced by a McKinsey survey where four local brands, including three startups, were ranked among the top five most reputable NEV brands, a stark contrast to the rankings for ICE vehicle brands where no local names made the top five (McKinsey, 2022).

Reflecting on these developments, an interviewee from a multinational automaker observed, '*It was not imaginable for me to go back to ten years ago. We had not imagined that some local brands would shed their inferior image in such a short time and become mainstream or even luxury brands.*' She also noted the impact of geopolitical factors on consumer preferences, adding, '*It is worth noting that the trade war with developed countries like the USA stimulated nationalism and could be considered one of the reasons.*'

These insights highlight the transformative changes in China's automotive market, where local NEV brands are emerging as strong contenders, benefiting from changing consumer attitudes and broader socio-political dynamics. This evolution marks a significant shift in the competitive landscape, with local players leveraging their newfound strengths to challenge established international brands.

Another notable trend for China's automotive OEMs was their international expansion, which had already begun in the previous period. On the supply side, Chinese brands boasted products with advanced technologies compared to traditional international OEMs. The global supply chain has matured and become competitive, with over 50% of components associated with China in 2020. Young consumers were more forward-looking on the demand side, emphasising technology, environmental protection, customisation, and openness to new brands (Roland Berger, 2022). Under these conditions, Chinese automotive OEMs embarked on their journey to expand abroad through products differentiated by advanced features, with China's total car exports exceeding 2 million in 2021 (CPCA, 2023).

These Chinese OEMs ventured into developed markets like Europe and Japan and emerging markets like South America, ASEAN, and the Middle East. However, as highlighted in the previous section, the USA-China trade war introduced uncertainty and high risk, limiting investment in the U.S. market. Among these markets, Europe was particularly favourable for NEV products due to supportive policies and strategies pursued by traditional automotive OEMs like Polestar, MG Motors (a subsidiary of SAIC), and BYD, as well as startups like Nio and XPeng (Carey, 2022).

OEMs producing low-cost, gas-powered products focused more on emerging markets, including Latin America (LATAM) and ASEAN, where the economy was still growing, and infrastructure was less developed. As indicated by interviewees, in the Middle East, especially within the Gulf Cooperation Council (GCC) countries, Chinese brands had established a strong presence during this period, with local OEMs like Chang'an, Geely, and MG experiencing rapid growth through high-value products sold primarily to foreign labourers in these regions. This market segment accounted for approximately 10% of the total exports during this period (Roland Berger, 2022).

In summary, the targeted socio-technical regime during this period was conducive to the growth of NEV products. Even though the total sales volume of the passenger car market remained stagnant, consumers were more willing to invest in better vehicles, presenting an opportunity for NEVs to gain market share through advanced technologies. Chinese consumers exhibited openness to new brands and were willing to consider local brands if their products were competitive with those of international brands. The trend of internationalisation encouraged local automotive OEMs to enhance their capabilities and develop international brands, particularly in the NEV sector, targeting European markets with higher standards. I will delve more into the peer socio-technical system section.

5.7.4 Internal level: niche

In this stage, the NEV sector has shifted from a niche market to a mainstream sector. International automakers like BMW and Volkswagen have rapidly entered the competition, notably in China. BMW's plan to launch 25 NEV models by 2023 and Volkswagen's target of selling 2 million NEVs by 2025 exemplify this trend (CATRC et al., 2020). By 2021, Volkswagen had already introduced four pure electric cars designed for NEVs (CATRC et al., 2021).

In 2021, NEVs, including commercial and passenger vehicles, exceeded a 10% penetration rate (CBIRC, 2023). By 2022, NEV sales volume will reach one-quarter of the total automotive sales, totalling around 7 million units, signifying a significant step towards NEV marketisation, as shown in Figure 5-30. Although the distribution of NEV energy types remained at approximately 20% PHEVs and 80% BEVs, Li Auto's success with range extension models prompted other companies, such as Dongfeng and SAIC, to introduce similar models (CATRC et al., 2022).

Reflecting on Li Auto's achievements, an interviewee from a state-owned company expressed surprise and acknowledgement of the industry's underestimation of range extension technology: '*Li Auto's success is way beyond our imagination. We did not expect such old technology to attract any car buyers. Now we know we were wrong and will try to fix it. I believe more range-extension cars will be available in the following years.*' This sentiment highlights a broader realisation within the industry that there is significant consumer interest in diverse NEV technologies, especially those that could solve range anxiety issues, including those that might have been previously overlooked.

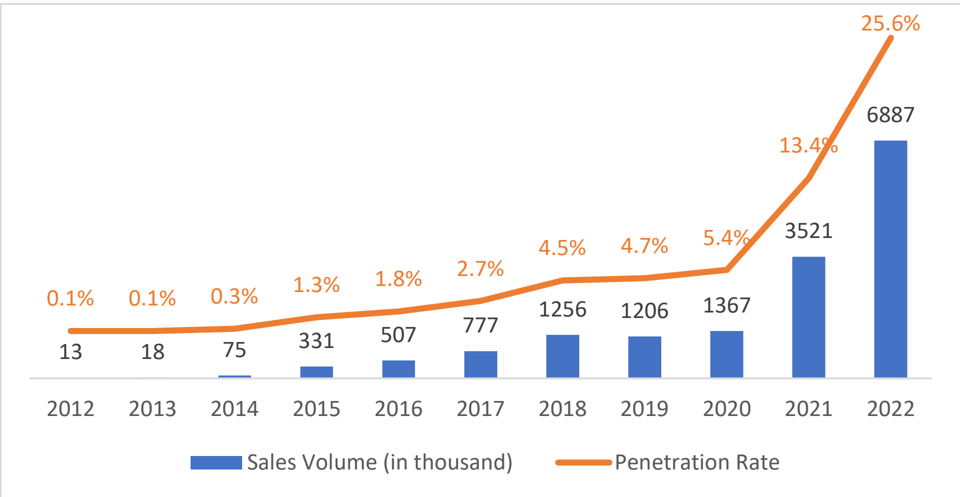

Figure 5-30 NEV sales performance in China, 2012-2022 (CAAM, 2022, CBIRC, 2023)

Figure 5-31 shows that the proportion of private owners of passenger NEVs saw a rapid increase from 50% in 2019 to 78% in 2021, reflecting greater consumer participation. Additionally, areas with restrictions on gas-powered vehicles accounted for around 30% of NEV sales in 2021, down from 40% in 2019, aligning the NEV sector more closely with the broader automotive industry. Policies and business-to-business transactions were the primary drivers in earlier stages, but now, consumer demand has become a dominant force in NEV sector development.

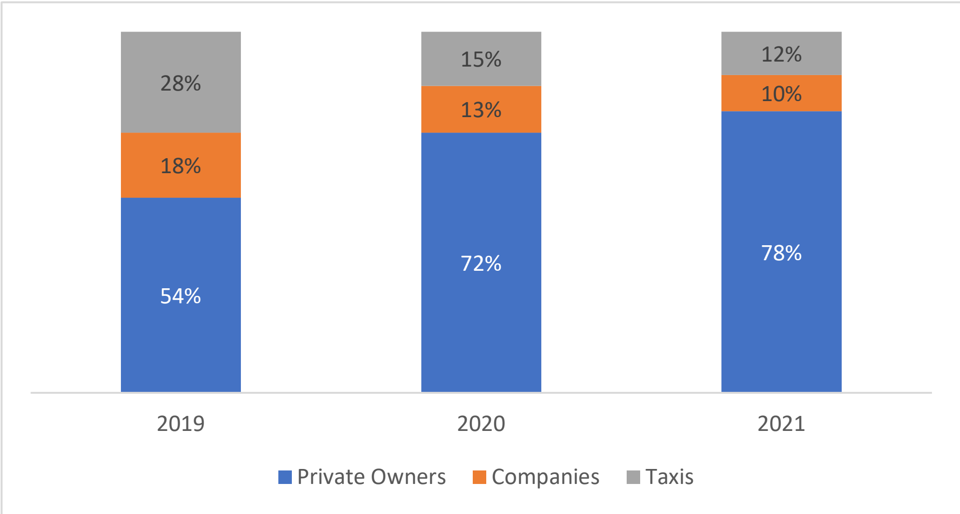

Figure 5-31 Owner type of passenger cars, 2019 to 2021 (CATRC et al., 2022, CBIRC, 2023)

Changing customer perceptions played a crucial role in this shift. Between 2019 and 2022, the percentage of potential car buyers considering NEVs rose from 55% to 68% (McKinsey, 2022). Ownership cost, environmental benefits, technology features, and reduced noise emerged as top purchase reasons for NEVs in 2022, displacing the previous emphasis on license plate availability. This transformation marks the NEV sector's evolution from a policy-driven market to a consumer-driven one.

Integrating new technologies, including autonomous driving, intelligent cockpits, integrated motors, and advanced power battery technologies like blade batteries, has boosted the competitiveness of NEVs (BYD Company Ltd., 2020, CATRC et al., 2022). These innovations have transformed cars into high-tech electrical products that enhance consumers' daily lives. Vehicle-to-grid (V2G) capabilities have also enabled NEVs to store and optimise electrical energy, making them integral components of smart cities (CATRC et al., 2021). NEVs are no longer perceived as inferior in terms of performance and utility but are seen as technologically advanced vehicles offering a superior driving experience (McKinsey, 2022).

Reflecting on this shift, an interviewee from a multinational automaker shared, '*We always looked down on NEV companies, especially start-ups including Tesla. We thought the technology required at least ten more years to mature enough to compete with ICE vehicles. But Tesla, BYD, and the leading local start-ups' performance proved we were wrong. Now we need to push our path of electrification.*' This acknowledgement highlights a significant underestimation of the pace at which NEV technology would evolve and become competitive.

Further emphasising the industry's slow adaptation, another interviewee from a multinational automaker remarked, '*Our management team still does not believe in the rise of the NEV sector; that's why we lost our market in China.*' This perspective underscores a broader hesitation within traditional automotive companies to fully embrace the potential of the NEV market, resulting in missed opportunities and market share losses in a rapidly changing automotive landscape.

The NEV sector has also witnessed a structural shift from vertical integration to network ecosystems. Alliances, mergers, and acquisitions among key industry players have become common. Companies leading these ecosystems have taken centre stage, with government support for cross-sector cooperation, such as energy and transportation, to stimulate diverse production and applications (State Council of China, 2020). The surge in demand has brought supply chain challenges, including rising material costs and reduced subsidies, putting pressure on automotive OEMs to adjust their prices. Material shortages and the COVID-19 pandemic have extended the waiting time for new cars (CATRC et al., 2022).

Since 2019, the Chinese government has been actively shaping the socio-technical transition of the NEV sector through policy interventions. On the supply side, energy efficiency policies have been implemented to facilitate the electrification of automotive OEMs. Simultaneously, on the demand side, financial tools have been employed to reduce purchase and ownership costs, stimulating NEV consumption and stabilising the market in a volatile environment (CATRC et al., 2020). As market stability was achieved, the Chinese government began phasing out subsidies for car purchases, redirecting its focus towards innovation-related policies. For instance, the government encouraged the development of new business models, such as battery swapping (CATRC et al., 2021).

It’s important to note that in 2020, some cities, facing economic challenges due to the COVID-19 pandemic, increased their quotas for gas-powered vehicles, potentially diminishing the advantage of NEVs in obtaining license plates. An estimated 225 thousand gas-powered vehicle quotas increase by 2025 was anticipated (CATRC et al., 2020). Additionally, the launch of China VI vehicle emission standards in mid-2019 led to clearance sales of vehicles with stage 5 emission standards, affecting the NEV market (CATRC et al., 2020).

Apart from market-related policies, the Chinese government has focused on improving the business environment and fostering innovation within automotive OEMs. Initiatives included lowering entry barriers for the NEV sector, promoting OEM independence, supporting foreign OEMs like Tesla in Shanghai, and providing incentives for new business models and technologies (CATRC et al., 2020).

In late 2019, Tesla established its GIGA factory in Shanghai, initially with a capacity of 150 thousand units and a planned expansion to half a million units. Tesla's entry into the Chinese NEV sector marked a significant milestone. Leveraging cost structure, technology, and brand recognition advantages, Tesla quickly became a leader in the Chinese NEV market. Tesla has impacted almost every dimension of the sector, including but not limited to design, product strategy, and pricing. Tesla's product features, such as large touch screens and sleek design, inspired other OEMs and startups. Local companies also adopted autonomous driving and intelligent cockpit features akin to Tesla's offerings, with some closely following Tesla's strategies.

As mentioned by interviewees, Tesla's impact on the automotive industry transcends its vehicles, influencing business models, brand communication, and the entrepreneurial approach of company founders. Local OEMs have embraced subscription models for features like autonomous driving, drawing from Tesla's customer-centric services. Founders now actively engage with audiences on social media, a strategy pioneered by Tesla for direct consumer interaction. This 'Tesla effect' has led to investments in infrastructure such as supercharging stations and the adoption of advanced technologies, marking a significant shift towards electrification (CATRC et al., 2021).

An interviewee from a multinational automaker noted, '*Everyone has been talking about Tesla since 2020. Its success has awakened us to the realisation that the era of electric vehicles is upon us, and it provides proof of profitability for us to negotiate with headquarters to allocate more resources for the electrification path in China.*' Meanwhile, a local start-up representative admired Tesla's benchmarks, saying, '*We want to copy everything from them, from product design to technologies adopted. Tesla* *has set up a new standard of form for us, showing us what an EV should look like.*' These reflections underscore Tesla's role in catalysing a broader industry shift towards electric vehicles, influencing both strategic direction and operational models across the sector.

As local automakers gained influence in NEV development, as elaborated in the previous section, international automakers sought collaborations and technology partnerships. For instance, BYD and Toyota established a joint venture in Shenzhen to develop BEVs. Great Wall and BMW formed a joint venture under the Mini brand for NEV production (Yang et al., 2023).

In this stage, sustaining a dominant position in the NEV market was challenging. Market dynamics significantly shifted, impacting established gas-powered vehicle leaders and NEV pioneers. Notably, leading NEV startups like Nio and XPeng showed remarkable momentum in 2021 but faced challenges in 2022 as traditional OEMs such as BYD and GAC introduced competitive products. Table 5-10 illustrates the sales volume performance of key NEV automakers.

Table 5-10 Sales volume of selected leading NEV automakers in China (CBIRC, 2023)

Brand	**2020**	**2020 Growth %**	**2021**	**2021 Growth %**	**2022**	**2022 Growth %**
Aion	66,371	88%	122,691	85%	213,838	74%
BYD	413,233	-7%	720,267	74%	1,603,229	123%
Tesla	146,399	223%	322,562	120%	441,697	37%
Li Auto	32624	NA	91310	180%	135296	48%
Nio	44,493	121%	90,866	104%	120,158	32%
XPeng	27,006	63%	96,641	258%	120,449	25%

Moreover, the second wave of cross-industry collaborations emerged, with internet giants like Xiaomi, Alibaba, and Baidu investing in the NEV sector. For example, Baidu established a joint venture with Geely to enter the NEV market as an automotive OEM.

Leading consumer electronics manufacturers also ventured into the NEV sector, further diversifying the market (CATRC et al., 2021).

Amidst market expansion and intensifying competition, talent requirements surged. Recruitment for the NEV sector grew by 544% in 2021 and remained high in 2022, with a 296% increase (maimai.cn, 2023). However, challenges included a lack of multi-skilled talents, inadequate human resource planning, and insufficient training programs. Collaboration with universities was also lacking, potentially hindering talent cultivation (maimai.cn, 2023).

As discussed, the journey of internationalisation of Chinese automakers started in the previous phase. The performance of Chinese automakers in Europe was impressive in 2021, with Europe overtaking the APAC market as the primary destination for Chinese exports, accounting for 48% of exported cars (Sebastian, 2021). Projections suggest that 10% to 15% of cars produced in China will be destined for European markets within 5 to 10 years. Challenges included limited internationalisation experience, adapting to European customer preferences, homologation requirements, government relations, political issues, cybersecurity, and GDPR compliance (Sebastian, 2021).

Infrastructure development played a crucial role in supporting the growing NEV market. However, during the initial stages of the COVID-19 pandemic, infrastructure projects were halted due to pandemic control measures. Operators faced cash flow challenges and funding shortages. Nevertheless, infrastructure recovery began in the latter half of 2020. While the growth of charging infrastructure did not match the rapid NEV market expansion, the number of charging pillars increased by 119% from 2019 to 2021. Expansion efforts extended to tier 3 and tier 4 cities, addressing infrastructure gaps in these immersive markets (HSMAP, 2022).

Yet, challenges persist, as highlighted by an interviewee: *'Charging remains a huge problem for car owners, especially during holidays. It is not uncommon to see people waiting for days to charge their car.'* This comment underscores the ongoing hurdles in meeting the changing needs of NEV owners, pointing to a critical area for further development and investment as the NEV market continues to grow.

Battery swapping emerged as a solution to alleviate range anxiety, with substantial investment in the value chain of battery swapping. In 2021, 160 thousand vehicles utilised battery-swapping technology, a 162% increase from the previous year. The battery-swapping stations reached 1,406, a 50% increase (Ibold and Xia, 2022). Nio was pivotal in providing battery-swapping services, accounting for over half of the stations. Challenges included cost competitiveness compared to traditional charging stations, limited standardisation for compatible models, and unproven profitability for OEMs (CATRC et al., 2022). Figure 5-32 shows the number of public charging pillars in this stage.

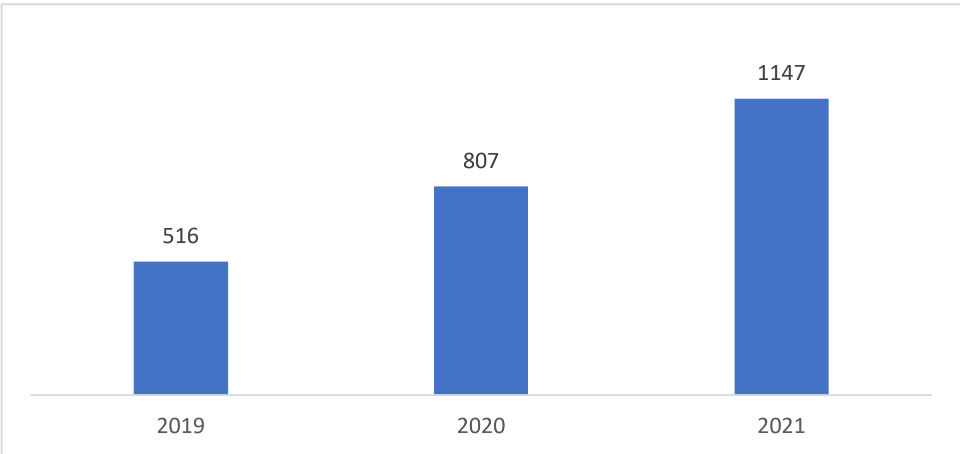

Figure 5-32 Number of public charging stations in China (in thousands), 2019-2021 (HSMAP, 2022)

In summary, the NEV sector transitioned from niche to mainstream, with sustained growth despite subsidy reductions. Established market leaders faced challenges, while new entrants like BYD and startups like Tesla expanded their influence. Cross-industry collaborations added diversity to the market. Talent demands increased with skills, human resource planning, and training challenges. Chinese automakers looked to Europe for internationalisation, beginning with Norway. Infrastructure development progressed but lagged behind market growth. Battery swapping gained momentum. Issues persisted, including supply chain and overcapacity challenges, leading to stricter government regulations (CATRC et al., 2022).

5.7.5 External level: peer socio-technical systems

In the preceding sections, we discussed how Chinese automotive OEMs, recognising the saturation of the domestic market, embarked on a journey to expand internationally. The socio-technical transition in Europe toward NEVs presented a unique opportunity previously inconceivable during the era of ICE vehicles. Unlike ICE vehicles, which are characterised by complex structures demanding high engineering capabilities, the era of NEVs has simplified car structures. Consumer priorities shifted towards driving range, intelligent cockpit features, and autonomous driving capabilities. Consequently, Chinese-made NEVs found openings in the European market, leveraging their technological and intelligent attributes.

In previous stages, Chinese automotive OEMs were predominantly receivers of input from developed markets and were primarily seen as consumers rather than contributors to product development. However, interviewees indicated deeper interactions between China and developed countries in this stage during interviews, significantly influencing the targeted socio-technical transition.

A veteran with experience across various automakers shared insights into this evolving relationship, noting, '*We could find the automakers in the USA start to install huge screens and more intelligent features such as biometric recognition and voice recognition for their products, which is from their experience in China.*' This observation highlights how Chinese market experiences and consumer preferences now influence product development strategies in developed markets. The adoption of features that gained popularity in China by American automakers signifies a shift towards recognising and integrating innovations driven by the Chinese market, underscoring the increasingly contributory role of Chinese OEMs in the global automotive industry's evolution.

While these Chinese automakers had not yet captured substantial market share, they had made significant inroads into minor European markets, particularly in the Nordic region. The potential of Chinese automakers in Europe has garnered widespread optimism, with Reuters predicting that by 2025, Chinese brands would account for 12% to 20% of the BEV market in Europe (Carey, 2022). This optimistic outlook has attracted talent with experience in European companies to Chinese automakers, bringing a wealth of knowledge about European markets and diverse cultural perspectives and networks.

The influx of European talent into Chinese companies has challenged cultural integration. An interviewee from the internationalisation department of a local startup shared their experience: '*We have encountered culture shocks; the working style between Chinese employees and European employees is very different. Both of us have tried to adapt ourselves to the new challenges, and we want to take advantage of both, including the speed and efficiency of Chinese employees and the mannered behaviour of European employees.*' This statement highlights the process of mutual adaptation and learning, aiming to blend the best aspects of both cultures to enhance collaboration and productivity within these expanding Chinese automotive companies.

The drive towards internationalisation required Chinese automakers to adapt to Europe’s unique labour laws, leading to the development of new human resource systems tailored for European operations. This adaptation extended to organisational structures and management systems, including talent management and development processes, to align with the diverse European market environments. These modifications also influenced practices within Chinese headquarters, fostering a more global outlook and encouraging innovation through cross-cultural interactions.

An interviewee highlighted the benefits and challenges of this transition, noting, ‘*The perceptions of unfair treatment among employees, leading to confrontations that required company resources for resolution.’* Despite these hurdles, the overall shift is argued to be beneficial, enhancing Chinese automakers' capabilities and promoting a more mature working environment. However, navigating the complexities of integrating diverse work cultures remains an ongoing challenge.

In addition to organisational changes, talent acquisition played a pivotal role in enhancing the capabilities of Chinese automotive OEMs. The need to comply with various homologation requirements and country-specific standards, such as Euro-NCAP, forced these Chinese automakers to bolster their engineering capabilities (Carey, 2022). Consequently, engineering centres were established in Europe, particularly in Germany. Collaboration between these engineering centres and the Chinese headquarters accelerated the development of engineering capabilities in China. The engineering design for next-generation products aimed to surpass the requirements of global models, leading to product improvements tailored to European markets.

Furthermore, whether assembling vehicles in Europe or exporting from China, establishing a global supply chain became a critical task for Chinese automotive OEMs. Assembling vehicles in Europe required sourcing components locally. Even for exported vehicles, local sourcing was necessary to support after-sales service, including repairs, to minimise transportation costs and ensure suppliers complied with European Union standards. For instance, one leading Chinese startup established a supply chain centre in the Netherlands to manage logistics.

In this stage, the peer socio-technical system, represented by the European automotive sector, exerted a significant influence by enhancing the dynamic capabilities of Chinese automakers in the NEV sector. The infusion of talent with diverse backgrounds, improved engineering capabilities for tailored product development, and the establishment of an internationalised supply chain all contributed to better adaptability to changing environments.

5.7.6 External level: associated socio-technical systems

In the context of NEVs, the supply chain has undergone a transformative shift compared to traditional gas-powered vehicles. The development of ICVs saw increased sensor installations, particularly in NEVs, given their structural advantages. LiDAR, microwave radar, cameras, high-resolution maps, positioning systems, and new decision-making systems played crucial roles in enhancing ICV capabilities by providing comprehensive environmental data (CATRC et al., 2022). These advances were driven by sophisticated chips, complex systems, and applications, thus rendering the semiconductor, telecom, internet, and power battery sectors as associated socio-technical systems of the NEV sector. New legal requirements, such as the Cybersecurity Law of the People's Republic of China, were introduced to address emerging challenges

(CATRC et al., 2022).

The semiconductor sector assumed a pivotal role in the transition due to its significance in enabling intelligent and connected features in modern vehicles. A stable supply of chips was essential for automotive sector development and the targeted socio-technical transition. Moreover, chips became integral to public safety as cybersecurity risks increased, threatening safety if chips controlling critical functions were compromised. Additionally, chips play a vital role in collecting vast amounts of data on external environments, locations, and customer behaviour, making them crucial for national security (CATRC et al., 2022).

Although the Chinese government introduced policies to support the semiconductor sector, they primarily focused on manufacturing and high-end semiconductors for general applications. Policies specific to automotive chips were lacking, and investments in critical areas, such as producing 8-inch wafers and mature manufacturing technologies for the automotive sector, were insufficient (CATRC et al., 2022). Despite the semiconductor sector's critical role in NEV development, investments and support during this period were insufficient, and the worsening China-US relationship exacerbated conditions. It is obvious that the semiconductor sector posed a risk to NEV competency and could negatively impact the targeted socio-technical transition.

Additionally, as ICVs became more prevalent, the significance of the telecom and internet sectors in the NEV industry grew. China has emerged as a global leader in 5G infrastructure deployment, road network scale, and satellite positioning systems, heavily involving the telecom and internet sectors. Separating software and hardware accompanied the rise of intelligent and connected vehicles. Hardware components in NEVs became more standardised, while software became increasingly customised.

Consequently, the traditional carmaker-centric value chain transformed, with ecosystem key players assuming central roles. Partnerships, rather than traditional supplier relationships, became the norm. This shift to 'software-defined vehicles' (SDV) amplified the importance of the telecom and internet sectors in the transition (CATRC et al., 2021).

An interviewee with experience in intelligent feature planning reflected on this shift, stating, '*Hardware used to be the key competencies of automakers, but now as the hardware becomes mature, we need software to make a difference among automakers. I believe the whole value chain will change in the future in addition to the human resources, process, and management changes we see today.*' This perspective underscores the transformative impact of software on the automotive industry, indicating a broader change in how vehicles are designed, produced, and valued. The increasing significance of the telecom and internet sectors in this transition points to a future where software capabilities are central to automotive innovation and competitive advantage.

Like Tesla's influence at the beginning of this stage, Huawei significantly impacted the NEV sector. Huawei established an automotive laboratory in 2014 and progressively became a crucial player in the NEV market (Song, 2023). Leveraging its leadership in smartphones, Huawei created an ecosystem compatible with Huawei phones. The company transitioned from providing technical solutions and components to automotive OEMs to adopting two additional business models: 'Huawei Inside', which involved deep cooperation with automakers, and 'Huawei's Selection,' where Huawei was deeply engaged in automaker operations, encompassing engineering, product design, marketing, and more. A notable example was the Aito, jointly designed by Huawei and Seres, which garnered over 70,000 units in sales in 2022 (CBIRC, 2023). Internet giants like Tencent, Baidu, Xiaomi, and Alibaba also invested in the NEV sector at various levels. Table 5-11 summarises some of the actions taken by these companies.

Table 5-11 Summary of the significant investment of leading internet companies in the NEV sector in the 5th stage (CATRC et al., 2021)

Company	Actions in the 5th Stage
Alibaba	Cooperated with SAIC to establish iM Motors and announced intelligent SUVs and sedans in January 2021.
Baidu	In January 2021, Baidu announced it would establish an automotive OEM, and Geely would be its strategic partner. The investment has been the most significant since the company announced Baidu CarLife in 2015.
Huawei	Established automotive laboratory in 2014 and automotive business unit in 2019. Then, the Hi-Car operation system for intelligent vehicles was launched in 2020.
Tencent	They signed a strategic cooperative agreement with Geely in January 2021 to help Geely develop their intelligent products.
Xiaomi	It was announced that an exclusively-invested subsidiary corporation would be established in March 2020 to develop and produce electric cars.

The power battery sector continued to play a vital role in the transition, having evolved over 20 years to become highly competitive globally. Innovations within Chinese power battery companies became crucial, shifting the sector's focus from government and policy-led initiatives to market-driven and business-operated endeavours (CATRC et al., 2021). The power battery market grew significantly, surpassing 100 GWh (154.5 GWh) in 2021, constituting around 52% of the global market, with six of the top ten power battery companies based in China (CATRC et al., 2022).

Unlike the semiconductor sector, China's global solid position in the power battery sector supported NEV development and shared expertise with automotive OEMs, enhancing NEV products. However, the risk of overcapacity loomed as major power battery companies planned to increase production capacity to 3 TWh by 2025, while expected demand ranged from 330 to 424 GWh (CATRC et al., 2022).

The emergence of V2G technology, which allowed power batteries to store electricity and relieve grid pressure, as mentioned in the previous section, fostered increased interactions between the NEV and energy sectors. V2G was in its early stages, with an unclear roadmap, a lack of profitable business models, and limited exploration of management systems and innovative technologies (CATRC et al., 2022). Despite its immaturity, V2G's potential as a grid component appealed to a country with substantial energy needs, warranting ongoing monitoring of its progress.

In summary, associated socio-technical systems during this stage can be categorised into four categories:

- **Development of ICV**: Semiconductor, internet, and telecom sectors played crucial roles in supporting the proliferation of intelligent features and operational systems in ICVs.
- **Increasing Market Opportunities**: Various sectors, including telecom, internet, and even the electric scooter sector (e.g., Niu Technologies), recognised new opportunities in the NEV transition, driving increased participation.
- **Growing Importance in Supply Chain Management**: The power battery sector's significant cost share and performance impact on NEVs regarding safety and driving range remained pivotal.
- **Emerging Smart City Concept:** The energy sector transitioned from solely an energy provider to a 'partner' in NEV sector operations, contributing to electricity supply optimisation through V2G.

While this research project could not comprehensively cover all associated socio-technical systems (e.g., the academic sector, shared mobility sector, etc.), it addressed vital sectors. It illustrated their profound influence and active participation.

5.7.7 Summary of the stage

Several international events unfolded during this stage, impacting China and global countries, with many of these events adversely affecting the targeted socio-technical transition. The ongoing US-China dispute disrupted China's NEV sector's supply chain, particularly for critical components such as semiconductor chips. Secondly, the Russo-Ukrainian war led to fluctuations in raw materials and critical component supplies. However, it also accelerated the transition to NEVs in Europe by limiting the supply of essential parts for internal combustion engine vehicles. Thirdly, the COVID-19 pandemic had detrimental effects on various aspects of the transition, including production, supply chains, and market demand. The chip shortage exacerbated supply challenges, especially since chip-supported intelligent features were crucial for NEVs. These events did not occur in isolation but influenced each other, creating a more complex landscape. However, amid these challenges, China's commitment to carbon neutrality positively impacted the transition by positioning NEVs as a critical solution.

Despite the volatile landscape, supply and demand dynamics in the automotive sector remained unstable, leading to fluctuations in the Chinese automotive market. Nevertheless, market upgrading persisted as consumers became more discerning and rational in purchasing decisions. Premium brands and more significant segments continued to gain market share. Additionally, as the market structure rapidly shifted, international brands' dominance eroded quickly, and consumers increasingly favoured local brands. Building on the foundation laid in the previous stage, Chinese automakers expanded their presence in the European market.

This stage marked the NEV sector's integration into the regime, with its market share surpassing 10% of the total passenger car market. All players from the internal combustion engine vehicle sector entered the NEV competition. The competitive landscape evolved rapidly, with early NEV launchers, primarily startups, initially taking the lead but subsequently losing ground as traditional automakers introduced their NEVs in the latter half of this stage. Alliances between companies and even sectors increased in response to heightened competition, resulting in diverse products and business models, particularly those featuring advanced intelligent capabilities. The Tesla effect significantly influenced the NEV sector during this period, shaping the industry for the foreseeable future.

Suppliers of intelligent features played a crucial role in the NEV sector, transforming it from vertical integration to a network system and fostering stronger bonds between automakers and these suppliers. Some actors from other sectors aspired to become critical players rather than mere participants, leading to a second wave of ‘cross-industry’ automakers.

The trend of internationalisation among local automakers continued, facilitating interactions with automotive sectors in different countries, mainly Europe. Operating in developed markets with stringent requirements gave Chinese automakers valuable experience in enhancing their products and management systems. Additionally, the influx of talent into European subsidiaries brought fresh perspectives to Chinese automakers, strengthening their dynamic capabilities to adapt to rapidly changing environments and diverse market demands.

As the primary supplier of NEV components, the power battery sector maintained its pivotal role, assuming a global leadership position and providing robust support to the NEV sector. The telecom and internet sectors also played essential roles by contributing intelligent features and promoting talent mobility across industries. Some actors in these sectors even ventured into becoming new NEV manufacturers. Lastly, the semiconductor sector, influenced by various landscape factors, negatively influenced the

NEV sector.

In summary, despite encountering fluctuations and numerous challenges, the electrification trend persisted, and the NEV sector ceased to be a niche market. During this stage, NEV products directly competed with internal combustion engine vehicles, enjoying high acceptance rates among consumers in most cities. The value and supply chains underwent significant reforms, indicative of sector maturity. Under these conditions, it is reasonable to argue that, barring significant landscape changes, the NEV sector still has become a mainstream part of the regime, necessitating continuous monitoring. The analysis is summarised in Table 5-12.

Table 5-12 Summary of market reformulation stage

Landscape (Environment)	Positive Force	• China's target for carbon neutrality in 2060. • Russo-Ukrainian war.
	Negative Force	• US-China dispute. • Russo-Ukrainian war. • The outbreak of COVID-19. • Chip shortage.
Internal Socio-technical System	Internal Regime	• NEV has become a part of the regime, and the transition has reached a new level. • The market has experienced significant fluctuations due to landscape factors. • The trend of market upgrading continued (in terms of car segments and brands). • Consumers could make more rational purchase decisions. • The brand images of local brands were enhanced, and consumers became more willing to purchase products from local automakers at premium prices. • The trend of internationalisation continued.
	Internal Niche	• The NEV sector became a part of the regime of the automotive sector in China, in addition to the ICE vehicle sector.

		• The NEV sector has impacted almost all actors in the targeted socio-technical system. • The variety of products increased to cater to the growing private market. • Intelligent features became standard in NEVs. • The sector evolved from vertical integration to a network ecosystem. • The Tesla effect became even more significant. • The NEV market fluctuated, with the market leaders changing almost annually. • More alliances were formed between companies and sectors. • A second wave of cross-industry carmakers emerged. • A variety of new business models emerged.
External Socio-technical System	Peer Socio-technical System	• As Chinese automakers entered international markets, more interactions were found between the automotive sector in China and Europe/APAC/Middle East. • The automotive sector in Europe had the most influence in different dimensions.
	Associated Socio-technical System	• Unstable chip supply from the semiconductor sector negatively influenced the targeted transition. • The telecom and internet sectors still played important roles, but the level of engagement has deepened, especially for Huawei. • The power battery sector became mature and competitive globally, positively influencing the targeted transition.

5.8 Summary of the chapter

In this chapter, the socio-technical transition under investigation has been systematically delineated into five distinct stages: exploration, pilot-run, market formation, maturation, and market reformation. These divisions are based on a comprehensive analysis of multiple criteria and expert opinions from the automotive sector. This stage-wise breakdown allows for a nuanced exploration of the varying characteristics exhibited at different transition phases.

The GIESTS Framework has been rigorously applied within each stage, encompassing its three hierarchical levels: global, internal, and external. This framework serves as a powerful tool for identifying environmental influences, assessing the impacts of related sectors and their associated actors, and comprehending the evolution within the targeted socio-technical system, which, in this context, is the automotive sector in China.

A significant portion of the analysis is devoted to uncovering the relationships between the automotive sector and its ancillary sectors alongside their respective actors. This exploration maps out the evolution of China's automotive and NEV sectors and highlights their co-evolutionary processes. The findings from each stage are encapsulated in table-based tools derived from the GIESTS Framework, offering a structured perspective on the transition dynamics.

The narrative progresses by integrating invaluable insights from expert interviews, supplementing the primary findings obtained from secondary data. This amalgamation of theoretical and practitioner perspectives enriches the comprehension of the socio-technical transition, presenting a holistic view of the sector's development and prospective direction.

Chapter 6. Key Findings of Expert Interviews

This chapter presents the outcomes of expert interviews, which serve multiple essential functions within the research framework of this thesis. The primary purpose of these interviews is to complement the case study findings derived from the GIESTS Framework, reinforcing the analytical results obtained from the framework. The insights gathered from these discussions have played a pivotal role in refining and enhancing the GIESTS Framework. It is essential to clarify that this chapter does not provide an exhaustive account of the interviews; instead, it aims to highlight critical points closely aligned with the research questions central to this project.

This chapter holds paramount significance within the overall research project. It substantiates the case study outcomes detailed in the preceding sections and offers additional context for the ensuing discussion. The section is structured into distinct sections that delineate crucial periods within the transition timeline, identify the primary actors within the targeted socio-technical system, highlight the critical external sectors influencing the transition, and articulate the distinctive characteristics of China's socio-technical transition. Furthermore, it ventures to project the persistent challenges of this transition. By integrating the perspectives of industry experts, this section enhances the validity of the research findings. It enriches the practical application of the GIESTS Framework, ensuring a comprehensive, evidence-based, and forward-looking analysis.

6.1 Turning points of the transition

The critical milestones identified by the interviewees are essential for validating the defined stages in the case study and understanding the most influential factors propelling the automotive sector's transition. Although there are various responses from interviewees due to their diverse backgrounds, this section summarises the most frequently mentioned milestones. Table 6-1 summarises these key milestones and their impacts on the transition.

Table 6-1 Summary of crucial turning points of the transition mentioned in the interview

Turning Point	Key Milestones	Year	Impact on the Transition
Announcement of directional blueprint	Three-by-Three Research and Development Strategy	2001	Set vision and initial direction for the NEV sector's development.
	Technology roadmap	2009	Provided concrete direction for pioneer automakers.
Launch of pilot-run projects	Ten Cities, Thousand Cars	2009	Created a protective space for NEV development and testing.
Increasing awareness of investors	Tesla's imported model launched in China	2013	Attracted more investment and participants to the NEV sector.
Trend of 'cross-industry' automakers	Local start-ups like Nio, Li Auto, and XPeng	2014-2015	I brought new concepts and talents from other sectors to the automotive field.
Stricter policies applied to the automotive sector	Dual-credit system	2017	Pressured automakers towards electrification and increased NEV product competitiveness.
Enhancement of the NEV sector's competitiveness	Tesla's localisation	2019	Provided profitability evidence to automakers, enhancing NEV sector competitiveness.
NEV sector became mainstream	BYD's ascendancy in the automotive sector	2021-2022	Demonstrated profitability for automakers and expanded NEV reach to lower-tier cities.

While conducting interviews, it was observed that not all critical milestones highlighted by the interviewees precisely matched the stages outlined in the case study. However, most of these milestones corroborated and lent credence to the case study findings. For example, formulating a technological roadmap in the 2000s marked the transition's exploratory phase for early adopters. At the same time, the ‘Ten Cities, One Thousand Cars’ initiative launch in 2009 signified the pilot-run phase, allowing niche players to assess the commercial viability of their products on a broader scale. An interviewee noted, ‘*The technological roadmap offered an initial direction for automakers, yet the 'Ten Cities, One Thousand Cars' program allowed the market to test the products on a larger scale.*’

Furthermore, most interviewees underscored the critical role of the dual-credit system and Tesla’s substantial impact on the sector. The introduction of Tesla models to the Chinese market in 2013 catalysed the rise of local start-ups, and the implementation of the dual-credit system in 2017 highlighted the government’s intent to bolster the NEV sector’s competitiveness. The localisation of Tesla in 2019, followed by its remarkable success, marked a pivotal transition of the NEV sector from a niche market to mainstream acceptance.

These findings succinctly address the initial two interview questions, offering a preliminary overview of the sector’s evolutionary milestones. A detailed exploration and discussion of these pivotal moments will be undertaken in the following Chapter, contextualising them within the framework and providing a comprehensive narrative of the sector’s development trajectory. However, while the interview results confirm the five stages this research delineates, it is essential to note that these stages may not encompass all facets of the transition. Notably, key developments, such as the emergence of leading local startups in 2014 and 2015, are not captured within the established stages. This oversight presents an opportunity for further refinement of the framework.

6.2 Influential actors

In this section, I analyse the diversity of perspectives among interviewees regarding the most influential actors within the NEV sector transition. Notably, perceptions of influence tend to vary based on personal experience within the sector. For instance, individuals with a background in local start-ups might prioritise Tesla's influence, whereas those from established international brands might highlight the role of BYD.

Table 6-2 consolidates the principal actors identified by interviewees, summarising their actions and consequent impacts on the transition trajectory. The synthesised results draw primarily from responses to the first interview question, with additional insights integrated from the third question's responses.

Table 6-2 Key actors of the internal layer identified by interviewees

Key Actor	Year	Action	Impact on the Transition
Tesla	2011	IPO	• Grabbed the attention of investors.
	2013	Imported models launched in China	• Attracted investment in the NEV sector and stimulated the establishment of local start-ups. • Defined NEV standards.
	2019	Localisation	• Enhanced supply chain capabilities. Intensified NEV sector competition. Provided profitability evidence.
Local Start-ups	The mid-2010s	Entered the NEV sector	• Introduced new talents and concepts.
	2020-2021	Initial business success	• Pressured traditional automakers. Innovated NEV business models and processes.
BYD	2021-2022	Launched blade battery technology	• Played a new role as a battery supplier; enhanced NEV competitiveness with cost-effective, high-safety batteries.
		Took the leading position in the automotive sector	• Demonstrated automaker profitability. • Extended NEV reach to lower-tier cities. • Shifting NEVs from niche to mainstream.

From these interviews, we could find that the influence of Tesla is consistently emphasised by nearly all interviewees, contrasting with social media and secondary data that highlight the more significant impact of local startups and BYD on the development of China's NEV sector. A detailed discussion of the above results will be featured in Chapter 8, which will delve into how these key actors have shaped the transition trajectory and their interactions with other stakeholders within the automotive sector. The analysis will also examine the nuanced influences and the ripple effects these actors have on the broader NEV landscape.

6.3 Influential sectors at the external level

During the interviews, respondents identified a range of external sectors pivotal to the transition, particularly in response to the second and fifth questions. While the insights from these discussions may not be as exhaustive as those derived from the secondary data analysis featured in the case study, they nonetheless offer valuable perspectives on the most influential sectors during the transition. Table 6-3 encapsulates the critical external socio-technical systems underscored by the interviewees, encompassing both peer and associated sectors. This summary not only enhances our understanding of the broader ecosystem influencing the transition but also underscores the interconnectedness of various sectors in facilitating or impeding progress towards automotive electrification.

Table 6-3 External socio-technical systems identified by interviewees

Type	Sector	Year	Impact on the Transition
Peer	USA's NEV sector (government)	The 2000s and 2010s	Served as a reference model for China's NEV development.
	USA's NEV sector (Tesla)	Post-2010	Tesla's IPO, imports, and localisation efforts influenced China's NEV trajectory, as identified in section 6.2.
	Europe's NEV sector	Post 2020	Internalisation by Chinese automakers spurred talent mobility and product

			enhancement.
Associated	Telecom sector & internet sector	From the mid-2010s	These sectors contributed technical solutions for A.C.E.S., investments, and NEV company formation.
	Power battery sector	From the early 2000s	The power battery advanced the transition and is crucial for NEV performance and cost.

The table delineates three sectors identified by interviewees as particularly influential in the transition process. It discusses how peer sectors set benchmarks that pressure China's NEV sector to evolve, how the telecom and internet sectors drive the smartification of vehicles, and how the power sector becomes a crucial element in the transition. In the forthcoming Chapters, these findings will be integrated with insights from the case study, crafting a holistic perspective on the external forces impacting the transition at various stages. This comprehensive analysis aims to deepen our understanding of the multifaceted ecosystem surrounding the transition, highlighting the critical roles played by different sectors in shaping the trajectory towards automotive electrification.

6.4 The distinctive characteristics of the focal transition

During the interviews, responses to the fourth question shed light on the unique dynamics of the transition within China's NEV sector. A recurring theme among interviewees was the pronounced role of the Chinese government in steering the sector's development—a contrast often drawn against the backdrop of governmental involvement in developed economies. An interviewee with experience in local and multinational automakers remarked, '*The Chinese government could be seen as the most pivotal actor in the transition. For local automakers, it essentially guides their operational strategies, whereas, for foreign automakers, it significantly hastens their decision-making processes regarding electrification.*' This observation underscores the government's authoritative stance and capacity to influence the industry's trajectory effectively.

Through secondary data analysis, we identified the significant role of government policies in driving the transition. Interviews provided more profound insight into how government strategies and tactics evolved throughout the transition. A key finding is the 'barbaric growth' of the niche market in China, a term encapsulating the government's aggressive and rapid expansion strategies. This method has been pivotal in fostering the 'China Speed,' a concept synonymous with China's swift development across various sectors. The next chapter will explore in greater detail the roles played by the Chinese government and the impact of barbaric growth, examining how these elements have influenced the trajectory of the NEV transition.

6.5 Persistent challenges in the transition

Despite the rapid growth of China's NEV market, increasing its share from 5% in 2020 to over 30% by 2023, interviewees pinpoint several persistent challenges, including infrastructure gaps, varying consumer demands, and adverse industry dynamics. Subsequent sections provide a detailed examination of these challenges.

6.5.1 Challenges in charging infrastructure and user experience

Interviewees highlighted the charging experience as a critical barrier to the future growth of NEVs in China. Despite the uptick in NEV ownership, the expansion of charging infrastructure and electrical grid capacity has lagged behind the rising demand for charging services. It was noted that long queues at public charging stations have become increasingly common during peak times, such as national holidays.

The challenge of long-distance travel in NEVs remains unresolved. As of 2023, public charging facilities were predominantly located in eastern coastal cities, leaving those intending to travel to less urbanised areas, especially in the west and north, facing significant difficulties. In some less developed regions, the existing grid infrastructure is inadequate to meet the car-charging demands of NEVs, particularly BEVs.

Several strategies have been deployed to mitigate these issues. One approach has been to promote home charging station installation with governmental incentives. These installations can satisfy the daily charging requirements of most drivers. However, in densely populated cities and due to the disparity in urban-rural development, some residents, particularly in major cities like Shanghai and Beijing, encounter obstacles in setting up home chargers, as mentioned by interviewees.

Furthermore, PHEVs and range-extended vehicles, like those offered by Li Auto, have been recognised as practical solutions for daily commutes and longer journeys. These vehicles, capable of driving over 150 kilometres on electric power alone, allow electric driving in urban settings and gasoline use for extended trips. The success of models from Li Auto has reportedly put pressure on local and international automakers, suggesting a potential shift in market dynamics.

An interview excerpt from a professional affiliated with a local automotive manufacturer reveals a strategic pivot influenced by Li Auto's achievements: *'Previously, our benchmarks were BEV producers like Tesla and XPeng. However, the interviewee shared that Li Auto's triumph has redirected our aspirations, urging us to emulate their success rather than solely focusing on BEVs*. This statement underscores a strategic recalibration within the industry, with Li Auto's model fostering a new competitive paradigm.

The insights gathered from these expert interviews suggest a shifting momentum towards PHEVs and range-extended vehicles, potentially expanding their market footprint within the NEV landscape. Such a trend indicates a broader diversification in vehicle preferences and adoption, signifying an adaptive market response to evolving consumer demands and technological advancements. This observation, pivotal to understanding the market's trajectory, illustrates the nuanced evolution of China's automotive sector, which is increasingly inclined towards embracing a wider array of NEV technologies in pursuit of sustainable mobility solutions.

6.5.2 Diversified Consumer Demand in China

This section delves into the multifaceted challenges posed by the diverse consumer demands for mobility solutions across China's extensive and heterogeneous landscape, which significantly influence the adoption rates of NEVs. The interviews underscore the variability in environmental, economic, and infrastructural contexts across different Chinese regions, which impacts the practicality and attractiveness of NEVs for local consumers.

One interviewee from northern China highlighted the climatic challenge: ' In northern China, the frigid winter temperatures can substantially reduce the driving range of BEVs. Gas-powered vehicles may be a more practical choice for individuals with long-distance travel requirements.' Addressing infrastructural and economic disparities, another interviewee focused on the western regions of China, remarking, 'China's western regions continue to face significant developmental disparities. In some areas, the electrical grids are ill-equipped to support charging activities. At the same time, lower income levels often deter local consumers from purchasing NEVs, which generally carry higher price tags than their gas-powered counterparts.' This statement illustrates the multifaceted barriers to NEV adoption, including infrastructural inadequacies and economic constraints.

While the potential of PHEVs and range-extended vehicles to bridge these gaps was acknowledged, as previously discussed, the interviewees also recognised that certain areas in China might continue to prefer conventional gas-powered vehicles due to the slower pace of infrastructure development and the economic constraints faced by local consumers. This ongoing preference suggests that, despite the rapid growth of the NEV sector, gasoline-powered vehicles are likely to maintain a significant market presence, particularly in the lower-priced vehicle segment of underdeveloped regions. The nuanced understanding of these regional disparities underscores the complexity of China's transition to NEVs, highlighting the need for tailored strategies that address different geographical areas' specific challenges and conditions.

6.5.3 Negative forces from the landscape

The analysis presented in the fifth stage of the case study uncovers significant challenges impeding the advancement of NEVs in China. Interviewees particularly underscored the impact of two external adversities: the ongoing geopolitical tensions between the United States and China and the global semiconductor shortage. These factors are poised to limit production capabilities and slow the pace of innovation in NEV technologies.

The U.S.-China dispute, alongside China's shifting diplomatic strategy towards greater self-reliance, has prompted the withdrawal of several multinational corporations. This shift has adversely affected the financial health of some state-owned automakers, which had benefited from profitable joint ventures with these international partners. As a result, these state-owned entities have scaled back on product development investments and faced challenges in securing essential high-tech components, notably semiconductors. Over half of the interviewees reported that their companies had to adjust their production strategies, prioritising high-margin products to mitigate the impact of the chip shortage.

Moreover, concerns were raised about China’s economic downturn since 2022, which is anticipated to extend over the coming years. This economic slump will likely curb automotive companies' investment in advanced technologies, shifting their focus towards immediate profitability rather than long-term innovation. This scenario is particularly troubling for local startups, which depend on financial market investments and may find it challenging to remain profitable under these conditions.

Another looming challenge is the escalating cost of raw materials, threatening the ongoing reduction in NEV production costs. A significant decrease in battery costs initially contributed to NEVs' growing competitiveness. However, with the global demand for raw materials essential for power battery production on the rise, sustaining this cost-reduction trend may prove difficult. Such economic pressures could influence the pace and direction of the NEV transition, potentially stalling progress towards broader adoption and technological advancement.

6.5.4 Synthesis of the prevailing challenges

In summary, while China’s NEV market has increased, it faces formidable challenges that temper optimistic forecasts. The principal impediments identified are as follows:

- **Inadequate Charging Infrastructure**: NEV growth has outstripped the expansion of charging facilities, particularly in remote western and northern regions. Solutions such as promoting home charging and integrating PHEVs and range-extended vehicles are being pursued.

- **Heterogeneous Consumer Preferences**: China's diverse geography and economic landscape mean NEVs do not represent a universal solution, with some regions still prefer ICE vehicles due to environmental and financial factors.
- **Disruptive External Forces**: International disputes and component shortages present considerable barriers to NEV advancement. At the same time, economic headwinds and raw material cost surges pose risks to investment and cost reduction efforts in the NEV domain.

Existing studies predominantly highlight the success of the electrification transition in China. However, interview insights reveal underlying risks contradicting this transition's seemingly smooth and flourishing nature. These findings help elucidate why the government has recently taken on a regulatory role to maintain the momentum of NEV adoption and guide the transition toward a more sustainable automotive sector in China.

6.6 Summary of expert interview and implications to the case study

In this section, we delve into the nuanced perspectives provided by interviewees, illuminating the multifaceted nature of the socio-technical transition in the electrification of China's automotive sector. These insights, drawn from a diverse group of practitioners, shed light on critical turning points, the roles of key actors, the impact of external sectors, variations among automakers, distinctive transition features, and future projections. This distilled synthesis aims to incorporate practitioner-contributed insights as a foundational element of our analysis. The forthcoming Chapter will expand upon these points in greater detail, integrating the interview findings with outcomes from the case study and secondary data analysis to offer a richer exploration of the transition landscape. Several findings emerged from the interviews:

- **Turning Points**: Interviewees identified several pivotal moments in the NEV sector's evolution. While there were slight discrepancies in the specific events highlighted, the collective identification of these turning points closely aligns with those derived from secondary data analysis, serving as a form of validation for the case study's accuracy.
- **Government's Role**: Both the case study and expert interviews underscored the government's instrumental role in shaping the transition. Interviewees reinforced this point and provided concrete examples of governmental initiatives and policies, fortifying the argument for the government's paramount influence.
- **Tesla's Impact**: The interviews detailed Tesla's significant contribution to the sector's development, categorising its influence into three distinct stages. This segmentation offers complementary information to the secondary data findings, highlighting Tesla's integral role in advancing the socio-technical transition.
- **Influential Landscape Factors**: Interviewees pointed out several landscape factors influencing the NEV transition. These insights serve as valuable supplements to the findings from secondary data, enriching our understanding of the external forces at play.
- **Unique Transition Characteristics and Roadblocks**: Finally, the interviews revealed unique aspects of the socio-technical transition specific to the NEV sector and identified key challenges that could hinder further progress. These insights are precious for stakeholders such as policymakers and scholars, providing direction for future strategic and academic endeavours.

In summary, while Chapter 5's case study offers a detailed analysis of the transition trajectory, the expert interviews in this chapter enrich our understanding with real-world insights from industry insiders. These insights confirm and expand upon the case study findings and highlight topics that require further exploration. These topics and their integration with secondary data and participatory observations will be extensively discussed in the following Chapters, enhancing the comprehensive understanding of the transition dynamics.

Chapter 7. Firm-level Analysis: the RCA Framework

In the previous parts of the thesis, the focus was primarily on sector-level transformation. However, I also recognise the importance of conducting firm-level analysis to understand how the resources and capabilities of automakers impact their behaviours and performance, enhancing the rigour of the research project. This study focuses on the second half of the 2010s, a transformative era for China’s automotive industry, marked by revolutionary innovations that reshaped competitive dynamics. The shift towards automotive electrification, propelled by increasing concerns over energy security and environmental sustainability, became particularly prominent (Teece, 2019). This period also saw a rise in consumer demand for vehicles equipped with intelligent features, highlighting the integration of automotive and information technologies (McKinsey, 2019).

The evolving landscape of China’s automotive sector has accentuated the performance disparities among automakers, reshaping market dynamics considerably. Established global manufacturers have witnessed dwindling market shares, whereas several newcomers and previously peripheral players have risen to prominence. While these startups initially gained market share due to supply-demand dynamics, they risked losing their first-mover advantages if they failed to enhance their capabilities. Despite reacting slower, traditional OEMs possessed strengths in product development, manufacturing, sales channels, and connections, making them formidable competitors (CATRC et al., 2022).

This chapter is meticulously structured to comprehensively examine capability development within the automotive industry. It begins with a brief introduction to the various categories of automakers. It then progresses to introducing the proposed framework, called the RCA Framework, based on the RBV and DC and delves into a comparative analysis of three selected automakers representing three types of automakers. Finally, it provides insights into resource and capability management mechanisms in a changing environment.

7.1 Categorisation of automakers

To effectively identify and characterise these key actors, the study adopts conceptual frameworks from two well-established theories mentioned in the literature review:

- Innovation Diffusion Theory by Rogers (1995): This theory offers a framework for understanding how innovations are adopted and spread within a society or sector. By applying Rogers' concepts, the study categorises actors based on their roles and influence in the diffusion of NEV technologies and practices. The categorisation includes innovators, early adopters, early majority, late majority, and laggards, each representing different propensities for adopting new technologies and approaches.
- Stakeholder theory proposed by Freeman (2010): Stakeholder theory provides a lens to identify and analyse the relationships and interests of various groups and individuals affected by or can affect the NEV sector. This approach helps recognise not only the direct actors involved in the manufacturing and distribution of NEVs but also the broader array of stakeholders, especially providing enlightenment on the role of the Chinese government.

In this section, I delineate a taxonomy of automakers based on their engagement in the industry's transformative phase, informed by three primary dimensions. This classification is pivotal for dissecting the complex landscape of automotive industry dynamics during significant technological and market evolution.

- **Geographical Origin**: Automakers are first demarcated into two groups—Local Automakers for those established within the domestic market and International Automakers for those with global or non-domestic bases.
- **Constitutional Nature**: A distinction is drawn between ‘traditional automakers’, such as Nissan or BYD, and ‘start-ups’, represented by Tesla or XPeng. Traditional automakers have a long-standing history and established market presence, while start-up automakers are recognised as new entrants challenging industry norms with innovative technologies and business models.
- **Temporal Engagement**: The automakers are further classified based on their timing of active participation in the industry’s transition:
    - ‘Pioneer Local Automakers’ are those local entities that participated in the transition in the exploration or pilot-run stages.
    - ‘Lagged Local Automakers’ are local entities that embarked on the transition during or after the maturation phase.
    - ‘Pioneer Multinational Automakers are international entities that initiated participation in the early market reformation years.
    - ‘Lagged Multinational Automakers’ proactively participated in the transition post-2022.

Building upon these distinctions, I have identified six automaker categories for analysis: pioneer and lagged local traditional automakers, pioneer and lagged multinational traditional automakers, local start-ups, and multinational start-ups like Tesla, the archetypal model for successful market entry internationally.

For clarity and conciseness in this discourse, ‘local automakers’ will refer collectively to both pioneer and lagged local traditional automakers, and ‘multinational automakers’ will similarly encompass pioneer and lagged multinational traditional automakers. This semantic simplification aids in focusing the discussion on broader strategic patterns without losing the granularity of individual categories. Figure 7-1 serves as a visual abstraction of this multifaceted classification.

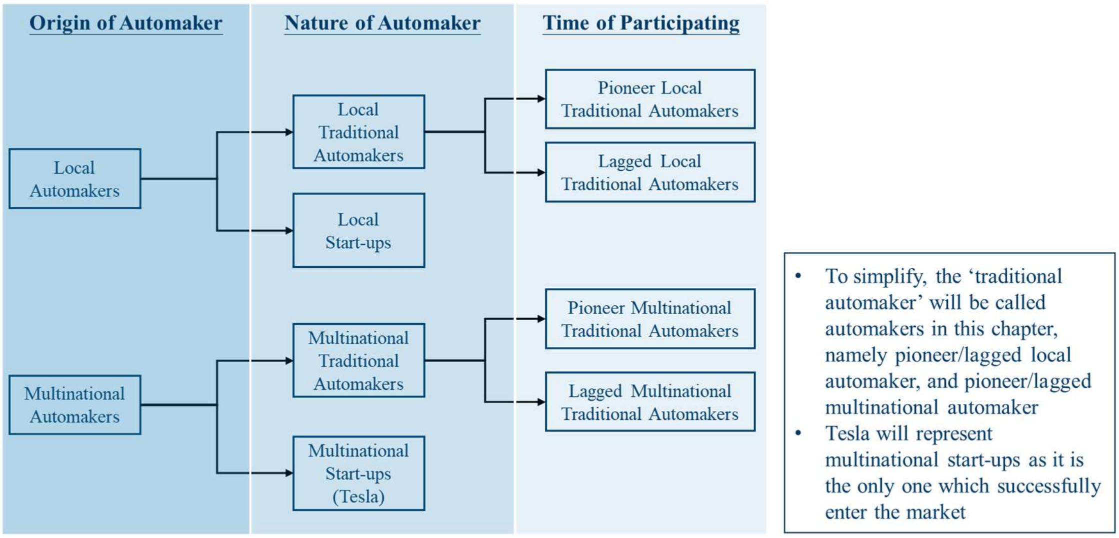

Figure 7-1 Categorisation of Automakers

In this chapter, I will focus on three iconic automakers: XPeng, representing local start-ups; Jeep China, representing lagged multinational traditional automakers; and BYD, representing pioneer local traditional automakers. I believe that analysing these three automakers will provide a comprehensive understanding of the industry's evolution and the strategies employed by different types of automakers.

7.2 The Resources-Capabilities Analytics Framework (RCA Framework)

7.2.1 Overview

The analytic framework synthesises insights from the RBV and DC concepts while also integrating hierarchical capability concepts from Winter (2003) and Wang and Ahmed (2007). Winter's work delineates zero-order capabilities as foundational for maintaining short-term operational viability and higher-order capabilities as transformative agents that evolve these foundational capabilities to secure competitive advantage. Wang and

Ahmed expand on this by categorising capabilities into four distinct levels, ranging from zero-order essential resources to third-order dynamic capabilities, which are pivotal for navigating market volatility.

The RCA Framework harmonises these insights by organising resources and capabilities into three distinct layers to examine a firm's ability to adapt to changes, secure competitive advantages, and sustain these advantages over time. The framework delineates non-VRIN resources as foundational yet less-differentiating assets necessary for essential operational functions and maintaining basic competency for surviving in the market, VRIN resources that underscore the firm's unique path dependency and heterogeneity as per Lockett and Thompson (2001), and dynamic capabilities that enable firms to adjust to environmental shifts, optimally reallocating resources to foster new competitive advantages. This layered approach offers a comprehensive tool for analysing how firms navigate and thrive in evolving market landscapes.

The framework incorporates dimensions of dynamic capabilities, as Barreto (2010) and Teece (2007) outlined, to enhance the analysis of dynamic capabilities within the framework. These dimensions include sensing opportunities and threats, making timely and market-oriented decisions, and reconfiguring the resource base. Numerous studies empirically validated these aspects, contributing to the framework's comprehensiveness and applicability. This inclusion ensures a detailed examination of how firms can detect, evaluate, and respond to changes in their external environment by adjusting their strategic resources, further solidifying the RCA Framework's utility in navigating the complexities of dynamic market landscapes.

Figure 7-2 visually summarises the framework, showing the progression from foundational resources to dynamic capabilities. This visualisation aids in comprehending how firms progress from essential operational competencies to advanced, dynamic strategies for environmental adaptation. By integrating RBV and DC concepts, the RCA Framework aims to capture firms' uniqueness and capacity to navigate changes more accurately, offering insights into how these factors influence firm performance beyond what DC analysis alone can reveal.

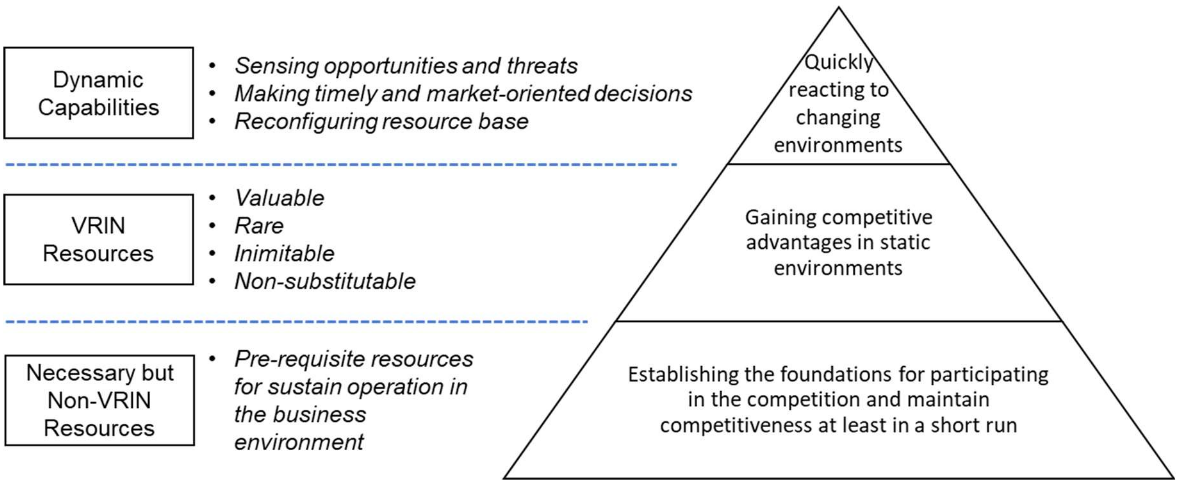

Figure 7-2 Overview of RCA Framework

7.2.2 Non-VRIN Resources

Winter (2003) highlights the importance of zero-order capabilities for firms to sustain operations and remain competitive. These foundational resources are crucial for revenue generation, resource reinvestment, and market presence. Like Winter's concept, we define non-VRIN resources as the resources crucial for a company's initial market entry and maintaining its competitive edge, at least in the short term.

These essential resources encompass tangible assets, such as financial capital and production facilities critical for daily operations, and intangible assets, like human capital and relationships with government bodies. While these resources allow firms to leverage existing assets and create value, they alone do not guarantee the achievement of competitive advantages in static markets. Instead, they provide the foundation for firms to engage competitively in the market.

It's important to acknowledge that these resources, even not highly differentiated, could still vary among firms. Although not as impactful as VRIN resources, they still influence firm performance. For instance, the product management system (an intangible resource) and production facilities (a tangible resource), while fundamental for an automaker's operation, differ in scale and maturity across companies and thus could result in different product quality. The case studies will further explore this perspective, highlighting how these resources affect a firm's market standing.

7.2.3 VRIN resource

Adopting RBV's perspective, this study delves into firm resources using Barney's VRIN framework, which posits that a firm's competitiveness and capacity to generate economic rent stem from the comparative scarcity of its resources (Barney, 1991, Peteraf, 1993, Barney, 1986). The VRIN resources layer within the RCA Framework must satisfy four criteria Barney (1991) identified: Resources must be valuable, enhancing the firm's strategy implementation to boost efficiency or effectiveness, which can range from cost reduction to entering new markets. They must be rare, not commonly held by competitors, making their scarcity a source of competitive advantage. Resources should be inimitable, complex for competitors to replicate due to factors like unique historical conditions or social complexity, and non-substitutable, with no alternative resources that competitors can use to achieve the same advantage. These dimensions underscore the significance of scarce resources and uniquely contribute to sustaining a firm's competitive position in the marketplace.

In line with the RBV, this research underscores the pivotal role of resources in establishing a firm's strategic competitive edge, noting the connection between valuable and rare resources and competitive advantage. That competitive advantage is related to performance, as Teece et al. (1997) and Newbert (2007) highlighted. Resources are identified as firm-specific attributes, organisational processes, knowledge assets, capabilities, and information; such attributes would also cause differences in performance across firms (Lockett et al., 2009).

While DC research often focuses on reallocating resources in response to environmental shifts, it sometimes overlooks their inherent value (Cardeal and Antonio, 2012). This study contends that existing VRIN and non-VRIN resources like production systems and facilities remain influential in dynamic environments, particularly in upholding competitive advantages facilitated by dynamic capabilities. Thus, including the VRIN resources layer in the RCA Framework is pivotal for a comprehensive understanding of strategic resilience and competitive sustainability.

7.2.4 Dynamic capabilities

Dynamic capabilities enable a firm to adapt to and navigate the competitive business landscape effectively. These capabilities encompass skills and strategies crucial for identifying threats and opportunities, making informed decisions promptly, and adjusting the resource base to changing market conditions (Teece, 2007, Barreto, 2010, Teece et al., 1997). The framework delineates dynamic capabilities into three sub-categories:

- **Sensing Opportunities and Threats**: This involves a firm's ability to monitor, scan, learn, and interpret factors in the competitive environment, such as shifts in consumer behaviour, technological trends, competitor actions, and policy changes

(Teece et al., 1997, Teece, 2007, Teece, 2019, Barreto, 2010). These market-scanning skills reduce uncertainties and enable prompt market responses (Alam et al., 2013).

- **Making timely and market-oriented decisions**: The capacity for rapid and strategic decision-making is crucial in dynamic settings. Firms that respond swiftly can capitalise on necessary transformations, gaining advantages over slower rivals. Delays in adapting to market changes can result in underperformance (Sebastian et al., 2020). This facet involves aligning decisions with market trends and customer needs, including innovating business models, products, or services (Teece, 2018a, Chen and Chang, 2013, Kindström et al., 2013) Tesla's rollout of its charging network and service plans is a notable example.
- **Resource Base Reconfiguration**: This aspect assesses a firm's capability to strategically utilise and reorganise resources and general capabilities in response to identified opportunities and challenges. These adjustments often stem from market dynamics or the firm's developmental requirements (Eisenhardt and Martin, 2000, Teece, 2007). Volkswagen's digital transformation, involving resource reallocation and new strategic partnerships, illustrates this capability.

These dimensions offer a holistic framework for assessing a firm's dynamic capabilities, enabling an in-depth evaluation of its ability to excel in a constantly evolving business landscape.

7.3 Comparative analysis of three iconic automakers

This section examines the impact of resources and capabilities on the market performance of three types of automakers in China's disruptive automotive environment from the late 2010s to 2023. This period, marked by substantial shifts, has significantly affected multinational, local traditional automakers, and local startups. Jeep China, BYD, and XPeng Motors are chosen to represent these categories. The study applies the RCA Framework to analyse how each automaker's resources and capabilities have influenced their market performance amidst these changes. The case study is organised into subsections, starting with an introduction comparing the three companies and then analysing their resources and capabilities. It concludes with a table summarising the findings and providing insights into the evolving dynamics of China's automotive market.

7.3.1 Overview of the three automakers

Jeep China's journey, beginning in 1984 as a Beijing Automotive Industry Corp. (BAIC) and American Motors Corporation (AMC) joint venture, reflects China's automotive industry evolution post the 'Open Door' policy (Aiello, 1991). Initially pioneering in the Chinese SUV market with innovations like car customisation and owners' clubs, Jeep experienced strategic shifts following Chrysler's acquisition of AMC in 1987 and further ownership changes. This led to the joint venture's renaming to Beijing-Benz in 2007 and Jeep's temporary exit from China. However, in the mid-2010s, Jeep re-entered under FCA's banner through a partnership with GAC, initially succeeding with models like Compass. Yet, by the late 2010s, sales plummeted despite new launches, culminating in bankruptcy and Stellantis's 2022 decision to limit Chinese operations to imports (Stellantis, 2022).

BYD's transformation from a 1995 rechargeable battery manufacturer to an NEV industry leader exemplifies strategic adaptability. After entering the automotive realm in 2003, BYD quickly became an NEV trailblazer, balancing NEV and ICE vehicle production. The pivotal move to cease ICE production in 2021, alongside innovations like the 2020 'blade battery,' marked BYD's commitment to sustainable mobility (BYD

Company Ltd., 2020). This shift affirmed BYD's position as a top traditional Chinese automaker in the NEV space. It significantly influenced the global industry's electrification trend, securing its lead in China's automotive market by 2022 and 2023.

XPeng, a 2014-founded company, rapidly emerged as a critical player in the electric vehicle sector with its 2018 G3 SUV. Despite initial challenges, the start-up gained traction with a successful 2020 IPO and the launch of the popular P7 sedan. This progress positioned it as a frontrunner among local startups. However, by 2022, sales growth had stalled (CBIRC, 2023), and financial strains had emerged due to high production costs and significant investment in development, indicating the difficulties in maintaining market performance beyond its initial surge.

7.3.2 Non-VRIN resources

They are the necessary resources for surviving in the automotive industry. They are derived from Winter's theory (Winter, 2003) and supported by primary data collected, and they hinge on achieving two key goals. Firstly, firms must possess the essential resources to develop and manufacture vehicles that comply with safety and regulatory standards. This foundational aspect ensures that products meet the necessary criteria for market entry. Secondly, the sustainability of operations is critical, necessitating efficient production processes, effective supply chain management, and adept resource allocation. These resources are vital for producing compliant vehicles and managing operations effectively, ensuring a firm can compete in this demanding sector.

Jeep China leverages its association with a globally recognised brand, drawing heavily on its U.S. headquarters for advanced product development to ensure its offerings comply with legal standards and retain market appeal. In China, the focus has been more on localising existing designs than on introducing groundbreaking innovations, resulting in a reliance on external suppliers for engineering solutions, notably in ACES technologies. This strategy has enabled Jeep China to capitalise on its international brand identity while adapting to the specific demands of the Chinese market. However, it exhibits an excess dependency on outside expertise for the latest technological advancements, resulting in a longer lead time for reacting to new product requirements.

BYD's transformation from a battery manufacturer to an automotive powerhouse has granted it considerable engineering capabilities, allowing it to produce vehicles meeting essential market and homologation needs despite some mechanical components not matching the sophistication of multinational automakers. This shift has enabled BYD to leverage its deep understanding of battery technology and cost control to offer a range of vehicles that cater to various market segments. BYD has cultivated a robust manufacturing base and fostered strong supplier relationships, underpinning its capacity for sustainable operation and positioning it as a significant player in China's competitive automotive landscape.

XPeng's foray into the automotive industry, marked by initial engineering challenges, was strategically managed through benchmarking and forming partnerships. Despite encountering early design and operational hurdles, XPeng's dedication to improving its product development and operational effectiveness has propelled it to become a significant player in the industry. However, it remains below the sector's average performance. This journey exemplifies the challenges and resilience required of local startups aiming to establish a foothold in the competitive automotive market.

In summary, GAC-FCA capitalised on the synergy of its parent companies to optimise operational efficiency. BYD leveraged its in-depth understanding of the local market and solid manufacturing foundation to gain a competitive advantage. As a newcomer, XPeng strives to overcome initial obstacles by adapting and learning. It's important to note that while all three automakers possess the non-VRIN resources essential for competing, differences in the scale and quality of these resources can significantly impact their performance, not just in stable environments but also in dynamic ones. This aspect will be explored further in subsequent sections.

7.3.3 VRIN resources

VRIN resources are crucial in establishing a firm's competitive advantage, particularly within relatively stable markets (Makadok, 2001). The period from the early 2000s to the mid-2010s represented a stable era for China's automotive sector, marked by steady growth. During this time, automakers possessing appropriate VRIN resources were well-positioned to build sustainable competitive advantages.

The 2015 relaunch of Jeep China under the GAC-FCA joint venture showcased the strategic significance of its VRIN resources, notably its renowned brand heritage and exceptional off-road engineering. These strengths enhanced Jeep China's market visibility and broadened its customer appeal (Zhang, 2017, sohu.com, 2021). The competitive advantages gained through these resources made the automaker grow rapidly in the mid-2010s.

BYD's shift from a battery producer to an automotive manufacturer leveraged its substantial cost management and technology expertise. The 'blade battery' launch in 2020 is a testament to BYD's commitment to innovation, offering various competitively priced products and reducing reliance on external battery providers, thus reinforcing its standing in the market (BYD Company Ltd., 2020). However, it's essential to acknowledge that until the mid-2010s, BYD was a relatively marginal player in the stable market segments, primarily due to its resources not being as robust as those of its multinational competitors. The significant surge in BYD's growth trajectory aligns with the increasingly dynamic market, a topic that will be further explored in this chapter.

XPeng, a newer entrant to the automotive field, has displayed crucial capabilities in product planning, development, and distribution, indicative of its intangible VRIN resources. The popularity of its models, such as the P7 and G6, is backed by XPeng's engineering expertise in energy management and intelligent functionalities, alongside creative marketing and sales strategies. This approach has allowed XPeng to establish a competitive edge while lacking competency in the perspective of non-VRIN resources.

However, the effectiveness of these VRIN resources may wane in the face of rapidly evolving consumer demands and disruptive market conditions, particularly beyond the mid-2010s, as we can see in the subsequent section, which delves into how these automakers have adapted themselves via dynamic capabilities in response to the shifting landscape of China's automotive market.

7.3.4 Dynamic capabilities

VRIN resources, pivotal for carving out competitive advantages in relatively stable markets, must be continually reassessed and potentially updated amid disruptive market shifts. Such updates become essential in rapid market evolutions like the A.C.E.S. trend in China's automotive sector, where incremental improvements or status quo maintenance fall short of ensuring sustainable success. Companies are thus compelled to adapt by modifying, reconfiguring, enhancing, or developing new VRIN resources to stay aligned with changing market demands. Adapting to these new market realities hinges on a firm’s dynamic capabilities, which enable it to reconfigure its resource base and update its strategic ‘toolkit’ in response to external changes. This section underscores the importance of possessing valuable resources and the ability to pivot and evolve these resources to meet the demands of a dynamically changing market landscape.

Firstly, sensing opportunities and threats: Jeep China’s hierarchical structure, heavily reliant on local teams for market intelligence, struggled from 2016 to 2020 due to leadership hesitancy in conveying Chinese market realities, leading to misalignment in understanding rapid A.C.E.S. technology evolution. This issue contributed to Jeep’s market share loss in evolving regions like APAC. This resulted in China’s joint venture closing and the termination of localised products in China.

In contrast, BYD demonstrated acute market sensitivity, adopting early electrification and shared mobility trends bolstered by local solid networks and governmental ties, as seen in the ‘Ten Cities, Thousand Cars Program’ (China Securities Journal, 2012). Founder Chuanfu Wang’s early vision for electrification significantly enhanced BYD’s responsiveness to market shifts (Chejiahao, 2023), and the company’s culture of innovation fostered a forward-thinking and adaptable approach, keeping it at the forefront of the automotive industry.

XPeng adopted a mixed approach, combining project-based innovation with top-down strategic insights. Its diverse workforce, tech sector expertise, and leadership’s industry connections allowed XPeng to effectively identify market trends and opportunities despite lacking a formalised working mechanism, maintaining its competitiveness in a dynamic industry landscape.

Secondly, in making timely and market-oriented decisions, Jeep faced challenges under the FCA umbrella from the Fiat-Chrysler merger due to its complex, multi-layered organisational structure. This led to slow decision-making and internal conflicts, particularly in strategy, product development, and resource allocation. This complexity delayed initiatives like collaborations for connectivity services and a sluggish response to China's NEV trend, as seen with the late 2019 launch of the Grand Commander PHEV, lagging behind competitors like BYD and Tesla (FCA Group, 2020).

In contrast, BYD's organisational structure, characterised by its flatness, has enabled quick and decisive actions. It is a key factor in its pioneering efforts towards electrification and strategic departure from internal combustion engines towards the luxury vehicle segment. This agility has positioned BYD to compete effectively across various market segments and secure a first-mover advantage, particularly in lower-tier cities where premium brands have yet to establish a strong presence. The ability to swiftly adapt and innovate, as evidenced by BYD's strategic manoeuvre (Hebang Consulting, 2023), underscores the competitive edge that a more streamlined organisational approach can afford a company in the rapidly evolving automotive industry.

XPeng, navigating the industry as a startup, demonstrates remarkable agility and market orientation in decision-making. Its strategic partnership with Haima in 2016 expedited market entry, and a flat organisational structure enabled quick responses to market changes. A 2023 reorganisation streamlined decision processes, allowing for rapid adjustments, although it presented risks of unilateral decisions (sohu.com, 2022). This contrasts with established firms like Jeep China, where entrenched structures and stakeholder complexities impeded quick decision-making.

Finally, reconfiguring resource base: as a subsidiary of a joint venture between Fiat and Chrysler, Jeep faced organisational challenges marked by tensions between the two entities, rich histories, and long-serving employees resistant to change. This led to barriers in implementing structural changes and adapting to new market demands. This created organisational inertia that hindered FCA’s responsiveness to market shifts, particularly in electrification and intelligent cockpit technologies.

In contrast, BYD consistently led China’s NEV market with its agile organisational structure, enabling rapid resource adjustments following decisions made by CEO and founder Chuanfu Wang. BYD’s continuous growth and adaptation culture mitigated inertia, as evidenced by its organisational changes to address competitive challenges and support a multi-brand strategy (Hebang Consulting, 2023).

XPeng displayed a dynamic that was oriented towards change and adaptation. Rapid growth led to organisational adjustments to respond to market conditions, including frequent layoffs and reorganisation. At the end of 2022, XPeng established product matrix teams and committees to optimise resource sharing and maintain agility in the evolving automotive industry (CnEVPost, 2023).

In summary, Jeep faced organisational inertia and slow adaptability challenges, reflecting difficulties in responding to rapidly changing market conditions. In contrast, BYD distinguished itself with its agility and proactive approach, effectively adapting to new market trends and demands. XPeng Motors, as a more recent entrant, demonstrated notable flexibility and quick responsiveness, underscoring its ability to adjust and thrive in the dynamic automotive industry. These contrasting dynamics among the three automakers underscore the varying degrees of success in leveraging and adapting to the fast-paced and evolving automotive landscape.

7.3.5 Linkage between resources, capabilities, and performance

In the rapidly evolving automotive industry of the late 2010s, the market performance of Jeep China, BYD, and XPeng Motors varied significantly, reflecting their varying capabilities in reacting to and sustaining operations in dynamic environments. Jeep China declined in 2018, struggling with limited dynamic capabilities and outdated core competencies, hindering its adaptation to market changes and technological advancements. In contrast, BYD achieved consistent growth, leveraging robust general and emotional capabilities to adapt to new conditions and innovate. XPeng initially saw rapid growth due to agile strategies but faced challenges in sustaining it, partially due to weaker foundational capabilities in areas like quality control.

Figure 7-3 illustrates the sales volume of Jeep, BYD, and XPeng in China, highlighting these divergent trajectories. Such results could be explained by the correlation with these automakers' resources and capabilities. Firstly, Jeep's market share suffered from outdated VRIN resources and inadequate dynamic responses. Additionally, XPeng, while agile, faced growth challenges due to weak non-VRIN resources that had to be reconfigured to sustain initial success. Lastly, with its balanced approach between resources and dynamic capabilities, BYD emerged as a clear leader in the sector, adapting effectively to the rapidly evolving automotive landscape. This analysis emphasises the critical role of resources in navigating the challenges and opportunities of a changing industry.

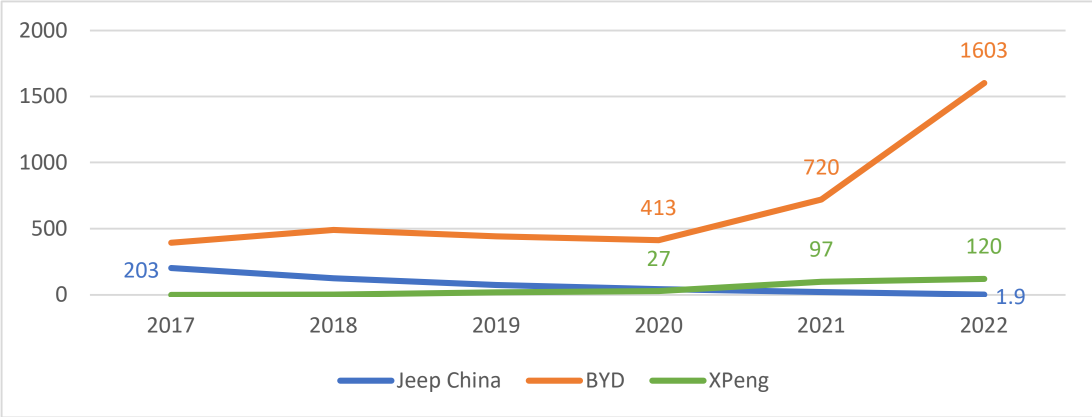

Figure 7-3 Sales Volume of three automakers (in thousands) (CBIRC, 2023)

Table 7-1 demonstrates the comparison and underlines the varying degrees of success each automaker experienced, directly linked to their respective capabilities in adapting to the evolving automotive industry.

Table 7-1 Summary of the linkage between various capabilities and market performance

Capability	**Jeep China**	**BYD**	**XPeng**
Non-VRIN Resources	Access to extensive resources from parent companies yet depended on external suppliers for cutting-edge technology.	Exhibited solid foundational resources, excelling in developing and manufacturing vehicles compliant with market standards.	Initially, it depended on strategic partnerships for market entry, gradually improving capabilities but still developing.
VRIN Resources	Leveraged its historic brand and specialised engineering for distinct off-road vehicle differentiation.	Demonstrated advanced battery technology and cost control, providing a competitive edge across its diverse product lineup.	Focused on innovative product planning, development, and distribution, distinguishing itself through business and technological innovations.
Dynamic Capabilities	Hindered by a hierarchical structure leading to prolonged decision-making and inertia in adapting resources for market change.	Displayed remarkable agility and decisiveness in strategic shifts, effectively adapting to the rapidly changing automotive landscape.	Showcased rapid adaptability and strategic decision-making aligned with market trends, effectively responding to new opportunities.
Impact on Performance	The decline in performance was noted in 2018, attributed to slow adaptation to evolving market demands.	Achieved consistent growth by leveraging agile market adaptation and a robust bundle of resources, maintaining a leading market	Witnessed substantial growth in 2020 and 2021, though growth rates have slowed due to challenges in maintaining a

		position.	competitive edge with existing resources.

7.4 Characteristics of firm-level transition

Key insights from the study enhance understanding of the dynamic capabilities framework and its applicability in the evolving automotive industry:

- **Resources and Dynamic Capabilities' Equally Importance and Different Impacts**: While dynamic capabilities often catalyse initial market success, enduring competitiveness is anchored in the synergistic relationship between dynamic capabilities and a firm's resources, non-VRIN and VRIN. These resources lay the groundwork for firms to build, reconfigure, and scale their operations to maintain early success. BYD exemplifies this principle, leveraging its manufacturing prowess and supply chain efficiencies to sustain growth and remain competitive.
- **Dynamic Capabilities as a Driving Force**: XPeng, despite its challenge in extending and sustaining newly developed competitive advantages due to less robust non-VRIN resources, maintains its market presence through rapid adaptation to changes. On the other hand, BYD's proactive approach towards embracing new technologies has solidified its status as an industry frontrunner. Conversely, Jeep China's struggle with adaptability has significantly hindered its performance, underlining the critical role dynamic capabilities play in determining a firm's success or decline in the rapidly evolving automotive sector.
- **Inertia from Existing Resources**: Existing resources, especially path dependency, can significantly hinder progress when not aligned with evolving market trends. For instance, Jeep's historical emphasis on mechanical expertise became a liability

in adapting to new technological trends. This results in a delayed response to the market's shift towards innovation in intelligentisation and connectivity.

These findings underscore the complex relationship between various capabilities and market performance in the rapidly changing automotive industry, providing critical insights for industry players and strategic decision-makers.

7.5 Mechanism of resource and capability status in a changing environment

Leveraging insights from the study and the findings presented, it elucidates the workflow that depicts how firms react to emerging challenges within dynamic environments, emphasising the impact of the various layers within the RCA Framework on these responses. Figure 7-4 provides a detailed conceptual diagram which illustrates how firms adapt to competitive market challenges, focusing on the pivotal role of dynamic capabilities in recognising and tackling these challenges. This adaptation mechanism involves cultivating new non-VRIN and VRIN resources and strategically reorientating existing ones. Such strategic adjustments are fundamental for carving out new competitive advantages. This visual guide aids in comprehending the methodologies firms employ to adapt and respond to shifts in their operational context, thereby navigating through the complexities of evolving market landscapes effectively.

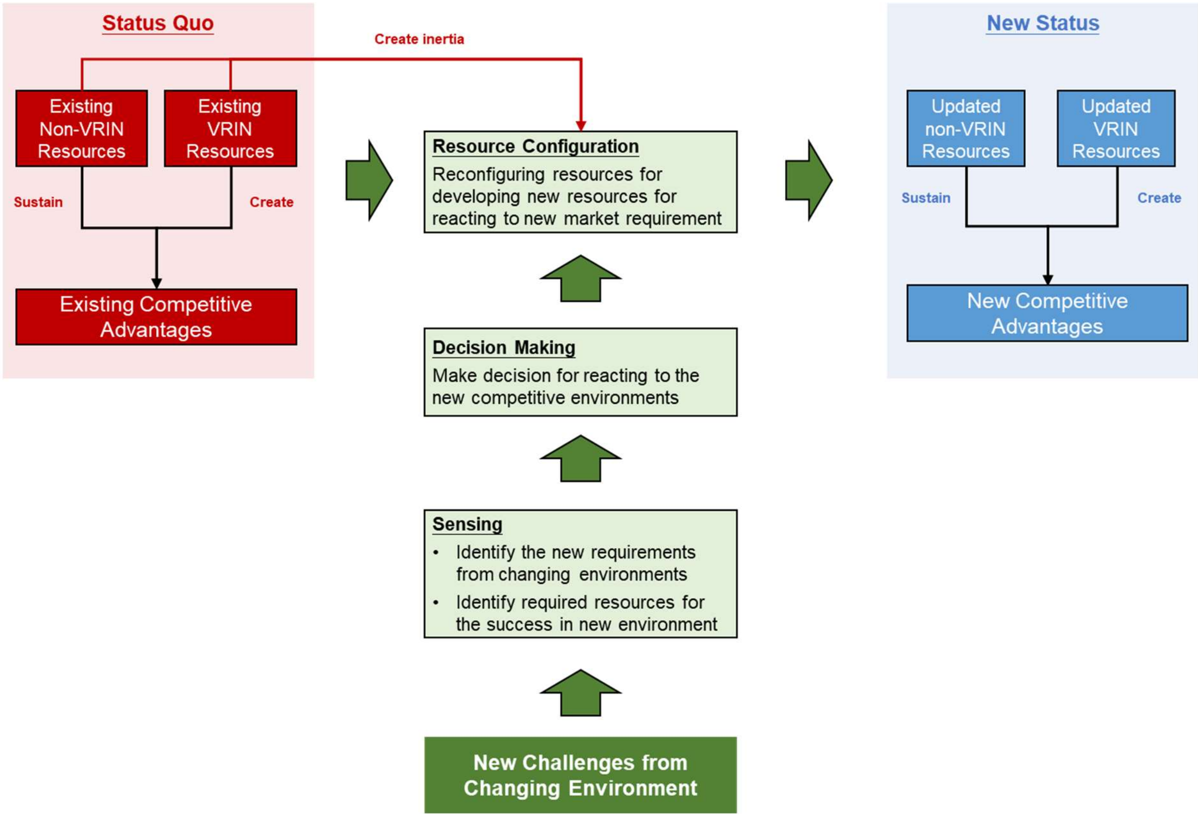

Figure 7-4 Mechanism of the firm's resource and capability status in a changing environment

Dynamic capabilities serve as a pivotal mechanism for firms to adapt swiftly to market changes. The inertia arising from existing path dependencies within a firm's resource base often impeded this process. The strategic reallocation of resources is crucial for rapidly acquiring and developing necessary VRIN resources, thereby facilitating the development of competitive advantages aligned with new competitive landscapes.

This analysis underscores the critical function of dynamic capabilities in enhancing corporate adaptability, from identifying new market demands in disruptive environments to reconfiguring existing non-VRIN resources. It further emphasises the significance of the influences of existing non-VRIN resources in supporting the sustenance of newly developed competitive advantages. Firms endowed with abundant non-VRIN resources can readily reinforce their newly acquired competitive edge through reallocation rather than by acquiring or enhancing non-VRIN resources.

For instance, BYD has skilfully leveraged its broad non-VRIN resources to rapidly adapt, seize new opportunities, establish refreshed technological reserves, and form new path dependencies via its dynamic capabilities, augmenting its already established competitive advantages. Conversely, XPeng faces challenges due to its limited resource pool, which restricts its ability to effectively reallocate resources in response to emerging opportunities and environmental shifts, thus struggling to bolster its competitive stance.

In this chapter, I have proposed a framework based on DC and RBV to understand the resources and capabilities of the three automakers. This framework helps identify a mechanism to explain the relationship between these resources and capabilities and their dynamic environment. In the next chapter, I will delve into the roles played by and the influence of the Chinese government in the transition, providing a comprehensive analysis of its impact on the automotive electrification journey in China.

Chapter 8. Government's Role

8.1 Overview

The breakneck speed of China's economic growth over the past four decades, often referred to as 'China Speed,' has impressed the world and continues to impact the country and the rest of the globe; such achievement could be attributed to its productivity, centralised politic system, business culture, and huge market (Krosinsky et al., 2020). The Chinese government has been pivotal in fostering this rapid industrial development.

This facilitation has been through various strategies, including incentives for industries like electric vehicles (Wang and Mah, 2022), the creation of a 'quasi-market' role for the government (Chen and Chulu, 2023), and the implementation of industrial policies that have facilitated industrial upgrading and technological progress (Lin and Zhou, 2021). This achievement results from a combination of incentives, coordinated policies, financial support, long-term planning, consistent execution, and the formation of joint ventures. Over time, the government has transitioned from being a central actor to becoming a creator and facilitator of platforms conducive to innovation, a development noted by (Băzăvan, 2019).

Furthermore, the role of the Chinese government in industrial development can be articulated as evolving and multifaceted. Initially, the government emphasised state-led strategic planning and support for key sectors, a strategy detailed by (Gabriele, 2010). However, its approach has evolved, shifting towards becoming a platform creator and facilitator for innovation (Băzăvan, 2019). Despite the government's efforts, investment patterns in China are primarily driven by profitability and private entrepreneurship

(Holz, 2019). The government's industrial policies have successfully shaped markets and driven structural adjustment but have faced challenges in micro-level interventions (Chen and Chulu, 2023). Combining an effective market and a facilitating state has been crucial to China's economic success (Lin and Zhou, 2021). However, the government's policies have also been a source of concern, with discriminatory practices affecting the performance of private enterprises (Zhao, 2009). The government's role in industrial development has been complex, involving support, intervention, and challenges.

The government's strategies at different stages of industrial development have been characterised by practicality, adaptability, and a focus on industrial policies. The role of these policies in industrial upgrading and technological progress is emphasised by Lin and Zhou (2021) and Yusuf and Nabeshima (2008), with the latter stressing the importance of ownership reform. The evolution of China's industrial policies and two-stage catch-up strategy is further explored by Chen and Chulu (2023). Yang and Yu (2011) provide a quantitative analysis of the policies of strategic emerging industries and the effectiveness of state-oriented policies in rejuvenating key industries. However, Jinglian (2007) and Holz (2019) raise concerns about the sustainability of China's industrialisation path and the real impact of industrial policies on investment patterns.

The Chinese government has played a crucial role in the development of the NEV sector, providing incentives for EV purchases, coordinating policy measures, and creating a suitable social environment (Wang and Mah, 2022). This has been achieved through technological innovation, market demand, and government policy (Wu et al., 2018). The government has also facilitated the establishment of a domestic production network for NEVs, leveraging its regulatory parameters and market size (Yeung, 2018). Urban environmental policies and financial support have further enhanced the efficiency of large NEV firms (Li et al., 2019). The government's intense intervention has been successful in the initial stages of the NEV sector, and public policy has driven the co-evolution of market and technical niches in Hangzhou (Jin and McKelvey, 2019). The policy system has evolved through different stages, emphasising the role of technology in NEV development (Zhou et al., 2020).

In this chapter, the focus will be on examining the changing roles of the Chinese government throughout the different phases of the socio-technical transition in the NEV sector, guided by insights derived from the GIESTS Framework. The objective is to detail how these governmental actions have significantly influenced and shaped the development trajectory of the NEV sector, contributing to the phenomenon known as the China Speed (Krosinsky et al., 2020). Additionally, the discussion of the influences of local governments has been included. This analysis will highlight the pivotal role of policy-making, regulatory frameworks, and government initiatives in facilitating and steering the transition towards a more sustainable and technologically advanced automotive industry in China.

8.2 Government's roles in different stages

8.2.1 Exploration stage - the initiator

At the commencement of the exploration stage, the Chinese government played the critical initiator role, laying the conceptual and policy groundwork for advancing the NEV sector. This phase was defined by the government's efforts to draft and articulate a long-term vision and strategic trajectory for the sector's growth, as seen in policies such as the 'Three-by-Three Research and Development Strategy'. Such initiatives underscored the government's commitment to steering the sector's direction from its nascent stages.

In addition to policy formulation, the government actively fostered synergies between academic institutions and the industry, thereby constructing a trilateral industry-government-academia network. This strategic alliance was essential for advancing research and development, sharing knowledge, and synchronising efforts across all facets of the NEV field.

As the initiator, the government offered a strategic vision and engaged in the practical establishment of networks that were vital for nurturing the ecosystem required for the sector's subsequent growth. The facilitation of these networks set a firm foundation for the intricate web of collaborations that would underpin the maturation of the NEV industry. This stage was crucial as it encapsulated the government's foresight and preparatory action, serving as a beacon for the industry's future trajectory.

8.2.2 Pilot-run stage - the protector and incubator

During the evolution of the socio-technical transition towards the pilot-run phase, the role of the Chinese government was markedly transformed. Acknowledging the strategic relevance of the NEV sector, the central government enshrined its advancement within the national strategic framework, elevating it to a top national priority. This was a departure from the exploratory phase, where the government's role was more experimental and less directive.

In this enhanced capacity, the central government assumed a directive leadership position, actively steering the progression of the transition. The frequency and depth of coordinated efforts between central and local governments intensified, reflecting a robust governance approach. The period was marked by the initiation of several experimental projects, most notably the 'Ten Cities, Thousand Cars' program

(Xinhua.com, 2009). This initiative provided a quasi-experimental setting instrumental to the NEV sector's growth. It offered a safeguarded environment where new technologies could be tested and developed without the immediate pressures of the open market.

The government also leveraged these pilot projects as experimental platforms to extract insights for promoting and expanding the NEV industry, strategically using them to fine-tune policy measures and catalyse greater industry participation (Gong et al., 2013). In this phase, the Chinese government played the dual role of protector and incubator, creating a buffer zone around the NEV sector. It also laid the groundwork for the NEV market's eventual maturity and self-sustainability in the subsequent phase, ensuring a stable transition from a protected pilot phase to a competitive market environment.

8.2.3 Market formation - the director

In the market formation phase, the Chinese government assumed the role of a director, accelerating the establishment and growth of the NEV sector. On the production side, the government's strategies included various incentives to stimulate a broad base of entrants into the NEV market. This proactive stance helped spawn a new breed of 'cross-industry' automotive manufacturers, diversifying the industrial landscape and attracting extensive investment into the sector.

The government's efforts were equally vigorous on the consumption side, implementing a series of policy instruments to stimulate demand. These included direct monetary incentives, such as subsidies for NEV purchasers and non-financial perks, like exemption from license plate restrictions. In tandem with these measures, the government addressed a pivotal infrastructure need by escalating the deployment of charging facilities, thus easing the adoption of NEVs for consumers.

Despite these proactive measures, the sector faced impediments such as subsidy fraud and concerns over product standards. Nonetheless, the government's concerted push helped surmount these barriers, culminating in the development of a dynamic business-to-consumer (B2C) market (CATRC et al., 2015). These initiatives have contributed to resolving early market obstacles and firmly positioned China as a frontrunner in the global NEV industry.

8.2.4 Maturation - the facilitator

With over a decade of intensive developmental efforts behind it, the maturation of the NEV sector signified a pivotal shift in the role of the Chinese government to that of a facilitator. This phase of the industry's lifecycle witnessed the government concentrating on sculpting a market landscape where competition could thrive unfettered, directly influencing sustainability and innovation within the sector. Implementing a dual credit policy was a strategic move to balance corporate investment in NEV production with environmental concerns. Concurrently, the institution of more rigorous product specifications and setting industry-wide standards for essential components, like power batteries, elevated the sector's global standing.

Further strategic developments in market governance included tightening the criteria for market entry to ensure that only viable and innovative players could compete. A landmark decision in the government's facilitative role was the allowance for Tesla's end-to-end production in China, which considerably stirred the sector's competitive dynamics. Most interviewees have indicated that the ensuing 'Tesla effect', dissected later in this thesis, showcases the government's shifting focus from direct support to creating an enabling environment for industry evolution and international integration.

At this stage, the Chinese government's facilitation method recalibrated its involvement, prioritising a regulatory and supportive background role over direct intervention. This strategic retreat was designed not to reduce the government's role in absolute terms but to redefine it in a way that underscored its persistent relevance amid a transforming market and industry paradigm. The subsequent sections will further explore the impact and implications of such a transitional role of the government in the maturing NEV market.

8.2.5 Market reformation - the regulator

In this final stage addressed by the case study, the NEV sector's integration into the regime was almost completed. The Chinese government strategically scaled back its direct intervention, indicative of an evolution from a predominantly government-driven marketplace to one led by market forces and industry dynamics. In its refined role, the government is now principally concerned with regulation, maintaining a watchful eye over the sector's progression, ensuring that it continues along the trajectory envisioned in state plans, and adapting policies in response to the industry's maturation.

This period marked the Chinese government's transition to a regulatory actor, less focused on steering and more on stabilising and standardising the marketplace. Its responsibilities include continually monitoring the sector's health, enforcement of regulatory compliance, and policy recalibration to align with national economic and environmental goals.

The role shift throughout the socio-technical evolution of the NEV sector has exemplified the Chinese government's strategic skill. It has demonstrated a profound capacity to modify its degree and style of intervention to suit the shifting contours of the NEV industry, reflecting an overarching commitment to fostering innovation and guiding market evolution. The government's adaptation from initiator to facilitator to regulator reflects a keen strategic anticipation of the sector's needs, ensuring its involvement remains relevant and constructive in changing technological and market landscapes.

8.2.6 Summary of the role changes of government

The summarised roles of the Chinese government, corresponding to the sequential stages of NEV sector development, are detailed in Table 8-1. This comprehensive overview captures the dynamic nature of government interaction with the sector, providing a clear trajectory of regulatory and developmental policies from conception to market reformation.

Table 8-1 Summary of the roles of the Chinese government in different stages

Stage	Government Role	Description
Exploration	Initiator	• Vision setting • Policy drafting • Fostering cross-sector collaboration
Pilot-Run	Protector and Incubator	• Elevated NEV priority • Launched pilot projects • Nurtured tech development
Market Formation	Director	• Incentivized market entry • Stimulated demand • Expanded infrastructure
Maturation	Facilitator	• Enhanced competition • Standards optimisation • Facilitated Tesla's market entry
Market Reformation	Regulator	• Sector regulation • Policy monitoring and adjustment

8.3 Compare governments' influence between China and developed countries

Previous sections examined the Chinese government's multifaceted roles in steering the country through various phases of its transition to NEVs. Building upon that foundation, this section aims to contrast the degree of governmental influence in China's electrification of the automotive industry with that in developed countries. This comparative analysis offers a synthesised perspective from comprehensive research, including case study examinations and expert consultations. However, it refrains from delving into the specific conditions prevalent within individual developed nations, acknowledging the generalisations necessitated by the breadth of this study.

The Chinese government's resolve to accelerate the automotive industry's shift to electrification is a cornerstone of the country's broader strategic aims. This steadfast governmental engagement is spurred by an array of drivers: energy security concerns, a commitment to achieving carbon neutrality, the urgent need to mitigate critical air pollution levels, and the strategic intent to carve out a commanding position in the global industrial landscape (Zhou et al., 2020, Meng et al., 2022, Jiang and Xu, 2023). The distinctive political fabric of China amplifies the efficacy of government involvement, particularly the profound impact of central policy decisions on local execution, surpassing the influence observed in many developed economies.

A landmark in this endeavour was the 2009 policy directive by President Hu Jintao, which enshrined the NEV sector's growth within national economic planning, thus signalling significant shifts in resource distribution toward NEV development (Jin et al., 2021). This directive catalysed a wave of supportive actions from local governments and state-affiliated corporations. A case in point is the 'Ten Cities, Thousand Cars' initiative, which mandated the procurement of NEVs by localities and state entities, a phenomenon seldom seen in developed countries, where the government's sway over local purchasing is notably more tempered.

The Chinese government's deployment of 'political missions' to premier universities and state-owned auto manufacturers was pivotal in fostering technological advances in NEVs, a strategic move initiated under the auspices of the 863 Program (CATRC et al., 2022). The proactive solicitation of global expertise, as exemplified by the 'Thousand Talents Plan' and its alignment with the 'Talent Superpower Strategy' of the CCP's 17th National Congress, underscores the government's substantial investment in human capital, unusual for most developed nations, particularly in economically austere times.

Expert testimonies highlighted that China's investors and corporate community remain keenly attuned to governmental cues, with market success often hinging on alignment with the state's direction. The propensity for swift market mobilisation in response to government-indicated sectoral priorities contrasts with Western markets' more deliberative and policy-dependent mobilisation strategies.

The continuity of policy despite shifts in leadership, facilitated by China's single-party system, was another theme recurrent in expert dialogues. Such political stability ensures that long-term strategic objectives remain primarily unaltered, contrasting with the potential for policy uncertainty seen in the pluralistic democracies of developed nations, where government transitions can precipitate significant strategic redirections.

Finally, the discussion touched upon the relative absence of 'lock-in' mechanisms within China, characteristic of developed countries, where entrenched industrial interests may resist sectoral change. The formidable policymaking power of the Chinese government has enabled it to mitigate such inertia, empowering proactive infrastructural and industrial policy adjustments in favour of EVs. In this context, Chinese energy companies and auto manufacturers have shown agility in aligning with government-endorsed electrification goals, distinguishing China's approach from the more complex and occasionally contentious transition dynamics in developed countries.

In summary, the Chinese government's unique method of governing, characterised by decisive, top-down interventions, distinguishes its role in shaping the country's EV sector. The confluence of political will, strategic resource allocation, targeted talent acquisition, and a high degree of market responsiveness to governmental planning constitute the backbone of China's successful transition, setting a distinct model apart from the practices observed in developed economies. This intricate interplay of governance, technology, and market forces in China presents an interesting contrast to the multifaceted and often more contested terrain of policy and industrial change in developed nations. The analysis will further dissect China's distinctive transition path within the global EV marketplace.

Table 8-3 summarises the comparative insights gathered from the investigation, emphasising the distinctive trajectory of China's NEV sector transition as influenced by governmental, technological, economic, and social factors. The following subsection will extend the discussion by providing an integrative analysis of the transition's unique attributes in the context of global developments and internal Chinese market dynamics.:

Table 8-2 Comparative analysis: Chinese government vs. developed countries in NEV transition

Aspect	China	Developed Countries
Government Role	Directive: central to local government influence.	Facilitative; variable intervention levels.
Resource Allocation	Heavy government investment and support.	Diversified investments; less direct funding.
Policy Impact	Immediate market shifts; high sensitivity to government directives.	Gradual impact; dependent on policy confirmation.
Market Sensitivity	Quick alignment with government priorities.	Cautious alignment; reliant on market signals.
Consistency of Strategy	Steady long-term plans under a single-party system.	Subject to change with government turnover.
Talent	Strategic initiatives like	Driven by market conditions, less

Recruitment	'Thousand Talent Plan'.	government-led.
Lock-in Mechanisms	Low resistance due to strong government guidance.	Higher resistance from established sectors.

8.4 Roles of local governments

Beyond the central government, local governments, primarily at the provincial and city levels, play multifaceted roles in the NEV sector's transition through their interactions with various entities. This section examines two key interactions identified by interviewees: interactions with the central government and the influence of local governments on automakers.

8.4.1 Interactions between local and central governments

'*In China, the central government is the one to give direction to sectoral development; however, the local governments are the ones to execute these directional policies, leveraging the different circumstances among locations. That's why you could see different progress of automotive electrification among these places; the capabilities of local governments could be very influential,*' noted one interviewee. This comment highlights China's distinctive policy deployment mechanism, where the central government sets a strategic framework as a directional guide. Still, local governments retain a certain level of autonomy. This autonomy allows local governments to tailor national policies to their unique contexts, leveraging local strengths and addressing specific challenges.

Additionally, many interviewees pointed out that more capable local governments with abundant resources, such as a robust local automotive industry, high-income residents, and substantial funding, tend to advance faster in NEV adoption. For instance, cities like Shanghai and provinces like Guangdong have made significant strides due to resource availability and proactive policies. A notable example is Shanghai's license plate policy, which has been effectively utilised to boost the penetration rate of electric vehicles within a relatively short period. This case underscores how local governments can implement unique strategies that drive rapid progress, setting them apart from regions with fewer resources or less proactive governance.

8.4.2 Interactions between local governments and automakers

Guided by the central government's directional policies, local governments began implementing localised measures, often focusing on nurturing their local automakers. In the early stages of the NEV sector, when the market was still emerging and required protective spaces, local governments provided essential resources and favourable policies to support automaker development. This support helped some companies become pioneers in the NEV transition, such as SAIC, backed by the Shanghai government, and Geely, supported by the Hangzhou government.

As the sector matured, local governments shifted their strategies to create more favourable environments to attract a broader range of automakers to their regions. This was part of a broader effort to enhance the overall competitiveness of their locales. Notable examples include Tesla's Gigafactory in Shanghai and the relocation of Nio to Hefei in Anhui province. These moves were strategic decisions by local governments to boost their regions' innovative industry profiles and attract talent, enhancing their standing in the competitive landscape of NEV development. The competition between local governments to attract such high-profile investments often resulted in automakers receiving substantial resources and local policy support, further accelerating the electrification process.

8.4.3 The challenge of local protectionism

While local governments have played a crucial role in supporting the growth of their local automakers and advancing the electrification path, their actions have sometimes posed significant barriers to broader market integration. As discussed in the case study, local protectionism in the mid-2010s (the beginning of the market formation stage) became a serious issue (CATRC et al., 2017, Jin et al., 2021). Local governments often prioritised protecting their local automakers by creating barriers restricting market access for automakers from other provinces or cities, thus preventing them from entering or expanding their market share. This protectionist stance led to regional markets being dominated by local players, especially in the 2C (consumer) and 2G (government) segments. For example, in Shenzhen, most taxis and government vehicles were supplied by BYD, a local automaker.

One interviewee remarked, '*With the mindset of local protectionism among some local governments; it is challenging to introduce electrified products to these places if they are not produced locally or made by local automakers. This has been seen as a significant barrier, particularly in cities where local automakers are focused on gas-powered vehicles.*' The prevalence of local protectionism created a fragmented market landscape, where each region prioritised its local industry at the expense of broader sectoral coherence. This slowed the introduction of innovative products from outside and led to inefficiencies and duplicated efforts as local governments pursued isolated development paths.

Overall, while local governments have sometimes created barriers for external automakers and slowed national market integration through protectionist measures, their proactive engagement has been pivotal in accelerating the NEV transition within their jurisdictions. By providing targeted support and capitalising on regional strengths, local governments have significantly driven the growth of the NEV sector, catalysed innovation, and boosted the competitiveness of local industries. The dynamic involvement of local governments continues to be a critical force in the broader evolution of China's NEV market, showcasing both the complexities and the opportunities inherent in decentralised governance as a driver of sectoral transformation.

8.5 Summary of the chapter

This chapter examines the transformation of the Chinese government's role in the socio-technical transition within the NEV sector through the lens of the GIESTS Framework. The narrative details how the government's involvement evolved from being an initiator, laying the groundwork for the sector's development, to a facilitator of innovation, and eventually to a regulator overseeing the matured market. The government's approach was initially characterised by state-led strategic planning, providing substantial support to key sectors, including electric vehicles, through incentives and coordinated policies. This strategy facilitated industrial upgrading and technological progress, setting a foundation for the sector's growth.

As the sector progressed, the government's role diversified across different stages. During the exploration phase, it acted as the initiator, fostering industry-government-academia networks and setting long-term visions. By the market formation phase, it had become a catalyst, implementing policies to stimulate market entry and demand. In the maturation phase, the government's role shifted to that of a facilitator, enhancing competition and setting industry standards. Finally, in the market reformation phase, it assumed the regulatory role, focusing on the sector's health and policy recalibration.

Comparing China's approach to that of developed countries reveals distinct differences in governmental influence, policy impact, and market sensitivity. China's directive role, combined with strategic resource allocation and immediate market responsiveness, contrasts with the more variable levels of government intervention observed in developed nations. The government's ability to quickly mobilise market players in alignment with strategic priorities starkly contrasts the more cautious and policy-dependent market mobilisation strategies in Western markets.

Moreover, while acknowledging the overarching authority of the central government, this chapter also delves into the unique roles of local governments. It explores the complex interactions between central and local governments, as well as among local governments and automakers. These discussions illuminate the embedded complexity of sub-national-level governance and their significant influence on the sector's transition.

This comprehensive exploration highlights the pivotal role of the Chinese government in steering the NEV sector's development, from incentivising innovation and creating a supportive environment to implementing regulatory frameworks that guide the sector towards sustainability and global competitiveness. The chapter underscores the strategic adjustments and policy innovations that have propelled China to the forefront of the global NEV market, illustrating the government's critical contribution to the sector's dynamic evolution. I will discuss the key findings in the next chapter, building on the in-depth analysis in Chapters 6 to 8.

Chapter 9. Discussion and Conclusion

Building upon the detailed exploration of automotive electrification through the GIESTS Framework in Chapters 5 and 6 and the comprehensive examination of the government's influential roles in Chapter 7, this chapter goes beyond synthesising the key findings from the case study and expert interviews. It critically examines how the thesis challenges, advances, and refines existing scholarly understanding of socio-technical transitions. By addressing the research questions, the discussion highlights the theoretical and practical implications of the findings, demonstrating the value of the proposed conceptual framework. The chapter evaluates the GIESTS Framework's effectiveness in addressing gaps in the literature. It situates the insights gained from the case study and expert interviews within the broader discourse on socio-technical transitions.

9.1 The influential factors and actors in the transition

In this section, I will delve into the key actors and sectors that play the most crucial roles in the transition. These insights are derived from the GIESTS analysis of the targeted case and expert interviews, which collectively provide a comprehensive understanding of the forces driving this transformation.

9.1.1 Overview of the key actors and their entry into the NEV transition

The case study focuses on the transition within China's NEV sector and has comprehensively identified and analysed the various actors involved. The integration of expert interviews has played a critical role in refining and validating the initial observations about these actors, thus providing a clearer understanding of the central figures driving this transition.

Among these automakers, BYD and other pioneer local automakers initiated their participation in the transition during its early stages (the pioneer local automakers). However, BYD stands out as the only one deeply and actively involved in developing the NEV sector at the beginning of the transition, ultimately attaining a leading position during the market reformation stage after decades of dedicated effort. In contrast, the pioneer local automakers initially developed NEVs by government directives. Still, they shifted their focus to active participation in the transition only after Tesla decided to localise production in China, a pattern mirrored by most local automakers.

Local start-ups emerged in the mid-2010s, shortly after Tesla entered the Chinese market. Interviewees from these local start-ups have identified that Tesla's launch in China garnered significant attention from investors, resulting in an influx of investment capital (Wang, 2021). Consequently, many local start-ups, predominantly founded by actors from other sectors, were established to seize the opportunity and attract investors. Furthermore, Tesla's products profoundly impacted the NEV sector in various dimensions, a topic that will be explored in more detail later.

Interviewees have identified Tesla's localisation efforts as a pivotal activity in the industry transition. Not only did localisation enhance the supply chain capabilities of the NEV sector, but Tesla's market success also sent a clear signal to other automakers that the electrification trend was unstoppable. Consequently, in the late 2010s, most local automakers shifted their strategies from ICE vehicles to NEVs, joining some pioneer multinational automakers in this transition. Simultaneously, other lagging multinational automakers also began acknowledging the accelerating electrification trend.

However, multinational automakers exhibited a slower response for various reasons, even for pioneer multinational automakers, which will be discussed further in this section with a comparison to other automakers. Notably, the trajectory of BYD's success underscored the viability and profitability of NEVs, as interviewees indicated. The company's strategic foray into market penetration has significantly catalysed the sector's overall performance, with NEVs experiencing a steep increase in market share from a mere 5% in 2020 to an excess of 30% by 2023 (CBIRC, 2023), which has been a pivotal milestone, solidifying NEVs' position within the mainstream automobile product range. The delayed but decisive shift in strategic orientation by multinational automakers, prompted by BYD's performance, marks a critical point of analysis in understanding the global automotive industry's transition to sustainable technology.

Besides, the Chinese government has primarily orchestrated the transformation of the NEV sector, as discussed in the previous chapter. Their initial efforts were focused on defining a clear vision and trajectory for the sector. This involved the establishment of a foundational network, followed by the introduction of pilot initiatives. The primary aim of these initiatives was to equip the sector with invaluable experiential insights and technical expertise. The government's hands-on approach was complemented by incentives designed to nurture the nascent market. In subsequent phases, many refined regulations, standards, and guiding policies were introduced to ensure the sector's sustained growth. In essence, the government has played the role of a 'sailor' guiding the transition.

It is imperative to underscore the external socio-technical systems that solidified the Chinese government's unwavering commitment to expanding the NEV sector. The global environment has played a pivotal role in this context. China's increasing concerns about energy self-reliance and its accession to the WTO at the start of the millennium have been instrumental in shaping its strategic orientation toward NEVs. Interestingly, these global dynamics did not solely influence governmental actions but left a lasting imprint on other key stakeholders.

In addition to the government and different kinds of automakers, the power battery sector and technology-related sectors, including telecommunications and the internet, will also receive in-depth examination in this section due to their profound and enduring impacts on the transition trajectory.

The subsequent subsections will start with the roles played by key actors and then meticulously address the timeline, outlining the sequential entry of various automakers into this evolving landscape. This section aims to elucidate the interplay among these actors, primarily from the perspectives of different automaker categories. Finally, summarised figures will be provided chronologically at the end of this section to offer a holistic overview of the actor's entry into the transition, laying the foundation for the discussions in section 6.2.

9.1.2 The innovator: BYD

Upon its entry into the automotive space, BYD's foray into BEV development yielded its inaugural model in 2006. However, the nascent state of BEV infrastructure and a lack of clear governmental guidance delayed its launch. In a strategic pivot, BYD deployed the e6 BEV as taxis in Shenzhen in 2010 under the 'Ten Cities, Thousand Cars' initiative, providing invaluable insights despite modest sales.

Subsequent years saw a gradual realignment of BYD's focus towards NEVs, in tandem with supportive government policies and incentives. Though BYD's market influence was initially tempered by brand perception and limited sales, this era was instrumental in amassing technological prowess and market experience, setting the stage for significant post-2020 breakthroughs.

BYD has cemented its role as a transformative leader in the NEV market post-2020, leveraging its technological legacy to enhance its competitiveness. Pioneering advancements in battery technology mark the company's post-2020 trajectory, strategic dedication to NEVs, and a drive to mainstream these vehicles. Key developments include:

- **Innovation in Battery Technology**: BYD revolutionised battery safety and affordability with the 2020 release of its 'blade battery' technology. Addressing the limitations of traditional ternary lithium batteries, which offered high energy density but posed safety risks, BYD's blade battery improved the energy density of lithium iron phosphate (LiFePO4) batteries without compromising safety. Offering this safer, more cost-effective battery option to other manufacturers such as Ford and Tesla, BYD elevated its status to a primary supplier for notable automakers by 2023, directly impacting the market dynamics and pricing of BEVs.
- **Dedication to the NEV sector**: In a pivotal move in 2022, BYD became the first traditional automaker to announce its decision to discontinue the production of ICE vehicles. This strategic shift garnered the attention of critical multinational automakers, including direct competitors like Toyota and Honda. Previously, many multinational automakers perceived NEVs as niche products and underestimated the momentum of electrification. However, in response to BYD's announcement and its remarkable market performance in 2022, most of these multinational companies realigned their strategies and actively engaged in the NEV sector.
- **Transform the NEVs into Mainstream Products**: By securing its position as the

> leader of the NEV sector in China in 2022, BYD achieved a significant milestone. The success of BYD's products propelled the penetration rate of NEVs to over 20% in 2022, reaching 30% in 2023 (CBIRC, 2023). BYD was pivotal in transitioning NEVs from niche products to mainstream choices. Unlike Tesla and local start-ups that predominantly offer mid to high-priced EVs, BYD primarily focuses on mid to low-priced EVs, making them accessible to a broader consumer base. Moreover, BYD's extensive dealer network facilitated the adoption of NEVs, reaching lower-tier cities and rural areas.

An interviewee with experience at BYD remarked, '*Despite its leading battery technology, BYD has transformed the whole game, not like Tesla only targets top tier cities, it brought NEVs into lower cities, and it has directly challenged the leading position of the multinational mainstream automaker and force them to change the strategy.*' This perspective underscores BYD's pivotal role in reshaping the competitive landscape and democratising access to NEVs across diverse markets.

In summary, BYD, originally a battery supplier, has emerged as a transformative force in the NEV sector. With its pioneering blade battery technology, BYD addressed critical safety concerns associated with lithium batteries, making NEVs more affordable for consumers and stimulating competition in battery technology. Beyond innovation, BYD's unwavering commitment to the NEV sector, exemplified by its historic decision to discontinue ICE vehicle production, has prompted major multinational automakers to recalibrate their strategies and actively engage in electrification. By focusing on mid to low-priced NEVs and expanding its dealer network to reach even rural areas, BYD has propelled NEVs from niche products to mainstream choices, significantly increasing their market penetration in China. Through its multifaceted contributions, BYD has played a central role in shaping the NEV sector's growth and evolution, ultimately solidifying its position as a leader in the industry.

9.1.3 The passive innovator and early adopter: Pioneer local automakers

This subsection examines selected local automakers that, from the beginning, were designated to fulfil ‘political missions’ instrumental in NEV market formation. An interviewee with firsthand experience in one of these strategically positioned companies highlighted the significance of their role, stating, ‘*These automakers were integral to the exploratory initiatives, aligning with governmental visions to cultivate a cohesive ecosystem among industry players, government bodies, and academic institutions. Their involvement in this nascent stage was foundational, setting the stage for technological advances within the industry.*’ Their involvement in this nascent stage was foundational, setting the stage for technological advances within the industry.’

During the pilot-run phase, these local automakers were critical suppliers of initial NEV models for state-led projects, gaining early production experience and contributing to the government’s expanding proficiency in cultivating the NEV market. This experience proved invaluable as these automakers would later become leading figures in the industry’s development.

As the market matured, stark contrasts emerged among competitors: Tesla positioned its offerings at the premium end, while new entrants struggled for market traction with their NEV propositions. The established local automakers, in turn, formed strategic partnerships with tech companies from the internet and telecommunications sectors, broadening their NEV range. This foresight enabled them to capture the mid to lower-price market, which was critical for subsequent volume growth.

However, it’s essential to acknowledge these automakers’ varied levels of commitment. While some, like BYD and BAIC, were instrumental in driving the sector’s early development and transition, others were less ambitious and content with meeting the minimum requirements to benefit from state-funded incentives. '*These automakers just want to 'finish their homework' offered by the central government, which resulted in a loss of pioneered advantage,*' another interviewee pointed out.

This narrative underscores the complex interplay of motivations, strategies, and outcomes among local automakers in China's NEV sector. It highlights the significant impact of government-directed missions on shaping the industry's trajectory, the strategic positioning of automakers in response to market evolution, and the varying degrees of innovation and commitment within the sector.

9.1.4 The game changer: The Tesla Effect

Throughout the case study and expert interviews, Tesla emerges as a paramount player in the transition towards NEVs, leaving a lasting imprint across three distinct temporal phases within the 2010s. These phases encompass the early 2010s, marked by Tesla's successful IPO and heightened investor interest, followed by the mid-2010s when Tesla introduced its high-end Model S and Model X to the Chinese market, and concluding with the late 2010s, as Tesla localised its entry-level Model 3 and Model Y offerings in China.

Tesla's impact transcends mere product provision within the NEV sector, extending its influence across various dimensions. These dimensions include shaping consumer perspectives regarding NEVs, influencing the methodologies and concepts employed in NEV product definition by automakers, inspiring certain actors within associated socio-technical systems, steering strategic decisions made by other automakers, bolstering the competitiveness of the NEV supply chain in China, and serving as a compelling testament to market opportunities for automakers that initially hesitated to embrace the NEV sector, both multinational and local. These influences are detailed as follows:

- **Attracting Investor Interest**: As previously discussed, Tesla's successful IPO and the rising value of its stock captured the attention of investors in China, sparking interest in the NEV sector. While the immediate impact on China's NEV sector may not have been apparent right after its IPO, it prompted actors from various sectors to explore market entry. As mentioned by interviewees, this phenomenon could be a significant driver behind the trend of cross-industry car manufacturing in the mid-2010s.
- **Changing Perspectives Toward NEVs**: Before Tesla entered the Chinese market, most NEVs were perceived as lower-end, retrofitted gasoline cars with powertrain modifications, viewed unfavourably by consumers. However, Tesla disrupted this narrative by launching high-end products like the Model X and Model S, priced in line with luxury brands such as BMW and Audi. Coupled with advanced technologies and amplified by influencer endorsements (Key Opinion Leaders), Tesla's arrival reshaped consumer perceptions of NEVs. This shift is pivotal for local automakers' future introduction of high-end NEV models.
- **Setting the Standards for NEV Product Definitions**: Tesla's influence extended to the product definition of NEVs. Unlike traditional automakers whose product managers prioritised hardware features like matrix headlamps and leather seats, Tesla's emphasis on intelligent features delivered via a central screen and advanced ADAS functionalities set a new standard for NEV design. This redefinition prompted automakers to recognise the importance of intelligent features. It led to increased involvement of associated socio-technical systems, such as the internet and telecom sectors, in developing solutions. The resulting talent mobilisation is further elaborated in subsequent sections.

- **Role Model for Local Automakers**: Tesla served as a role model for local automakers, particularly start-ups, offering a blueprint for benchmarking. Early models released by local start-ups in the late 2010s and early 2020s mirrored Tesla's innovations, encompassing unique selling points, design aesthetics, pricing strategies, and product features. Tesla's brand-building journey and internationalisation strategy inspired local start-ups, with Nio and XPeng, for example, adopting innovative approaches. Additionally, some start-up founders drew inspiration from Tesla's leadership style, such as Xiaopeng He, the founder of XPeng. Without Tesla as a role model, local start-ups would have faced more significant challenges in rapidly developing competitive products during the early 2020s.
- **Increasing Competition within the NEV Sector**: In the maturation stage, the NEV market experienced substantial growth, primarily driven by government policies and incentives. However, from multiple perspectives, the sector remained non-competitive. Tesla's entry stimulated local automakers to enhance their product competitiveness to retain market positions, a pivotal factor in fostering competitive products during the market reformation stage.
- **Enhancement of the Supply Chain**: The Chinese NEV sector's supply chain initially lacked the maturity to support automakers in developing competitive products. As a recognised mature BEV manufacturer, Tesla initiated localisation in China, providing opportunities for local suppliers to upgrade their capabilities. In the market reformation stage, these enhanced supply chain capabilities assisted local automakers in delivering globally competitive products.
- **Evidence of Profitability in NEV Production**: Many interviewees noted that lagging automakers initially hesitated to participate actively in the NEV transition due to doubts about profitability. However, Tesla's sales performance exceeded expectations, compelling traditional automakers to enter the NEV sector; such

phenomena have been mentioned several times during interviews. This shift in direction elevated the transition to a new level.

To gain a deeper understanding of Tesla's influence throughout distinct phases of the NEV transition, it is beneficial to present a chronological overview of these effects, contextualising them about the three pivotal timeframes mentioned earlier. Tesla's impact can be discerned across these periods:

- **Early 2010s - IPO Success**: In this phase, Tesla's successful initial public offering (IPO) in the United States garnered significant attention from Chinese investors. This marked the first instance of Tesla's influence on the transition, as it ignited interest in electric vehicles and stimulated discussions surrounding NEVs within the Chinese investment landscape.
- **Mid-2010s - High-End Product Launch**: Tesla's entry into the Chinese market in the mid-2010s with high-end products like the Model S and Model X catalysed transformative changes. Not only did Tesla redefine the perception of NEVs, presenting them as technologically advanced and on par with luxury gasoline vehicles, but it also shaped consumer perspectives. NEVs were no longer viewed as mere powertrain-altered cars but were seen as high-competitiveness, albeit higher-priced, alternatives. Tesla's high-end products concurrently served as benchmarks for the local automotive industry, particularly inspiring start-ups across various dimensions, including product strategy, leadership style, and IPO strategies. Moreover, the successful launch of Tesla in China grabbed investors' attention again after the IPO and initiated the trend of the participation of actors from other sectors.
- **Late-2010s - Localization Impact**: Tesla's localisation efforts in China, which culminated in the production of entry-level models like the Model 3 and Model Y, represented the final phase of influence. Localising its operations in China

necessitated supply chain improvements and specific requirements for local suppliers. Tesla's exacting standards and demands consequently elevated the capabilities of the NEV supply chain in China. Moreover, Tesla's market performance provided compelling evidence of opportunities within the NEV sector, bolstering the confidence of previously hesitant automakers and prompting their active participation during the early 2020s.

Figure 9-1 below provides a graphical analysis of Tesla's influential role in shaping the NEV sector within the Chinese automotive sector. The timeline depicted spans Tesla's landmark IPO in 2010 to its strategic localisation efforts within China in 2019.

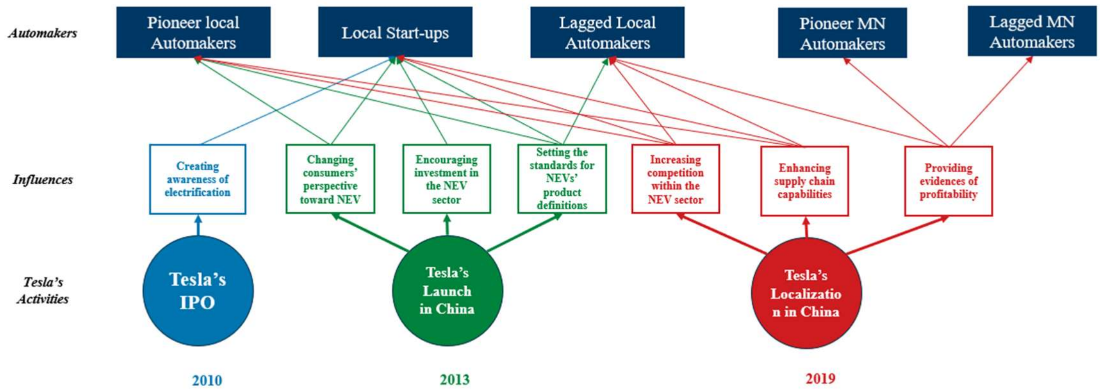

Figure 9-1 Visualization of the Tesla Effect on other automakers

The figure presented in this section illustrates the far-reaching impact of Tesla on various segments of the Chinese automaker landscape. It highlights that Tesla's localisation strategy has wielded the most substantial influence, permeating nearly every facet of the industry. Specifically, our analysis reveals that local start-up companies have been the primary beneficiaries of Tesla's influence. Initially, Tesla captured the attention of investors by emphasising the automotive electrification trend through its Initial Public Offering (IPO) on the NASDAQ. Subsequently, Tesla's entry into the Chinese market illuminated the market potential within China, further galvanising investor interest. Moreover, Tesla's presence has provided local start-ups with a role model to emulate, enhanced their supply chain capabilities, and intensified competition within the sector.

Furthermore, Tesla's localisation efforts have bolstered China's standing in the global NEV landscape and catalysed traditional automakers to reevaluate and pivot toward electrification, especially during the early 2020s. This shift in strategy has encompassed lagging local automakers and pioneering multinational automakers and lagging multinational automakers, categorised as late adopters and laggards in the context of innovation diffusion, as identified in this section.

An interviewee from a local start-up elaborated on the Chinese government's strategic rationale for encouraging Tesla's localisation, stating, '*It's the government's purpose to invite Tesla to localise in the market. The government wants it to not only push the path of electrification but also increase the capability of the value chain, which I think is very smart.*' This perspective underscores the dual objectives of the government's strategy: to accelerate the transition towards electric vehicles and to enhance the competencies and capacities within the local automotive value chain.

In summary, the ascendancy of China's NEV sector has been marked by a gradual reduction in Tesla's relative influence as local automakers have surged ahead. Initially, Tesla played a catalytic role in the market with its pioneering business model and innovative technology, profoundly shaping industry trends and consumer perceptions. However, as the sector matured, Chinese automakers swiftly adapted, gaining substantial market share and, in certain aspects, outperforming Tesla in the domestic arena. The entry and ascendance of traditional automakers transitioning to NEV production have further diversified the competitive landscape, tempering Tesla's dominance. Nevertheless, Tesla's early contributions to the sector's development remain a foundational cornerstone underpinning the current success of the NEV industry in

China. The transformation of Tesla from a market stimulator to one among many competitive players encapsulates the dynamic evolution of the NEV industry, underscoring the intricate interplay between innovation, market dynamics, and government policies in shaping the sector's trajectory.

9.1.5 The quick follower: Local start-ups

The emergence and ascension of local startups in the Chinese NEV market following Tesla's entry marked a period of significant industry-wide transformation. These startups, leveraging expertise from the telecom and internet sectors, propelled forward-looking changes, heralding a new era of talent mobility, scenario-based product planning, accelerated product development, and inventive business models. They transformed the industry from focusing on traditional competitor-based approaches to one attuned to the customer's evolving needs and creating more tailored driving experiences. This subsection examines the multifaceted impacts of these startups on the industry's transition, which are as follows:

- **Talent Mobility from Associated Sectors:** As highlighted in the previous subsection, Tesla's IPO and entry into the Chinese market inspired investors to support local start-ups in the mid-2010s. An interviewee highlighted this dynamic, noting, '*These start-ups, including Nio and XPeng, often had backgrounds in the telecom and internet sectors, attracting talent from these sectors.*' Some of the talents who were founders of these start-ups brought fresh perspectives and innovative thinking to the automotive sector. As elaborated below, this cross-sector talent mobility influenced various aspects of the NEV industry, spanning product planning, development, new business models, and more.
- **User-Cantered Planning Process**: Traditional automakers primarily relied on

conventional benchmarking methods to define and equip their vehicles. However, local start-ups, particularly those with backgrounds in the internet and telecom sectors, shifted their focus towards user needs rather than competitor benchmarks. They introduced a 'scenario-based' product planning process that allowed product managers to define products based on real customer needs. This approach gained popularity in the early 2020s, particularly among product managers responsible for NEVs, enhancing the competitiveness of NEVs compared to traditional ICE vehicles that were still planned to use traditional benchmarking techniques.

- **New Product Development Process**: Local start-ups shocked traditional automakers with their speed in launching new products in the late 2010s. These start-ups adapted and modified product development processes from traditional automakers while integrating elements from the Internet and telecom sectors to address the increasing complexity of intelligent features and software. Interviewees have indicated that the adaptation aimed to reduce the overall time required to launch new products. The emergence of Over-The-Air (OTA) updates allowed these start-ups to release products that weren't perfect at launch but could be optimised post-release through updates. These developments prompted traditional automakers to reassess their product development processes. For example, one interviewee mentioned that their multinational company began adopting agile methods for developing intelligent features, a crucial step in reducing the time required to launch NEVs, given the larger share of intelligent features compared to ICE vehicles.
- **Innovative Business Models for Automotive Disruption:** Local start-ups, lacking the same capabilities as traditional automakers regarding quality systems, management systems, manufacturing, and cost control, explored alternative ways to compete. They introduced innovative business models, exemplified by Nio's unique service offerings detailed in the case study. An interviewee from a local

start-up elaborated on the effects of these business models, stating, '*These innovative business models increased awareness about these new companies among both traditional automakers and consumers, positioning them as innovators in the industry.*'

- **Elevation of Local Brand Positioning:** Before leading local start-ups emerged, local automakers predominantly targeted the lower-end market segments, with brand positioning considered lower than mainstream local automakers. Value for money was the primary purchasing driver for their targeted customers. However, the advent of leading start-ups offering premium services, advanced technologies, distinctive designs, and innovative business models reshaped perceptions of local brands. These local brands were no longer seen as inferior products, contributing to the ability of traditional automakers to launch NEV brands targeting the premium market in the reformation stage, as detailed in the case study.
- **Disruption and Adaptation:** The unexpectedly strong market performance, particularly in 2021, sent shockwaves through the lagged local and multinational automakers. These companies underwent drastic strategy changes and allocated more resources to NEV development. They also studied local start-ups and sought to leverage their unique characteristics to transform various business dimensions, such as product definition and product development processes, as discussed above, to enhance their competitiveness in the NEV sector.

Local start-ups reshaped the Chinese NEV landscape post-Tesla's debut, infusing innovations from the telecom and internet domains. These entities championed user-centric product planning, swift development, and pioneering business models. Their agile approach, underscored by Over-The-Air (OTA) updates, allowed continuous product enhancement post-launch. These start-ups expedited product evolution and elevated local brands from budget alternatives to competitive innovators. Their 2021 market successes prompted automotive leaders, both local and international, to recalibrate their NEV approaches, imbibing the novel strategies of these emerging players.

9.1.6 The majority: lagged local and pioneer multinational automakers

In addition to the aforementioned local start-ups and the selected few local automakers mentioned earlier, several other local automakers initially refrained from active participation in the NEV sector until the onset of the market reformation stage. Their entry into the NEV sector was predominantly catalysed by the localisation of Tesla and the remarkable success of local start-ups in the early 2020s, as elaborated upon in the following paragraphs.

Towards the conclusion of the maturation stage, when the Chinese government decided to facilitate Tesla's localisation efforts within China, a cohort of traditional local automakers known for their responsiveness to market trends began allocating more resources toward NEV development. Notably, not all local automakers opted to reallocate most of their resources to NEVs at this juncture; some continued to reserve a significant portion for traditional gas-powered vehicles. However, certain automakers, such as GAC, discerned the market opportunities presented by Tesla's success and decided to adjust their strategies to accommodate NEVs.

In the early stages of the market reformation phase, local start-ups garnered substantial attention from consumers, government agencies, and investors due to their robust market performance and sustained growth momentum. Inspired by the achievements of these local start-ups, other traditional automakers that had previously hesitated finally committed to a directional shift and active engagement in the NEV sector. This transition prompted local automakers' launch of numerous new sub-brands, all aiming to capitalise on the burgeoning NEV market.

Some pioneering multinational automakers, including Volkswagen, began preparing for the electrification trend early on, initiating their participation almost simultaneously with lagging local automakers. Inspired by Tesla's success and the potential for profitability, these pioneer multinational automakers launched their NEV products in the early 2000s.

Although these latecomers to the NEV sector did not significantly contribute during the initial two decades of the transition, their belated participation wielded a profound impact on the transition's trajectory. These automakers possessed extensive dealer networks in lower-tier cities, significantly enhancing the presence of NEVs in these regions and facilitating the sector's expansion to previously underserved areas.

It warrants attention that some local traditional automakers primarily committed resources to NEV projects as a strategic compliance measure during the developing phase of NEV development. This allocation was often more aligned with achieving regulatory benchmarks - colloquially as 'delivering homework' - than driving the research and innovation in the NEV domain forward. Their engagement was a calculated response to secure governmental mandates and financial incentives rather than a reflection of a genuine commitment to technological advancement in the early stages.

However, as the industry evolved, these automakers shifted from this compliance-based approach to a more active and strategic role in the NEV market. This shift was catalysed by several key factors, as explained by an interviewee from a local automaker: '*This transition was influenced by the local market's response to Tesla's entry and the* *dynamic progression of local start-ups, compelling even the most traditional manufacturers to re-evaluate their position and contribution to the NEV sector.*' By paralleling the proactive strategies of earlier-discussed local automakers, these companies began to intensify their focus on NEV development to become significant players in the field. This shift denotes a critical phase in the overarching narrative of China's NEV sector, marking a move from political compliance to competitive engagement. The progression of these automakers' involvement provides a comprehensive perspective on the multilayered evolution of the NEV industry in China.

9.1.7 The laggard: the lagged multinational companies

Since China joined the WTO, multinational automakers' strategies in its automotive industry have evolved significantly due to the complex interplay between government policies and market forces. Initially focusing on ICE technology, these corporations capitalised on joint ventures to maintain market dominance from the 2000s through the 2010s, benefiting from the Chinese government's technology acquisition strategy.

During the preliminary phase of NEV development, these multinational corporations cautiously approached NEV production by adapting existing ICE platforms to comply with new regulations, such as the dual-credit policy. This compliance-driven approach resulted in a portfolio of NEVs lacking the competitive edge and innovative features championed by local firms. The hesitation of multinational firms to fully embrace NEV development stemmed from two principal factors: the initially tepid domestic demand for NEVs within China and the unclear profitability in the emergent NEV market. Despite some companies' early exploration of electric vehicle technology in the early 2010s, the economic justification for a full-scale shift was not compelling, leading to a reticent investment stance.

The turning point for these lagged multinational automakers' engagement came with Tesla's triumphant entry into China and the demonstrable market viability of BYD's performance, particularly its remarkable sales volume in the post-2022 period upon transitioning from ICE vehicles. An interviewee from a multinational automaker highlighted this strategic shift, stating, '*The acknowledgement of a burgeoning market for NEVs prompted multinational firms to recalibrate their strategies toward electrification aggressively.*'

By the mid-2020s, even traditionally conservative multinational automakers were increasing their commitments to electrification, evident through strategic investments in local start-ups, collaborations with Chinese automakers, and engagement with crucial battery suppliers like CATL. This paradigm shift underscores a maturation within the industry, characterised by comprehensive market coverage and active participation from all automotive stakeholders in fostering the NEV sector's growth.

9.1.8 The cornerstone: the power battery sector

The power battery sector, particularly within BEVs, assumes paramount importance, as emphasised by interviewees. Its significance emanates from its dual role: first, as a substantial contributor to the material costs associated with NEV manufacturing, and second, as the determinant of critical features such as driving range and energy efficiency, which profoundly influence consumers' purchase decisions.

The parallel evolution of the power battery sector and the NEV industry underscores their intrinsic interdependence. During the nascent stages of the transition, the power battery sector relied heavily on extensive support from the government, academia, and even traditional automakers due to its vulnerability. However, as the sector matured and achieved technological breakthroughs, it emerged as a critical enabler, offering improved and competitive power batteries for NEVs.

Our case study findings reveal local automakers' prescient recognition of the power battery sector's significance as they advanced from the maturation stage onwards. Most NEV manufacturers recognised the sector's pivotal role, leading to various forms of engagement, including alliance formations, direct investments in power battery suppliers, and providing technical support to these suppliers.

The Chinese power battery sector achieved global leadership status in the market reformation stage. Among the prominent players, CATL emerged as the world's largest and most influential power battery supplier, serving numerous global automakers (CATRC et al., 2021). Simultaneously, BYD, renowned for its success as an NEV manufacturer, extended its influence as a significant power battery supplier. The flourishing power battery sector propelled the NEV sector's remarkable growth during the market reformation. The symbiotic relationship between these two sectors is undeniable; without the concurrent development of the power battery sector, the NEV sector's remarkable achievements would remain unattainable.

The power battery sector is paramount, significantly influencing NEV production costs and critical attributes like driving range and energy efficiency. This sector's evolution and the NEV sector showcase a symbiotic relationship. Initially, the power battery sector leaned heavily on external support but later evolved as a cornerstone for NEV advancements. Local automakers recognised this sector's significance, leading to diverse collaborative efforts. China's power battery sector, with giants like CATL and BYD, achieved global prominence by the market reformation phase. This sector's rise was fundamental in propelling the NEV industry's success, underscoring the essential interdependency between the two.

9.1.9 The enabler: technological sectors

The advent and rise of the technological sectors in China, such as the Internet and telecom sectors, have sculpted significant changes across consumer demographics and business sectors. Delving deeper into its transformative effects, particularly in the automotive domain, the observations include the following:

- **Increasing Consumer Demand for New Technologies**: The digitisation wave that increased in the early 2010s has precipitated a radical transformation in Chinese consumer profiles. Case study analyses reveal that the digital revolution, driven by the internet sector, has fostered a heightened consumer demand for innovation. In an era characterised by accelerated adoption of digital technologies. An interviewee encapsulated this trend, noting, '*Consumers exhibit a pronounced preference for intelligent features, which NEVs, with their advanced technological integration, are uniquely positioned to satisfy.*'
- **Empowerment of NEVs through Technology: Technological advancements, particularly in the domain of the internet and telecommunications**, have endowed NEVs with an expanded suite of intelligent functionalities. During the formative and mature stages of the market, when NEVs faced issues such as cost constraints and limited driving ranges, the convergence of automotive and technological expertise significantly improved their value proposition and market penetration capabilities.
- **Evolution in Management Practices**: Interview data indicates a talent migration from the technological to the automotive sector, engendering a strategic overhaul in management approaches within automotive OEMs. This transition reflects a

departure from traditional project management practices toward more agile, innovation-driven methodologies, facilitating more responsive and iterative development processes within the NEV sector.

- **Innovation-led Disruption by Start-ups**: Many tech-sector leaders, now at the helm of local automotive startups, aim to revolutionise the automotive ecosystem. Leveraging innovative thought processes, they introduce novel business models, sales paradigms, and product visions – like the emphasis on intelligent cockpit and autonomous vehicles. Such pioneering efforts instil a renewed dynamism, propelling the NEV sector's progression.
- **Deepening Tech-Auto Collaboration**: The symbiotic relationship between technology firms and NEV development is intensifying, with technological contributors transforming into critical partners in the automotive sector. The industry witnesses this deepening relationship through collaborative projects that envision and actualise new vehicle technologies, such as V2X (vehicle-to-everything) communication systems. Technology giants like Huawei exemplify this trend, asserting substantial influence over the strategic direction of established automotive companies.

In essence, the technological sectors, primarily driven by the internet's influence, have reshaped consumer preferences and catalysed pivotal shifts within the automotive industry, fostering an environment conducive to the growth and evolution of NEVs.

9.1.10 Summary

In this section, the analysis has been centred on the key players shaping the trajectory of the NEV sector in China, utilising the GIESTS Framework introduced in the earlier case study narrative. Enriched by insights from expert interviews, this examination encompasses a broad spectrum of stakeholders, ranging from government interventions to individual automakers. It culminates with an exploration of the substantial impacts of two prominent automakers on the evolution of this sector. Figure 9-2 describes these entities' participation and influence on other actors, providing a concise visual reference for the stakeholders discussed in this sector.

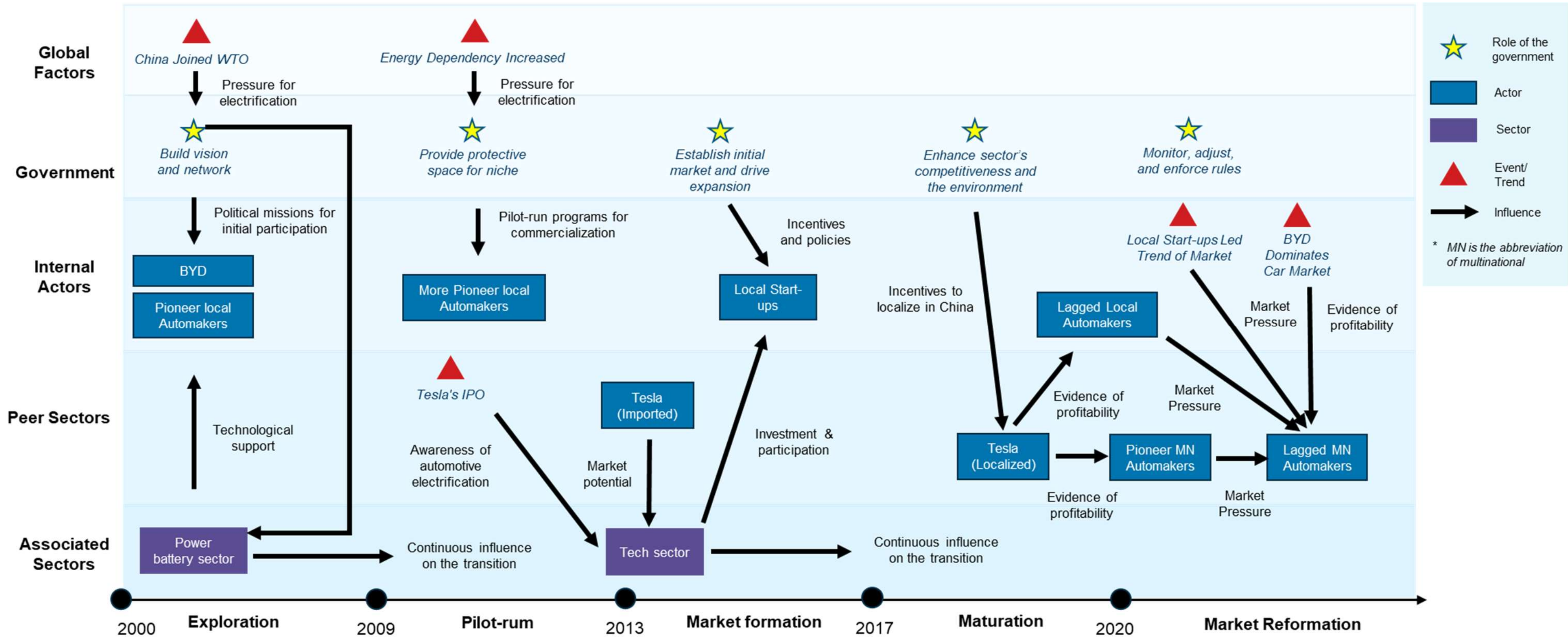

Figure 9-2 Summary of actors' participation and their influences

The graphical illustration above underscores the enduring influence of two sectors external to the automotive industry per se yet integral to the NEV transition. The power battery sector is depicted as an influential force starting from the exploration phase and maintaining its significance throughout the various stages of the transition, as elaborated upon in previous sections. Concurrently, technology sectors began to assert their significance from the market formation phase, propelling the drive towards an 'intelligentised' NEV marketplace.

At the heart of this transition lies the orchestrative role of the government, assuming diverse responsibilities across the trajectory of the transition. Initially, the government provided vision and direction, facilitating market establishment and expansion. In the later phases, it fostered a conducive competitive environment while maintaining oversight over the transition process. Alongside these entities, the onset of participation from various automakers is also delineated. The subsequent figure provides further clarity regarding the catalysts prompting these automakers' engagement.

On the global level, external pressures were pivotal in motivating the government's initial decision to champion NEVs. Influences such as China's accession to the WTO and concerns about energy dependency, as outlined in the case study, were instrumental in shaping this decision. Faced with these challenges, the government selected local automakers to spearhead the transition during the exploration and pilot phases. Tesla's entry into the Chinese market further catalysed the engagement of tech-sector actors by presenting lucrative market opportunities and attracting more significant investment into the NEV domain, leading to the rise of local start-ups.

Tesla's successful localisation efforts and impressive market performance were a compelling showcase of the viability and profitability of NEV production, mainly to previously hesitant local automakers and some pioneering multinational automakers. Simultaneously, burgeoning local start-ups began to erode market share, alongside the participation of lagging local automakers and pioneer multinational automakers, exerting pressure on the lagging multinational automakers. Eventually, the success stories of Tesla's localisation and BYD's market achievements provided irrefutable proof of NEV profitability, compelling these lagging multinational automakers to join the transition. By this juncture, all prominent automakers in China's automotive sector had embarked on the journey toward NEVs.

This section highlights the influential actors and sectors driving the transition, particularly emphasising the internal socio-technical system. Previous empirical studies employing traditional MLP, such as those on 5G technology (Lee and Yu, 2022), green energy transitions (Yang et al., 2022), and automotive electrification (Krätzig et al., 2019, Rao, 2020, Wu et al., 2021b), have primarily concentrated on internal socio-technical systems, government interventions, and policy impacts. However, these studies' discussions surrounding external socio-technical systems are often superficial or absent.

In contrast, this section demonstrates how the GIESTS Framework advances the traditional MLP framework proposed by Geels (2002). By integrating external socio-technical systems and considering their spatial dynamics, the GIESTS Framework offers a more comprehensive understanding of the roles played by external actors. It elucidates how these actors, operating beyond the internal regime, significantly shape and influence the trajectory of socio-technical transitions. This advancement not only addresses the existing gap in the literature but also enriches the analytical capability of transition studies by bridging internal and external dynamics.

Additionally, the findings in this section provide a deeper analysis of the interactions and relationships between diverse actors, highlighting how their co-evolution shapes transition pathways. Unlike previous studies that focus primarily on government and policy impacts (Yin and Huang, 2023, Jiang and Xu, 2023), this analysis uncovers the collaborative and adaptive dynamics among automakers, suppliers, and technology innovators, illustrating how these interactions drive mutual capability building and influence the system's evolution. This perspective broadens the understanding of socio-technical transitions by emphasising the relational complexities beyond a policy-centric lens.

In the ensuing section, I will present a more comprehensive analysis of the transition, examining its defining characteristics and the intricate interplay across various layers through the lens of the GIESTS Framework.

9.2 The characteristics of the transition trajectory of China

Following the exploration of pivotal actors and sectors within the transition, this section aims to delve deeper into the distinctive traits of the transition, referencing prior discussions and evaluating through the prism of the GIESTS Framework and the RCA Framework. The discussion highlights China's approach to fostering innovation and nurturing emergent sectors. Subsequently, I will illuminate the intricate dynamics between internal and external socio-technical systems. Culminating this discourse, I will furnish a holistic perspective on the entirety of the transition.

9.2.1 The pattern of niche development

Based on the comprehensive case study conducted within the framework of GIESTS and the insights gleaned from expert interviews, a distinct and remarkable pattern emerges in the Chinese government's approach to industrial development. This approach distinguishes itself from practices observed in other countries. It can be segmented into several key stages, as identified in the case study: exploration, pilot run, market formation, maturation, and market reformation.

In the exploration stage, the Chinese government establishes a broad directional framework, providing a vision for the industry's development. Notably, the government exercises less control over specific standards and regulations during this phase. This approach creates an environment conducive to innovation and experimentation, allowing industry participants to explore innovative solutions, including new business models. This stage aims to set up the technological roadmap and reserve required technologies for future development.

The government becomes more proactive as the industry progresses into the pilot-run and market formation stages. It introduces attractive incentives and policies to create a protective space for the NEV sector first, stimulate growth and competition, and attract more investment and players to participate in the transition. While a structured framework emerges during these phases, it remains flexible, accommodating diverse approaches and solutions. The government's overarching goal is to foster a competitive landscape within the industry, promoting the emergence of multiple successful entities.

An interviewee with experience at a government-selected automaker shared insights into this strategy, stating, '*Crucially, the government intends to cultivate several 'winners' within the industry. These successful entities, often automakers excelling in the NEV sector, become industry role models.*' Their influence extends beyond market dynamics; they actively participate in collaborative discussions with the government, contributing to establishing industry standards and regulations.

In the market formation stage, the Chinese government has started to improve the competitive environment and increase the competitiveness of the NEV sector through a more mature incentive system, regulations, and standards, along with more significant restrictions on the establishment of new NEV companies by enhancing the qualification requirements for producing NEVs. This distinct pattern, often referred to as 'barbaric growth' by interviewees, becomes particularly pronounced during the maturation stage of the industry. Its primary objective is the rapid development of innovations with minimal consideration for costs and potential challenges that may arise. It initially involves limited control over industry participants to create a protective space, expand the market, and enhance participants' capabilities through hands-on market experience, with less emphasis on creating a mature and sustainable environment in the early stages. Subsequently, the focus gradually shifts towards maturing the environment while maintaining flexibility. Finally, it introduces stricter regulations and restrictions on the targeted sector to ensure the development trajectory aligns with desired goals.

The overarching aim of this unique pattern is to achieve what is often referred to as 'Chinese speed', a concept rooted in China's nature as a follower striving to catch up with developed countries as swiftly as possible. The summarised representation of this distinctive pattern is presented in Table 9-1.

Table 9-1 Summary of the pattern of the development of the NEV sector in China

Stage	Government Role	Goal of the Government	Government Actions
Exploration	Initiator	Setting the industry's trajectory and technological roadmap for NEVs.	Providing a broad framework and encouraging innovation while exerting minimal control over regulations.
Pilot-run	Protector and Incubator	Creating a safeguarded niche for NEVs and laying the groundwork	Introducing incentives and policies to boost growth. Assigning political tasks to

		for future progress.	state-owned firms for NEV progress.
Market Formation	Catalyst	Fostering initial consumer market for NEVs. Attracting diverse players and identifying prospective industry leaders.	Implementing a structured yet flexible framework. Incentivising participation and spurring competition to identify 'winners'.
Maturation	Facilitator	Promoting competitive local NEV manufacturers. Enhancing the sector's competitive environment.	Elevating the winners to model status, involving them in strategic discourse. Instituting more robust regulations.
Market Reformation	Regulator	Elevating the NEV sector's global competitiveness. Guaranteeing long-term sustainable development.	Supporting local players' internationalisation. Strengthening the supply chain. Transitioning to a market-driven model. Adjusting policies and regulations based on new conditions.

Figure 9-3 illustrates the government's dynamic roles and evolving priorities across distinct stages of niche development within the NEV sector. Initially, the government's primary focus was accelerating sectoral growth, striving to maximise participation through subsidies, incentives, and favourable policies while maintaining low entry thresholds for automakers and minimal regulatory oversight. This initial phase was characterised by the government's emphasis on rapid development and increased industry participation, facilitated by financial support mechanisms that required minimal qualifications from participating automakers, resulting in a relatively laissez-faire development trajectory.

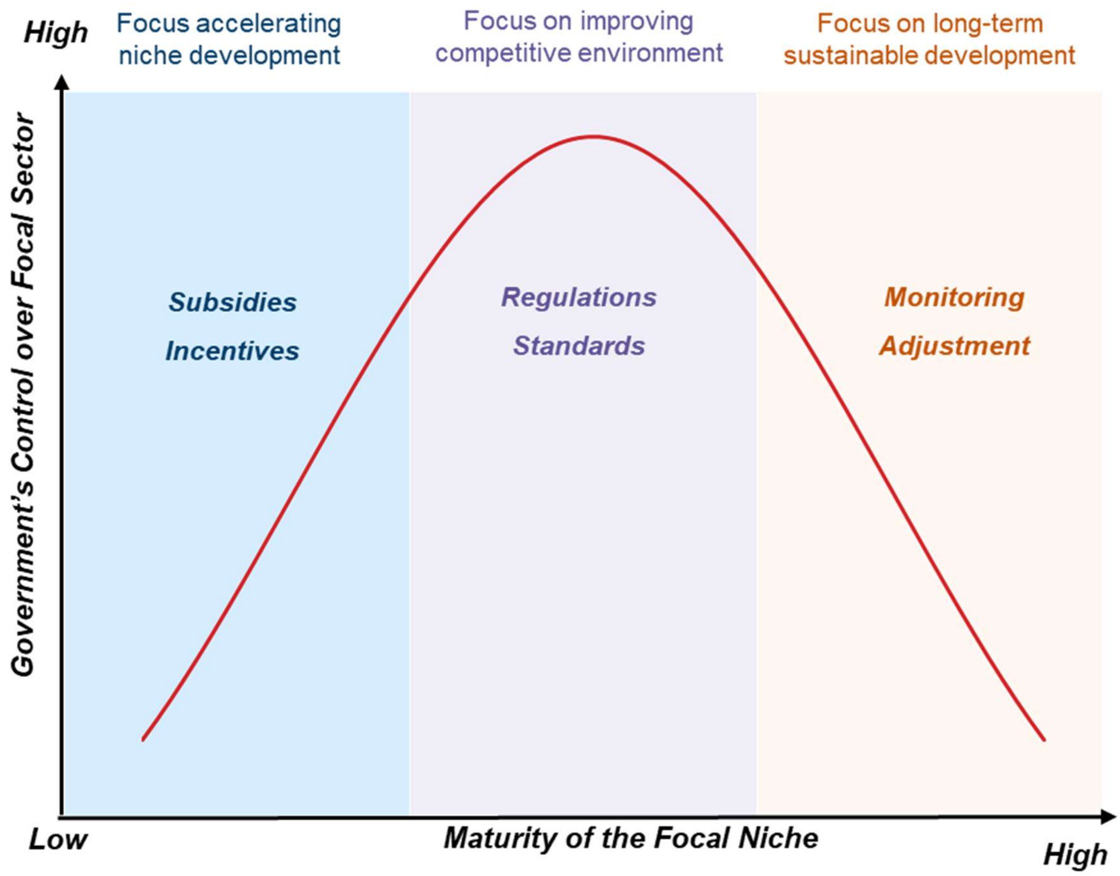

Figure 9-3 The relationship between government focus and maturity of the niche

As the NEV industry matured, there was a strategic shift in government priorities to foster a competitive landscape conducive to the sector's sustainable growth. This transition involved the implementation of more stringent regulations and an enhanced governance framework to guide the sector's developmental trajectory. The government's role transitioned from that of a growth catalyst to a regulatory moderator, underlining its commitment to ensuring the long-term viability and competitiveness of the NEV market.

Subsequently, as the sector transitioned from a niche to an integral part of the automotive industry and the competitive landscape matured, the government began relinquishing some of its control over the NEV sector. It assumed the role of a regulator, maintaining vigilant oversight of the focal sector while offering support and adjusting policies and regulations to further its development, including initiatives to promote internationalisation. This evolving governmental role is a critical aspect examined in this research.

Interestingly, a similar pattern has been identified by an interviewee with experience in the flying car sector in China, albeit with some variations. The Chinese government has also set a clear development direction in this sector and provided substantial financial support. Once a flying car or OEM successfully launches a product, even if it is not yet mature for mass production, that company is designated an industry role model. It gains the privilege of participating in discussions with the government to shape standards and regulations for the sector.

9.2.2 Implications of this pattern and comparing with developed countries

In the above context, it becomes evident that 'speed' precedes China's foremost objective in catching up with global industry leaders as swiftly as possible. This approach is characterised by a 'move first, think and improve later' pattern, markedly distinct from the practices of most developed countries, which typically establish mature standards and regulations before product launches, especially in industries with heightened safety concerns, such as automotive manufacturing. This unique pattern hinges on the considerable authority of the government to allocate substantial resources for development. Consequently, it poses challenges for developed countries, particularly democratic ones, that must consider diverse voices from various parties.

Despite its notable advantages, including an exceptionally rapid pace of development (deemed 'unimaginable' by interviewees) in gaining a leading position in the global NEV market, this pattern has been accompanied by significant challenges and resource inefficiencies during the transition. Many of these issues stem from a lack of early-stage regulations and oversight. Several significant issues identified through the case study and expert interviews include:

- Instances of fraud, where automakers produced uncompetitive or even unsellable products solely to secure incentives.
- A proliferation of start-ups that essentially 'built castles in the air', presenting compelling stories to attract funding or investment without ultimately delivering tangible products.
- Numerous products fail to meet fundamental requirements for being considered 'cars', encompassing quality, safety, and more aspects.

This pattern carries substantial risks. Suppose the initial direction and vision set by the government are misguided. In that case, technological gaps prove impossible, or the sector's rapid growth becomes uncontrollable due to ineffective regulation, the transition is highly susceptible to failure. In such scenarios, the resources invested are squandered, with the potential for more dire consequences if China's economic growth stalls or decelerates. The collapse of the P2P lending sector is an illustrative example of such a failure, where ineffective regulation led to the sector's downfall.

In summary, the Chinese government's approach to industrial development unfolds through distinct stages, from exploration to maturation. Across these phases, the government actively promotes innovation and competition, nurturing the rise of industry leaders who play pivotal roles in shaping industry standards and regulations. This characteristic pattern, often described as 'barbaric growth', transcends the boundaries of the NEV sector and extends to other emerging industries, serving as a testament to China's dynamic approach to fostering innovation and achieving industry leadership. While this pattern carries inherent risks and can lead to resource inefficiencies, it also enables the NEV sector to experience unprecedented growth and secure a leading position in the global market. While this approach may not be directly replicable in developed countries, it offers valuable insights for developing nations seeking to catch up. It is a valuable reference for future researchers investigating Chinese government strategies and policies.

9.2.3 The uniqueness of Chinese consumer engagement in NEV adoption

In addition to the evolving government role in the NEV sector, it is essential to recognise the unique dynamics of the Chinese market that significantly influence NEV adoption. These distinct characteristics have been elucidated through the case study performed in the previous chapter, as well as expert interviews and surveys conducted by reputable consulting firms. An interviewee from a marketing team stated, '*Chinese consumers exhibit a heightened receptivity to innovative products, particularly those incorporating intelligent features, and a strong desire to remain at the forefront of evolving technologies, driven by a fear of technological obsolescence.*' These consumer traits can be attributed to several key factors:

- **Short Car Ownership History**: In China, widespread car ownership is a relatively recent phenomenon, predominantly post-2000. Earlier, vehicles were mainly limited to government officials. This late entry into car ownership means Chinese consumers are less influenced by traditional automotive cultures prevalent in older markets. As Miller (2020) noted, this results in a flexible attitude toward varied car designs and types, reflecting rapid societal changes and a desire to showcase sophistication through vehicle choices. Hence, there is a greater openness to new products and features.
- **Younger Consumers**: Chinese car buyers are younger than their North American and European counterparts, particularly in the NEV segment. For instance, NEV

buyers in North Europe are typically older than those in China. This age difference is significant, with customers in China being approximately 20 years younger than those in Germany, as noted by Hubertus Troska, the President of Mercedes-AMG GmbH (McKinsey, 2019). One interviewee remarked, '*Younger consumers exhibit a pronounced preference for NEVs due to their advanced technologies and the technological positioning of NEV brands,*' a sentiment echoed by several others. Importantly, these younger consumers do not harbour stereotypes that local brands are inferior, making them more receptive to domestic NEV manufacturers.

- **Impacts from the Internet Sector**: The interviews and sector analyses also underscore the profound influence of the Internet sector in shaping consumer expectations and behaviour in China. The digital immersion of the Chinese lifestyle has rendered advanced technology a marker of social standing and sophistication. Integrating NEVs with consumers' digital ecosystems through features enabling V2X capabilities positions these vehicles as transport mediums and extensions of a connected tech-centric existence.

These distinctive characteristics of the Chinese market, characterised by a receptiveness to innovation, a youthful consumer base, and the internet's pervasive influence, collectively contribute to the robust growth and adoption of NEVs in China's automotive landscape. Understanding and leveraging these market dynamics are pivotal for stakeholders in the NEV sector seeking to thrive in this unique and evolving ecosystem.

This section highlights the unique trajectory of China's NEV sector, characterised by rapid scaling and simultaneous development across multiple levels of the socio-technical system. Distinctive features include the pivotal role of local governments in fostering niche innovations, the integration of global and domestic actors, and the influence of external systems like international standards. These findings reveal a unique pattern where accelerated technological adoption and policy support drive transitions, offering valuable insights into socio-technical transitions in developing economies.

9.3 Influence of associated socio-technical systems

As previously emphasised, the Chinese government's unwavering commitment to developing the NEV sector has translated into significant resource allocation in alignment with this national strategic objective. Consequently, various socio-technical systems delineated within the GIESTS Framework have seamlessly integrated into the socio-technical transition trajectory. Notably, China's preeminent position as a leading NEV market has mitigated the influence of peer socio-technical systems, with only a select few entities, notably Tesla, wielding substantial impact.

The composition of these critical associated socio-technical systems has evolved throughout distinct stages of the transition. This section briefly overviews these transformations and their consequential effects on the transition trajectory. However, it is imperative to delve deeper into specific associated socio-technical systems, notably the power battery sector and technology-related sectors such as the internet and telecommunications industries, which have been discussed in the previous section.

9.3.1 Exploration stage

In the initial phase of the NEV sector transition, the absence of essential technologies posed a fundamental challenge, necessitating a focus on science and technology development to establish a solid foundation for future growth. During this stage, academia emerged as a crucial contributor, providing the necessary talent pool, research laboratories, and essential equipment to support these endeavours. Notably, the development of battery technology assumed paramount importance, as elaborated in Section 6.1. At this juncture, the power sector encompassed various stakeholders, including academic institutions, local automakers (mainly state-owned entities), and power battery suppliers.

9.3.2 Pilot-run stage

As pilot-run projects increased during this phase, there was a significant surge in car ownership, resulting in a heightened demand for essential infrastructure, particularly charging stations. The energy sector played a pivotal role in addressing this new requirement. With solid support from local governments, government-owned leading grid companies viewed this period as an opportunity to enhance their significance and challenge the dominant position of energy sector oil companies. These grid companies contributed to constructing necessary infrastructure and actively participated in developing charging standards during this pivotal juncture.

In contrast, oil companies, traditionally regarded as paramount players in the energy sector, also made substantial investments in charging station construction. This differed from the situation in developing countries, where oil companies are often seen as potential impediments to transition due to their vested interests. In this context, the state ownership of these oil companies compelled them to align with the central government’s directives.

The power battery sector continued to play a crucial role in this phase. Despite ongoing performance improvements and reduced power battery costs, which enhanced their competitiveness, the sector played a pivotal role in lowering the overall purchase cost for consumers. This cost reduction bolstered consumer willingness to adopt NEVs, laying a solid foundation for forming the NEV market in subsequent years.

9.3.3 Market formation stage

With over a decade of development and preceding pilot-run initiatives, the Chinese NEV sector had laid a foundational groundwork, albeit still grappling with significant barriers, including high costs and underwhelming product performance, hindering its penetration into the 2C market segment. To address these challenges, NEV manufacturers sought collaborative solutions with other sectors.

In tackling the issue of low product competitiveness, the rapidly advancing telecom and internet sectors offered avenues for enhancing product differentiation. This was achieved by incorporating intelligent features such as virtual personal assistants and augmented reality navigation, albeit at an early stage of maturity and stability. These features bolstered product competitiveness and served as unique selling points, attracting early adopters to the NEV market.

Additionally, automakers forged partnerships with power battery manufacturers, aiming to augment the driving range and performance of NEVs, reduce costs, and enhance price competitiveness. This era witnessed the establishment of several alliances and joint ventures, enriching product competitiveness and bolstering the technological capabilities of power battery suppliers through collaborative technology exchanges with automakers.

However, the emergence of low-speed electric vehicles as a frugal innovation, trendy in lower-tier cities, employed rudimentary technologies, offering little support to technological advancement. This phenomenon cast NEVs in a negative light as inferior products in these regions, potentially impeding the broader transition efforts.

9.3.4 Maturation stage

In the maturation stage, the A.C.E.S. trend continued its relentless growth, transitioning from advanced features for NEVs to becoming essential within the Chinese automotive sector. However, NEVs still enjoyed a competitive edge in this stage due to the nature of being superior carriers of these A.C.E.S. features, enhancing their overall appeal in the market.

This trend impacted product competitiveness during the transition and fostered deeper interactions among the associated socio-technical systems. Key sectors, including the internet, power battery, telecom, energy, and shared mobility, actively engaged with the NEV sector. Collaboration extended beyond technology development, encompassing the deployment of innovative business models.

For instance, in addition to the power battery sector's ongoing efforts to reduce costs and enhance the performance of power batteries to enhance the competitiveness of NEVs and expand the use cases of NEVs from intra-city to inter-city mobility, collaborative partnerships with other sectors, such as the internet, telecom, and energy sectors, have facilitated the integration of resources among these sectors, providing consumers with a seamless charging experience.

These interactions gave rise to novel concepts and innovative business models, leading to the launch of numerous pilot projects. These concepts not only heightened awareness of the NEV sector among Chinese consumers and investors, particularly for local start-ups but also attracted early adopters from the 2C (to-consumer) market seeking unique features and new services. Furthermore, they promoted the 2B (to-business) market by offering extended driving ranges and cost-effective solutions, aligning with the prevailing shared mobility trend in the landscape.

9.3.5 Market reformation stage

This stage can be characterised as the most complex stage in the transition of the NEV sector in China. In addition to the substantial growth and continuous fluctuations in the NEV market, the landscape has introduced challenges to the transition, notably the ongoing US-China dispute. Against this dynamic backdrop, the influence of associated sectors has gained even greater significance, as discussed below.

The expanding market opportunities within the growing NEV sector have lured the internet and telecom sectors, traditionally providers of intelligent features, to deepen their involvement in China's NEV industry. Numerous alliances have been formed, and these companies have moved beyond supplying solutions to automakers, becoming increasingly integrated into the product development process. These firms have sometimes taken the lead in defining product specifications, exemplified by Huawei's role in Arcfox (a BEV brand owned by BAIC) and Seres. Notably, some entities like Xiaomi have ventured to establish their automotive OEMs to compete directly in the 2C market.

With the rising demand for chips in advanced intelligent vehicles, the semiconductor sector has emerged as a pivotal player. However, due to technological disparities and the ramifications of the US-China dispute, semiconductors have become a potential bottleneck in the transition. The progress of the NEV sector could be significantly influenced by the status of development within the semiconductor industry.

The continued significance of the power battery sector, as observed in previous stages, can be attributed to its global leadership in supplying competitive batteries to automakers. This critical role ensures that NEVs can deliver improved product performance, particularly in terms of extended driving range, while reducing consumer purchasing costs concurrently.

9.3.6 Summary of the associated socio-technical system in the transition

Based on the above discussion, we can see that a complex interplay of socio-technical systems and government commitment has shaped the trajectory throughout the five stages of the NEV sector transition in China. The influence of associated socio-technical systems, driven by China's dedication to NEV development, has evolved, as shown in Table 9-2.

Table 9-2 The participation of associated socio-technical systems in different stages

Stage	**Issue encountered**	**Associated Sector**	**Impact**
Exploration	Lack of technology	Academia Power Battery	We are laying the foundation for technological development and infrastructure (positive).
Pilot-run	Lack of infrastructure	Energy	Constructing infrastructure and developing charging standards (positive).
	Low product performance	Power Battery	Reducing battery cost (positive).
Market Formation	Low product competitiveness to attract 2C consumers	Internet Telecom	Providing intelligent features for product differentiation (positive).
		Power Battery	We are reducing costs and enhancing the driving range (positive).
	Demand for low-cost mobility solution	Low-speed EV	Grabbing resources from NEV and decreasing the image of BEV (negative).
Maturation	Limited use cases	Power Battery	Enhancing driving range

			(positive).
	Low product competitiveness compared to ICE vehicles	Power Battery	Battery cost reduction (positive).
		Internet Telecom	Provide intelligent features for product differentiation (positive)
Market Reformation	Increasing demand for NEVs from the market	Power Battery	I can support large quantity requirements with reduced cost (positive).
		Internet Telecom	Participating deeply in the NEV sector to better serve a variety of consumer demands (positive).
		Semiconductor	The inability to support a sufficient number of chips has reduced the production capacity of NEVs (negative).

The table elucidates the variegated roles played by diverse sectors in addressing sector-specific challenges across distinct stages of development. The academic sector has been instrumental in furnishing essential resources for technological advancement. At the same time, the realms of internet and telecom have bolstered NEVs by facilitating product differentiation, thereby augmenting product competitiveness. Notably, the power battery sector stands out for its consistent and pervasive influence throughout the transition.

In sum, this research project delineates the progression of China’s NEV sector, underscoring its evolution as a product of multifaceted interactions amongst socio-technical systems, robust governmental backing, and exogenous stimuli. This convergence has paved the way for an expeditiously transforming and influential market milieu. It is discernible that despite inevitable adversities originating from pivotal socio-technical systems, the overarching impact on the transition remains primarily positive.

9.4 Influence of peer socio-technical systems

While China indisputably occupies the position of the foremost global NEV market, marked by its unprecedented transition pace, it is essential to recognise that this rapid advancement is primarily attributed to internal factors and other domestic contributors, as corroborated by the findings of the case study and insights from expert interviews. Nevertheless, it is imperative to acknowledge the substantial influence peer socio-technical systems exert on the trajectory of China's NEV sector. While not the primary driving force, this influence has significantly shaped the sector's development. This subsection delves into three critical dimensions through which peer socio-technical systems have impacted China's NEV sector, presenting them in chronological order for clarity and comprehensiveness below:

- **Policy Systems in the United States**: The policy systems in the United States, dating back to the 1990s, have served as a point of reference for the Chinese government when formulating its NEV development policies. Notably, policies such as the Corporate Average Fuel Economy (CAFE) standards, aimed at improving fuel economy and reducing vehicle emissions while incentivising NEV production, and California's Zero Emission Vehicle (ZEV) program, which mandated automakers to include ZEVs in their sales portfolios, exerted direct influence on NEV sales. These U.S. policies influenced the policies subsequently enacted by the Chinese government, with the dual credit system emerging as a transformative policy. Several interviewees addressed the pivotal role of the dual credit system in prompting traditional automakers to pivot their strategic direction toward electrification.

- **Tesla Effect**: Tesla's impact on the Chinese NEV sector can be delineated across three phases. In the early 2010s, Tesla's presence on NASDAQ drew the attention of Chinese investors to global NEV developments. Subsequently, in 2014, the launch of Tesla's Model X in China via imports galvanised the domestic investment landscape, spurring increased participation by companies and professionals from diverse industries. Finally, in 2019, Tesla's successful localisation efforts and strong market performance compelled traditional automotive OEMs to incorporate electrification into their strategic plans. While these three phases of Tesla’s influence have been briefly mentioned, a comprehensive analysis of their impact is provided in the preceding section (Section 6.1).

- **Internationalisation of the Chinese Automakers**: Recognizing the stagnation of the domestic automotive market in the late 2010s, Chinese automakers embarked on internationalisation initiatives to explore growth opportunities in foreign markets. This strategic shift has significant implications for the NEV sector, as it brings the Chinese automakers into contact with peer socio-technical systems, particularly the automotive sectors in European markets. During this internationalisation process, European markets have influenced the development of China’s NEV sector in multifaceted ways. They have facilitated the flow of international talent into the Chinese market through market subsidies and have driven Chinese automakers to enhance their fundamental capabilities as automakers, such as quality systems and management processes, to meet European markets' stringent product requirements and standards. These cross-border interactions have thus contributed to the advancement of the Chinese NEV sector.

This subsection highlights three critical dimensions of this influence: U.S. policy systems shaping China’s NEV policies, Tesla’s transformative impact across phases, and Chinese automakers’ internationalisation efforts exposing them to external dynamics, particularly in European markets. These interactions illustrate the complex interplay between local and global factors in advancing China’s NEV sector. Their influences in the five stages of the transition have been summarised in Table 9-3.

Table 9-3 Summary of the impacts of peer socio-technical systems in different stages

Stage	**Peer Socio-technical Systems**	**Impacts**
Exploration	The NEV sector of the	Influence from peer sectors

	California state government	informed governmental guidance and shaped associated sectors' engagement.
Pilot-run	The NEV sector of the California state government	Continued government-to-sector influence mirroring exploration phase.
Market Formation	Tesla (from the NEV sector in the United States)	Demand for intelligent features fostered by Tesla's product strategy involved associated sectors more actively and grabbed potential investors' attention.
Maturation	Tesla (from the NEV sector in the United States)	New standards and feature expectations set by Tesla influenced the product landscape and sector engagement.
Market Reformation	Tesla (from the NEV sector in the United States)	Tesla's market success and stringent standards prompted increased capability development in Chinese supply chains.
	The NEV sector of the European countries	Chinese automakers' European expansion necessitated product alignment with European standards and demands.

9.5 The dynamics between peer and associated socio-technical systems

The central premise of my thesis has underscored domestic factors as primary catalysts for China's emergence as a global leader in the NEV market. Yet, it is indispensable to recognise the significant role peer socio-technical systems play. This interaction extends beyond China's automotive industry, being reciprocally influential with the peer systems that have been instrumental in this domain's evolution.

China has markedly leveraged its national strategy to elevate the NEV sector, mobilising extensive resources and ensuring comprehensive sectoral engagement since the early 2000s. This resolute involvement is predominantly ascribed to governmental initiative and guidance. In the face of limited Indigenous experience and technology in the NEV domain, China has drawn on the experiences and advancements from peer socio-technical systems, shaping its strategic vision and influencing the related industry’s trajectory through governmental policy directives.

The advent of Tesla in the mid-2010s precipitated a new phase of development within China’s NEV sector, spurring heightened awareness and surging investments. This led to increased sectoral development velocity and diversified sector participation, with certain entities transitioning into NEV manufacturing. A notable example is UC’s founding team (a leading web browser in China), which, after integration with Alibaba, directed significant investments into XPeng Motors, illustrating the sector’s transformative cross-sector dynamism.

Interview findings highlighted Tesla’s role in redefining product concepts, focusing on intelligent vehicle features. This redefinition spurred demand for such innovation, thus involving the internet and telecom sectors more deeply in the NEV transition to meet these new automaker requirements.

As the decade drew to a close, Tesla’s successful market assimilation and the demonstrated profitability of NEVs swayed even traditionally cautious manufacturers toward electric vehicle production. This shift signalled a broader industry trend, with various sectors initiating a ‘cross-industry car building’ phase. Notably, companies like Xiaomi aligned their strategies to reflect the extensive potential seen in this market. The stringent quality benchmarks set by Tesla’s supply chain localisation also compelled Chinese suppliers, particularly in the power battery domain, to escalate their capabilities.

Additionally, with concerted efforts to penetrate European markets, Chinese NEV makers’ push for international presence initiated complex inter-industry engagements. These efforts have necessitated that the ancillary sector, including power battery and internet services, reassess and upgrade their offerings to comply with the stringent European market standards and consumer expectations. Table 9-4 summarises these interactions.

Table 9-4 Interactions of peer and associated socio-technical systems across NEV development stages

Stage	Peer Socio-technical Systems	Associated Socio-technical Systems	Influences
Exploration	The NEV sector of the California state government	Academia sector Power battery sector	Peer systems experience informed policy and strategic direction, influencing associated sectors.
Pilot-run	The NEV sector of the California state government	Energy sector Power battery sector	Continuation of strategic guidance and influence from the exploration phase.
Market Formation	Tesla from the USA's NEV sector	Internet sector Telecom sector	Tesla's product innovation created new market demands, integrating associated sectors.
Maturation	Tesla from the USA's NEV sector	Internet sector Telecom sector	Tesla's product leadership redefined sector expectations, encouraging wider industry adoption.
Market Reformation	Tesla from the USA's NEV sector	Power Battery sector	Tesla's performance and standards drove sectoral upscaling.
		Telecom sector Power battery sector	The recognition of profitability from Tesla's success catalysed various sectors to engage in the NEV transition.
	The NEV sector of the European countries	Internet sector Telecom sector Power battery sector	International market expansion influenced alignment with global standards.

Finally, it is imperative to acknowledge that the external socio-technical systems and their dynamics delineated in this research project represent key elements identified through the GIESTS Framework and expert interviews. This compilation does not constitute an exhaustive list, and other external factors that could influence the transition may exist, warranting further exploration in future research endeavours.

The findings of Sections 9.3 to 9.5 underscore the critical role of the GIESTS Framework in analysing the influence of external socio-technical systems and their interactions with peer systems. The framework reveals dynamic feedback loops, such as how advancements in battery technology are amplified by concurrent developments in charging infrastructure, accelerating the transition's pace and scope. The GIESTS Framework bridges a critical gap in the literature by addressing the often-overlooked role of external systems. It enhances scholarly understanding of how cross-system dynamics shape socio-technical transitions, particularly in rapidly evolving contexts like China's NEV sector.

9.6 Summary: the interactions between layers of the GIESTS Framework

In Section 6.1, I initiated the discussion by identifying the key actors involved in various stages of the transition. This identification was based on a case study conducted within the GIESTS Framework. After this, I further discussed these actors, elucidating their significance, behaviours, activities, and roles during the transition trajectory. Moreover, I addressed the pivotal factors essential to developing the NEV sector. The primary findings from the case study chapter have been briefly summarised and discussed in this section.

In Section 6.2, I explored the interplay between peer and associated socio-technical systems and the interactions between external and internal socio-technical systems and the broader landscape. I have incorporated the following figure to encapsulate prior discussions and present a comprehensive view of the transition, emphasising the interactions across different layers. This visual representation presented in Figure 9-4 serves as a synopsis of the research project and is instrumental in validating the conceptual figure delineated for the GIESTS Framework.

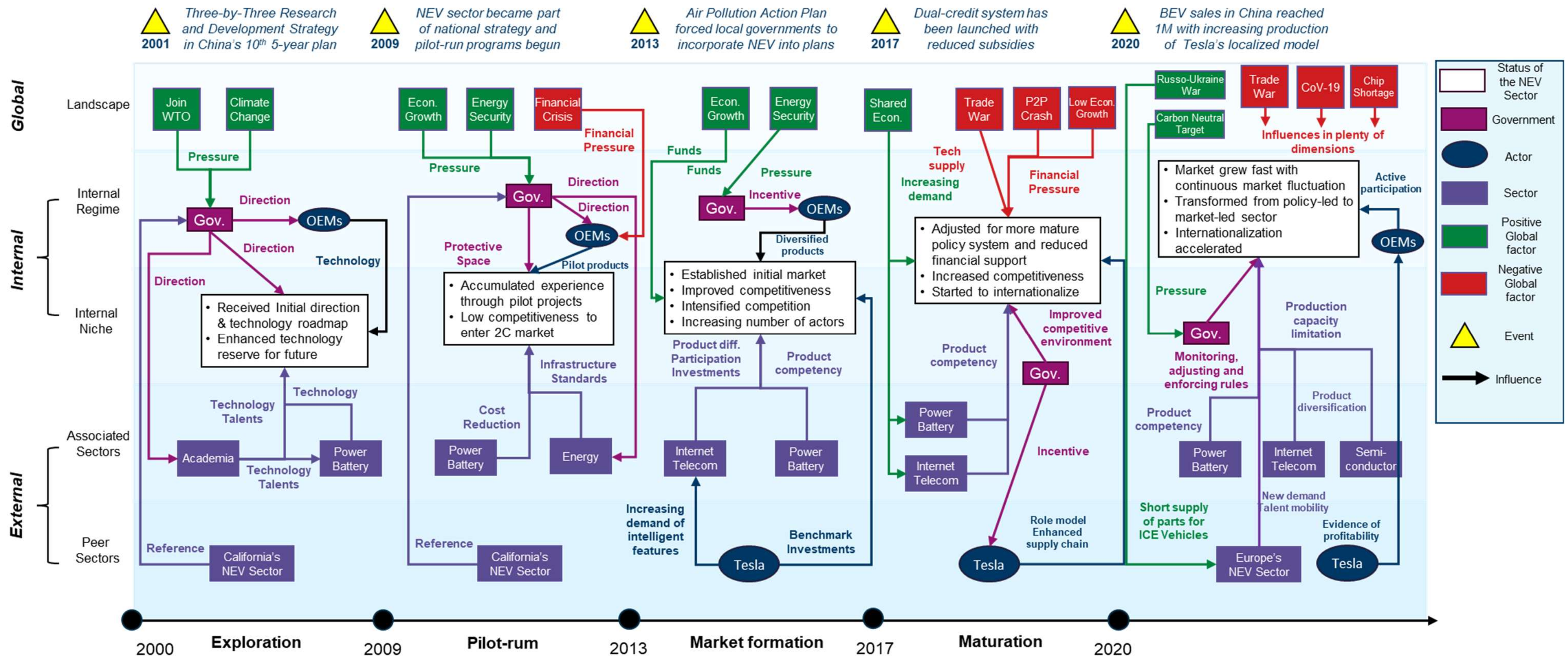

Figure 9-4 Summary of the interactions between different layers of the GIEST framework

From the preceding figure, it becomes clear that China's accession to the WTO and the burgeoning international discourse on climate change prompted the Chinese government to focus strategically on the NEV sector—this decision aimed to position China competitively in the global market and address climate change challenges. Initially, the government's role was crucial in directing the NEV sector's vision, aligning with academia and the power battery industry, and leveraging insights from peer socio-technical systems in the United States.

During the sector's formative stage, selected local automakers, particularly the state-owned ones, and associated socio-technical sectors like academia and the power battery sector collectively contributed to technological advancements under governmental direction. This phase was marked by governmental initiatives establishing pilot projects and allocating substantial policies and subsidies to create protective niches for NEVs. Despite the financial crisis and mounting energy dependence, these efforts underscored the government's commitment to transitioning towards NEVs.

In the pilot-run stage, chosen automakers began producing pilot NEV models, aligning with government directives. The energy sector collaborated with the government to develop NEV charging standards and infrastructure, while the power battery sector focused on reducing battery costs. However, the products remained non-competitive, necessitating continued governmental protection.

By the market formation phase, the government's strategy shifted to enlarging the market base through financial support to automakers and related socio-technical systems. The entry of Tesla into the Chinese market catalysed this process, reshaping consumer expectations and attracting substantial investments. The advent of Tesla not only intensified market competition but also elevated demand for advanced features like intelligent cockpits and autonomous driving. In response, sectors like telecom and internet actively engaged in the NEV domain, investing in startups, forming alliances, and even launching NEV companies.

In subsequent stages, the government’s role evolved from foundational support to fostering sustainable growth and strategic alignment with broader objectives. This included incentivising Tesla’s localisation in China, demonstrating the sector’s potential and heightened supply chain competitiveness. The international expansion of Chinese automakers into European markets further stimulated cross-border interactions, enhancing the sector’s dynamism.

The final stages saw continued support from the power battery, internet, and telecom sectors, diversifying product offerings to meet diverse consumer needs. However, the semiconductor sector’s supply shortages posed a challenge to market expansion. Complex domestic and international dynamics, such as the US-China tensions and the Russo-Ukrainian War, compounded by the COVID-19 outbreak and economic slowdown, introduced new complexities to the sector’s transition.

Despite these challenges, the NEV market witnessed rapid growth. It evolved from a niche to a significant part of the automotive regime, transitioning from a policy-led to a market-driven sector. Table 9-5 outlines the roles of these layers throughout the transition, complemented by the GIESTS Framework and the government’s evolving role.

Table 9-5 Summary of the roles of different layers and the government in the transition

Level	Global		Internal		External		Role of Government
Sub-level	**Positive**	**Negative**	**Niche**	**Regime**	**Peer**	**Associated**	
Exploration	• Joining WTO	n/a	Initial direction and technology roadmap. Enhancing technology reserve for the future.	Supporting technology based on the government's direction.	• Providing references for the government and associated sectors.	• Supporting the development of required technologies for future development.	Initiator
Pilot-run	• Energy dependency • Growing economy	Financial crisis	Pilot-run projects to accumulate experience. Establishing a foundation for future development.	Participating in pilot-run projects by providing pilot products based on the government's direction.	• Providing references for the government and associated sectors.	• Supporting the niche to build foundations for future development, including infrastructure and technology.	Protector and Incubator
Market Formation	• Energy dependency • Growing economy	n/a	Establishing initial market. Improving product competitiveness. Intensive internal competition.	Providing more products to the market to enhance product diversity.	• Providing references for the niche and generating new market demand for associated sectors.	• Providing intelligent features for product differentiation. • More actors to invest and actively participate in the	Catalyst

						niche.	
Maturation	• The boom of the shared economy	• Low economic growth • US-China trade war • P2P crash in China	Improving the competitive environment. Maturing policy systems, standards, and regulations. Enhancing the overall competitiveness of the sector.	Local traditional automakers have switched strategies to participate actively in the transition.	• Serving as a benchmark for local automakers and associated sectors. • Providing evidence of market opportunities for traditional automakers.	• Providing intelligent features and reducing costs for further product competitiveness enhancement.	Facilitator
Market Reformation	• Carbon neutrality focus • Russo-Ukrainian war	• US-China dispute • Russo-Ukrainian war • Chip shortage • CoV-19	Ensuring sustainable development. Transforming the sector from policy-led to market-led. Accelerating internationalisation.	Most traditional automakers are shifting their direction towards NEV. The NEV sector has become part of the regime.	• Improving the competitiveness of the supply chain. • Actively interacting with the EU through internationalisation.	• Providing a diverse range of products through active participation in the product development process. • Weaker sectors may limit the capacity of the NEV sector.	Regulator

Broadly, the GIESTS Framework has illuminated the overarching trajectory of China's NEV transition, offering a comprehensive lens to analyse its complexities. Insights from the case study, enriched by expert interviews and structured within the framework, not only addressed the research questions but also uncovered more profound revelations, such as the pivotal roles of government, the distinctive growth pattern, and the intricate interlayer dynamics shaping the transition. This section will further evaluate the efficacy of the GIESTS Framework, discussing its strengths, limitations, and broader implications for advancing the study of socio-technical transitions.

9.7 Research implications

At this juncture of the research, I have concluded a comprehensive case study utilising the GIESTS Framework. The study leveraged secondary data sources and participatory observation methods to dissect the environmental influences, principal actors, and sectors across the five developmental stages identified within the NEV sector. This section fulfils a dual objective: critically appraises the GIESTS Framework's utility against the initial research queries, evaluating its robustness in conceptual analysis. Concurrently, it underscores this study's substantial academic and practical contributions, emphasising its scholarly and sectoral significance.

In the following discourse, the methodological application of the GIESTS Framework to the research questions will be meticulously examined. The discourse will outline this study's distinctive insights into the academic field and its operational impact on the NEV sector's evolution in China. Furthermore, this section will provide a candid account of the research limitations and chart prospective research directions, pinpointing unexplored territories that warrant academic attention.

9.7.1 The answers to the research questions

Let's revisit the research questions identified in Chapter 3:

- What are the primary sectors, actors and factors responsible for the evolution of China's NEV sector from a niche entity to a dominant force within the automotive sector between the early 2000s and the early 2020s?
- Why are these sectors, actors and factors influential in driving this transition, and how do they shape and impact the trajectory of this transformation?

I crafted the GIESTS Framework to address these inquiries, leaning heavily on MLP, SNM, and multi-scalar MLP paradigms. While the MLP supplied a foundational structure, encapsulating the regime, niche, and landscape layers, the SNM sharpened the niche's definition. The multi-scalar MLP introduced a spatial facet to the GIESTS Framework. Recognising the intricate fabric of the Chinese market and its automotive sphere, I introduced the 'global, internal, and external' dimension for a nuanced categorisation of diverse elements and sectors and their corresponding actors across various transition strata. The 'peer and associated' concept was incorporated to pinpoint sectors from the external spectrum more adeptly.

I partitioned the transition arc into stages in the next phase, drawing insights from governmental documents, observatory findings, and pertinent scholarly works. This distinction underscores the distinctive features of each phase, which were subsequently refined and honed based on expert dialogues. Employing the GIESTS Framework to these demarcated stages facilitated the recognition of salient sectors, their primary stakeholders, and overarching environmental forces linked to the transition. Chapter 5 (case study) sheds light on the interrelationships of these discerned entities and the transition, juxtaposing case study outcomes with insights from expert consultations. The pivotal sectors and stakeholders were pinpointed in Section 6.1, alongside a comprehensive analysis of their bearing on the transition's trajectory.

Delving deeper into Chapter 7, I explored the evolution trajectory, contrasting the governmental roles in China with those in developed nations, identifying the distinct blueprint of new sector maturation and consumer behaviour in China, and illuminating the intricate interplay between external and internal socio-technical frameworks. This was supplemented with insights into the interaction dynamics across various external socio-technical systems and persisting impediments constraining further transition. A bird's-eye view of the desired socio-technical shift elucidates the interwoven dynamics across various layers and their influence on the transition's path.

The potency of the GIESTS Framework becomes evident as a tool for discerning pivotal transition agents and evaluating their transition impacts. Harmonised with expert dialogues, this conceptual scaffold proves instrumental for dissecting intricate socio-technical shifts, particularly in burgeoning markets, wherein external elements wield significant influence. Moreover, the RCA Framework has helped to explain the firm-level phenomena that happened with the sectoral transition.

We could find the efficacy of the GIESTS Framework to help us identify the influential participants in the transitions and their impacts on the transition. Combined with the expert interviews, the conceptual framework is robust in helping researchers analyse complicated socio-technical transitions, especially in emerging markets where many external factors have impacted the transition.

9.7.2 Implications of research

This research, delineated in Chapter 3, was committed to bolstering the concept of MLP through the inception of a pioneering framework designed to encapsulate interactions across transition strata. This enhancement was attained by weaving internal and external dimensions and peer and associated dynamics into the extant MLP. A prominent goal was to dissect the socio-technical shift towards electrification chronologically. As elucidated earlier, these aspirations were realised through the GIESTS Framework and an expansive case study. Herein are the salient contributions of this research:

- **Extend the Scope of MLP to Explore Better Intricate Socio-technical Transitions**: The GIESTS Framework was developed to analyse intricate socio-technical transitions, particularly those influenced by external socio-technical systems. It is well-suited for countries like China, where a powerful government can allocate significant resources to drive the transition, and various sectors and actors have participated. Moreover, the framework is intentionally designed to be flexible, allowing for modifications to meet the needs of other researchers or practitioners seeking a deeper understanding of complex transitions. Detailed information about the GIESTS Framework can be found in Chapter 3.
- **Determination of the Sectors, Actors, and Factors Integral to China's Electrification Transition and Their Influence on its Trajectory:** Leveraging the GIESTS Framework, the research identified sectors, actors, and environmental factors that could impact the targeted socio-technical transition at different stages. Furthermore, with the assistance of expert interviews, the study distinguished the most influential entities among those identified by the GIESTS Framework. Further details can be found in Chapter 5 and Section 6.1.
- **Illuminating Interplays Among These Sectors, Actors, and Elements and Their Pivotal Role in Shaping the Targeted Socio-technical Transition:** After identifying crucial sectors, actors, and global factors relevant to the targeted socio-

technical transition, the research delved into how these entities interacted and shaped the transition trajectory. This provided more profound insights into the successful transition of the Chinese NEV sector. Some interactions identified were rarely discussed in previous studies, such as those between peer and associated socio-technical systems and their impact on the targeted transition.

- **Highlighting the Distinctiveness of the Chinese Market**: The case study findings were analysed to identify the Chinese market's unique aspects, including the Chinese government's distinct role compared to developed countries, the unique characteristics of consumers and the transition trajectory of innovative sectors in China. Such findings provide valuable reference materials for researchers delving deeper into transitions in China and offer insights for decision-makers considering market entry into China.
- **Offering a Comprehensive and Sequential Perspective of China's Electrification Transition and Interlayer Interactions**: In Chapter 6, the entire transition trajectory from the early 2000s to 2022 is summarised in a figure. The interactions between different layers and how they influence the transition trajectory are highlighted and discussed. Such a comprehensive presentation of the transition trajectory helps address a gap in the literature on the Chinese NEV evolution, where interactions between layers and a holistic view are rarely found.
- **Extraction of Transition Insights from Participatory Observations and Industry Expertise**: A distinctive aspect of this research project is the author's eight years of industry experience in strategy planning-related roles and interviews with industry veterans who hold significant roles in various automakers. This differs from most similar studies that primarily rely on secondary data. Participatory observations and insights from these senior practitioners have allowed for a deeper understanding of the transition, including the impact of policies on decision-making and the interactions between automakers and external

sectors. Combined with the proposed conceptual framework, these insights enhance the research project's ability to generate valuable insights.

In summary, this research project augments the theoretical underpinnings of socio-technical transition studies, especially within the multi-level perspective. The conceptual framework has been crafted as a solution to the research questions posed in this study and as a tool for future researchers and professionals examining other complex socio-technical systems. Additionally, the study furnishes a thorough understanding of the focal socio-technical transition, enriched by insights from expert interviews and eight years of participatory observations. These insights, which include decision-making rationales of automakers and pivotal moments in the transition, are invaluable to researchers, industry strategists, policymakers, and governmental bodies alike.

9.7.3 Limitations of the research project and suggestions for future research

While this research project has endeavoured to be as detailed and comprehensive as possible, it remains infeasible to encompass all nuances of the discussed socio-technical transition. Furthermore, although the expert interviews aimed to garner perspectives from a diverse range of practitioners, our connections fell short in securing inputs from employees of the Chinese government, mainly due to confidentiality concerns. As a result, the interviewees are comprised solely of employees spanning various automaker categories: start-ups, state-owned entities, local private firms, and local start-ups. These interviewees predominantly occupy managerial to senior positions within their respective organisations. It is essential to note that while the myriad results obtained using the GIESTS Framework underscore its proficiency in analysing the chosen socio-technical transition, this does not necessarily attest to its universal applicability. Subsequently, I will present the four principal limitations of this research endeavour.

- **Lack of Insights from the Chinese Government**: One of the primary limitations is the absence of direct insights from government representatives. Given the pivotal role of the Chinese government in guiding and shaping socio-technical transitions, especially in the realm of electrification, such insights would have added depth to the study. While the perspectives of automakers offer significant value, the views of government employees would have enriched the understanding of policy decisions, regulatory shifts, and strategic priorities that played an influential role in the transition.
- **Lack of Deep-Dive Analysis of Individual Sectors**: The research project provides a holistic view of the socio-technical transition, covering various sectors, actors, and the global factors which could impact the targeted socio-technical transition. However, the study did not delve into a deep-dive analysis of each sector. A more granular exploration could have unravelled nuanced dynamics and relationships specific to individual sectors or actors, further illuminating their roles in the transition.
- **The GIESTS Framework Requires More Empirical Studies for Broader Applicability**: While the GIESTS Framework has demonstrated its efficacy in analysing China's electrification transition, its applicability to other socio-technical transitions remains to be seen. The framework's broader validity would require empirical testing across various contexts, sectors, and regions to ascertain its universal relevance and potential areas of refinement.

Potential trajectories for future research might encompass the following based on the identified limitations:

- **Zooming into Specific Phases**: One of the discerned stages could be singled out for in-depth exploration, potentially revealing intricate details and richer insights into the specific nuances of that phase.

- **Reassessing from Varied Perspectives**: The transition could be re-examined from alternative standpoints, such as that of governmental bodies. Such a shift in vantage point might unveil different facets or challenges not captured in the initial analysis.
- **Comparative Case Studies**: Undertaking comparative studies between different socio-technical transitions within China or comparing the same transition across various nations could elucidate the adaptability and robustness of the conceptual framework. Such comparisons would also highlight the peculiarities of different contexts and the framework's efficacy in navigating these variances.

While the current research project has shed considerable light on China's electrification trajectory, the road ahead beckons opportunities for more prosperous, more granular insights that can further fortify our understanding of such socio-technical transitions.

9.8 Conclusion

This research embarked on a quest to unravel the intricate dynamics and nuances underlying China's socio-technical transition toward electrification within its automotive sector. Employing the innovative GIESTS Framework, primarily extended from the concept of the MLP, this study provides a panoramic yet meticulously detailed view of the complex nature of this transition. By employing a meticulous blend of qualitative and quantitative methods, complemented by participatory observations and expert interviews, this research weaves a rich tapestry of insights that contribute significantly to our comprehension of socio-technical transitions within the context of China and its external influences. Moreover, the PCA Framework has been adopted for analysing firm-level transition, providing further insights that complement the results of the GIESTS Framework, which primarily focuses on sector-level transition.

Several vital contributions have emerged from this research endeavour. Firstly, the GIESTS Framework has proven invaluable, not only in the context of this specific study but also as a versatile tool that can aid other researchers navigating similar terrain. Secondly, the study has illuminated the pivotal roles played by various sectors, actors, and external influences in shaping the trajectory of electrification in China. Thirdly, by delving into interactions across multiple layers, this research offers a nuanced understanding of the systemic interplays propelling this transition forward.

Nevertheless, as is the case with any academic undertaking, this research project has its limitations. While these constraints have been duly recognised, they also serve as beacons guiding potential avenues for future investigations. Whether through the adoption of alternative theoretical frameworks such as dynamic capabilities to address firm-level evolution paths, a deeper exploration of specific transition phases, conducting comparative studies to refine the framework through additional empirical studies, or examining the subject from varied perspectives, the horizons for further research are vast and inviting.

Beyond its academic merits, this research bears profound real-world implications. By unravelling the unique characteristics of the Chinese market, the role of its government, and the dynamics among various stakeholders, the findings offer invaluable insights for policymakers, industry strategists, and prospective market entrants.

The socio-technical transition toward electrification in China is not merely a study of technological advancements but a testament to the harmonised interplay of societal, political, and economic forces. As the world stands at the precipice of numerous such transitions, whether in the realms of energy, urban planning, or transportation, the insights gleaned from this research hold the potential to inform and inspire actions across borders.

In conclusion, this thesis stands as a testament to the power of interdisciplinary research, exemplifying how the fusion of diverse perspectives can offer a holistic view of complex phenomena. Gazing toward the future, I hope that such comprehensive insights will continue to guide our endeavours, making transitions smoother and more sustainable for all.

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