# REGIME CONFLUENCE IN SOCIO-TECHNICAL TRANSITIONS:

## A STUDY OF CONNECTED, AUTONOMOUS, SHARED AND ELECTRIC VEHICLES

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# ABSTRACT

This PhD research aims to investigate sustainable future automobility by using socio-technical transitions theory (STT). Automobility plays multi-functional roles in society not only as commuting tool but also serving tool for serving higher quality of life, freedom of movement, and increasingly is associated with environmentally friendly concepts. This emergent form of automobility integrates many aspects ranging from connectivity (C) between vehicles and to everything else, to vehicle automation (A), car sharing (S), and electronic powertrain (E), which ultimately may combine to provide automobility as an on-demand service. Therefore, these so-called 'CASE' (connected, autonomous, shared, electric) vehicles bridge automobility freedom of movement in physical 'limited' spaces with 'unlimited' virtual spaces into one seamless experience, fundamentally transforming the meaning of automobility. Hence, this research has the following issues to address: is it possible for the four features (CASE) to combine? If this becomes a prevalent trend, could they redefine automobility, and with what consequences?

To answer the relevant research questions, mixed data collective methods have been conducted. In which, secondary data extracted mainly from governmental documents, companies' official webpages, professional online websites, and the grey literature. Meanwhile, primary data via interviews are used to further verify the cases' validity. Hence, 340 instances of CASE developments identified during the research have been collected to construct an empirical storyline supplemented with 33 in-depth interviews. Additionally, we have highlighted 7 corporate cases in the traditional automotive industry and 4 outsiders to illustrate the CASE transformation process.

The main findings are: 1) network theory could supplement STT to provide insights into the relationships between 'niche' areas and the 'regime'; 2) regime boundary dissolution and network reintegration help new niches emerge at regime level; 3) CASE concepts have allowed 'outsiders' to challenge automotive OEM incumbents; and 4) the automobility transformation pathway is following 'dealignment - realignment' pattern.

The thesis concludes many individual initiatives have failed but some remain, finding a development path for a multiplicity of reasons (political, market-driven, corporate strategy or environmental requirements). These half-mature niches and networks will finally challenge existing rules and regulations and thus push society and technology forward to reach to another 'balance'. However, to reach a new 'balance' is a huge challenge that requires to leverage different stake holders such as environment sustainability, policymakers, customers and of course car manufacturers.

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## LIST OF ACRONYMS

| | |
|---|---|
| **ACEA** | European Automobile Manufacturers Association |
| **ACRA** | American Car Rental Association |
| **ADAS** | Advanced Driver Assistance Systems |
| **AFI** | Alternative Fuels Infrastructure |
| **AI** | Artificial Intelligent |
| **BAIC BJEV** | Beijing Automotive Industry Co. Beijing Electric Vehicle |
| **BEV** | Battery Electric Vehicles |
| **CAAM** | China Association of Automobile Manufacturers |
| **CASE** | Connected, Autonomous, Shared and Electric vehicles |
| **CATL** | Contemporary Amperex Technology (China) |
| **CCAV** | Centre for Connected and Autonomous Vehicles (UK) |
| **CCC** | Committee on Climate Change |
| **DARPA** | Defence Advanced Research Projects Agency |
| **DCMS** | Department for Digital, Culture, Media and Sport |
| **DfT** | Department for Transport (UK) |
| **DoT** | US Department of Transportation (US) |
| **DPF** | Diesel Particulate Filter |
| **EU** | European Union |
| **EFTA** | European Free Trade Association |
| **FCA** | Fiat Chrysler Automobiles |
| **FPF** | Future of Privacy Forum |
| **GAC** | Guangzhou Automobile Group Co Ltd (GAC Group) |
| **GCCA+** | Global Climate Change Alliance+ |
| **GCF** | Green Climate Fund |
| **GM** | General Motors |
| **GV** | GV Automobile Technology (Ningbo) Co. Ltd |
| **HEV** | Hybrid Electric Vehicle |
| **ITF** | Corporate Partnership Board of the International Transport Forum |
| **IoT** | Internet of Things |
| **JLR** | Jaguar Land Rover |
| **JV** | Joint Venture |
| **LiDAR** | Light Detection and Ranging |
| **MaaS** | Mobility-as-a-Service |
| **MLP** | Multi-Level Perspective |
| **MOSI** | MOS Intelligent Connectivity Technology Co. Ltd. |
| **MoU** | Memorandum of Understanding |
| **MSPF** | Mobility Services Platform |
| **NBM** | (International Conference on) New Business Models |
| **NCSL** | National Conference of State Legislatures |
| **NEV** | New Energy Vehicles (China) |
| **NEVS** | National Electric Vehicle Sweden |
| **NHTSA** | National Highway Traffic Safety Administration |
| **NPF** | National Policy Framework (EU) |
| **OEM** | Original Equipment Manufacturer |
| **O2O** | Online-to-Offline service |
| **PHEV** | Plug-in Hybrid Electric Vehicle |
| **QDI** | Quasi-Diagonal Integration |
| **REF** | The Regime Evolution Framework |
| **REM** | Road Experience Management |
| **RQ** | Research Question |

| | |
|---|---|
| **R&D** | Research and Development |
| **SMMT** | Society of Motor Manufacturers and Traders (UK) |
| **STRN** | Sustainable Transitions Research Network |
| **STT** | Socio-Technical Transitions Theory |
| **UK** | United Kingdom |
| **UN** | United Nations |
| **UNCTAD** | United Nations Conference on Trade and Development |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **USA** | United States of America |
| **V2G** | Vehicle to Grid |
| **VW** | Volkswagen |
| **WCC** | World Climate Conference |
| **WMG** | Warwick Manufacturing Group |

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# Chapter 1

# Introduction

The first chapter displays a general conceptual framework of entire thesis. It includes the process of lifting the research questions, the motivation and allocation of research arena -- the automobility and socio-technical transitions theory, and a basic outline of each chapter.

## 1.1 Research Background

For decades, there has been an increasing investment in technology research and development, culminating in the applications of innovation in daily life that make life easily accessible. Vehicle is one of the consequences of such highly technological development, it performs a special role in both personal and business mobility. The systems onboard vehicles have steadily been upgraded over a century that becoming safer, smarter, and more functional. In which, a particular interest on future highly automated and connected vehicles has been focused in recent years. This is not only an automobile system upgrading process, but also likely to change travellers' commuting habits and broader attitudes to mobility. Building autonomous vehicles is expected to reshuffle the structure of the automotive industry and constitution an innovative threshold for all players no matter whether traditional car manufacturers or new entrants.

To achieve a sustainable future, the change in the transportation sector is needed. Technology helps the transformation ranging from energy consumption alternation, in-/inter- car Internet connectivity, to users' preference, ownership and adoption. These assumptions were introduced by Daimler in 2016 to develop the availability of CASE vehicles. Which means, a vehicle that carries functions of connectivity (C) autonomous (A) sharing (S) and electric (E) (Daimler 2016).

How these four elements emerged over last decade, and to be integrated as one is very interesting. Electric powered vehicles have been developed even before the fuel powered vehicles were created. The immature technology of the battery was the biggest drawback so that it gave a chance to develop fuel powered vehicles. Even to date, it is still costly which impels users to choose fuel powered vehicles in terms of the integration of battery package. The thriving future of fuel powered vehicles have been finally interrupted again by electric powered vehicles as the issues in battery technology have been gradually solved. Around 2009, many companies claimed to that future vehicle market would be electric-powered. Some companies such as Tesla insist that electric vehicles are the future of the automobile industry, this becomes a catalyst to introduce electric vehicles into mass market.

Meanwhile, the Internet has become widely used, so vehicles cannot be an exception that lack connectiveness. Therefore, the connection between vehicles, or vehicles with other infrastructures, need to be highly developed to maintain connectivity and share data dynamically. The advanced usage of connectivity is in automation. The connectivity system could be controlled remotely, i.e. with no driver in the car. As a result, the system acts as the remote driver through acquired data. In addition, military autonomous vehicles were highly developed and that helped to apply autonomous technologies into the commercial vehicle context to deal with more complex terrain. It is worth noting that the autonomous and connected vehicles are recognised as the outcomes of intelligence of Internet and technology in the millennium.

Sharing platforms have become popularized from around the same period in 2009. Taxi and vehicle renting were the original ways of vehicle sharing. Ride and vehicle hiring/sharing further applies an extension that offers vehicle and ride sharing through an automobile platform. This transforms mobility from public to private, from off-line to on-line, from fixed to be more flexible.

Therefore, the four elements were strongly under development, especially 2009 onwards after the economic crisis and the recognition of sustainable development. The CASE vehicle needs to be integrated inevitably as a special topic to investigate the possibility and capability of future sustainable transport transition.

Meanwhile, there is a growing literature on socio-technical transitions theory (STT) in all scientific areas. The evolution of transportation offers an interesting example to explain how this theory works. The theory framework has explored macro, meso and micro levels how long-term stable elements such as political systems, and daily based societal dynamics interact with niche social-technical innovations. It also could narrow down to a single case with one or more elements to explain how the pressure, opportunities and failures can be analysed with the theory. Nevertheless, socio-technical transitions are mostly applied in the archival or historical cases, there is a relative lack of research on future dynamics of ongoing events.

Therefore, under this circumstance, the main purpose of this research is analysing connected, autonomous, shared and electric vehicle (CASE) in socio-technical transitions theory, to explain 1) how far STT is useful to analyse the future dynamic of unpredictable, 2) to what extent will convergence of the CASE elements create a new form of automobility and 3) to what extent is it possible to sustainability transform transportation system to a future mobility as a service.

Overall, the research on socio-technical transitions theory in CASE will address the following questions during the research procedure:

**RQ: How far can STT theory help in explaining the emergence and future prospects of CASE vehicles?**

a) To what extent are connected, autonomous, shared, and electric technologies, integrated into one vehicle, to be commercially released on the mass market from around 2020?

b) What are the potential business challenges pertaining to the integration of CASE technologies in one vehicle?

c) Any supplementary theories needed beyond STT to explain how these CASE technologies have been developed and brought to the market?

Broadly speaking, the underlying interest is to understand how far these new forms of mobility contribute to enhanced sustainability, and whether new sub-cultures, behaviours and attitudes emerging around these new technologies?

## 1.2 Research Motivation

A detailed literature review will be expanded upon in the Chapters 2 and 3, while here I would like to highlight why this research is grounded in the empirical domain of the automotive industry. Undoubtedly, the first reason is that this is a highly relevant area for the study of technological change, and a natural extension of my precious studies in Transportations and in Logistics and Operations Management. The more I have learned, the more I realized empirical domains may have similarities no matter whether in supply chain management, or transportation, or technology management: there is a need to address business, social and environmental issues, find better solutions and achieve better results. All these contributions intend to build a harmonious future through a path of 'sustainability' even with a micro change. This is a colossal task but can also be very specific topic, can be reduced to a selected area, an action, but also can be drafted a rule and regulation to guide how to formalize the world order. I hope I can dedicate my power to build a better world, too. So how is my topic relevant to sustainability or simply to say, is socio-technical transitions theory really an insight into the sustainability of a product, a company, or an entire industry? In terms of automotive manufacturers, is the quest for technological innovation a slogan or a gimmick to create an autonomous vehicle which it is claimed could deal with multiple environmental issues?

The second reason is, there is a wide gamut of choices in transportation to address the issues of unsustainability, while I have chosen connected, autonomous, shared and electric vehicles (CASE) as my research lens. They offer possible future mobilities, indicating a trend of rapid technological change. Some technologies or concepts are effective upon specific issues: for example, electric powered vehicles could address toxic exhaust gas emissions at point of use. Some concepts such as ride sharing and hailing schemes are less encouraged officially but have emerged by the social activities of new market entrants. In the case of UBER, for example, the regulatory authorities in many countries were not prepared for the operation of this business model innovation (Wells et al. 2020b). China, for instance, is without any political sustenance for electric bike emergence but with a huge blank space driven by users' necessity. Since this concept has been recognized, vehicle manufacturers and technical enthusiasts have been eager to expand the market from a new form of CASE mobility from by around 2020. My research is concerned with exploring how long will the vision of CASE take to be fully realised, and will it become a pervasive new automobility?

The third reason for this research is that each CASE mechanism seems individual and independent from each other. However, while this research started from an interest in an investigation of autonomous vehicles and their contribution as one of approaches of future transportation, it quickly became apparent that automakers were trying to prove a wider portfolio of inter-connected innovations. For instance, along with Industry 4.0 and emergent circular economy concepts, the sharing of assets has become a new potential stream of income widespread that penetrate in automotive industry. Passenger cars sharing takes multiple forms: traditional car rental, a ride share during the same journey, a ride hail online by a self-employed driver, a vehicle may be shared by a group of people, etc. Vehicle connectivity has become a feature allowing communication with other vehicles and infrastructure to help better mapping and navigating.

The last but not the least reason is that the automotive industry can be perceived as a typical socio-technical ecosystem self (see Chapter 2, Section 2.3) in which are embedded all the elements of socio-technical transitions theory include the 'softer' elements such as cultures of mobility, relevant legislations, governance, and regulatory framing, brand loyalty, commuting infrastructures, and many other mutually reinforcing elements.

All these reasons implying that CASE is an unpredictable trend in the near future under the context of societal and technology sustainability innovation. The automotive industry and the realm of automobility therefore offer a ‘living lab’, a dynamic unfolding of the permeation of technologies into society, in which the concepts within socio-technical transitions theory could be analysed almost in ‘real time’. Therefore, the domain of the research is in the automotive industry and automobility.

## 1.3 Overview of Research Methodology

The designed research questions point to uncertain future scenarios. Based on the theoretical and political literature review, the research will use mixed methods to collect relevant data to enrich results and reduce bias. There are few highlights among the research process. On the one side, we found socio-technical transitions theory is too broad to explain a such complex domain hence network theory has been added to illustrate specific diverse but convergent trends. And on the other side, alongside the documentary data collection, interviews were involved to investigate the views of relevant expert academics, journalists, engineers, and other interest groups towards the impact of CASE on the industry and on future automobility. Multiple vignette case studies are carefully selected in which each case can represent a typical geographic or business area with its corresponding market position and strategy. Cases are individual but collectively illustrate the corporate contribution to sustainable socio-technical transitions. Interviews are more concerned with perceptual cognition related to the research questions, as a complementary explanation of the cases.

## 1.4 Thesis Structure

### 1- Introduction

This chapter covers the background, research questions, aims and objectives of this study.

**2- Literature Review**

This chapter covers literature review from a theory and concept perspective, covering the multi-level perspective, socio-technical transitions theory, network theory, and business models and how in the instance of the automotive industry as a socio-technical transition system, transitions theory can be augmented by the application of these other insights. The chapter explains how STT theory has been developed, why it is relevant to the research, and why these related conceptual framings will be applied in this research. Specially, the conceptual of regime convergence is deployed. The literature review identifies the gaps in the current status of research that has been conducted to date, and what has not yet been considered.

**3- Political and Historical context**

This chapter covers selected vehicle markets in the world and see how and what legislations and regulatory interventions pertain in each arena. Supportive regulation is another factor apart from the automobile industry itself to impulse autonomous and connected vehicle commercialization to relevant markets. This offers opportunities from a landscape level for both traditional automakers and new entrants test their products via simulation and on the road by machine learning and other possible techniques dealing with real possible collisions. National conditions have to be highlighted in an individual chapter because administrative regulations vary from one country or region to another, it is difficult to generalize as a whole. Other relevant stakeholders correspondingly have also been analysed resulting from CASE vehicles e.g. insurance sector. Again, historic actions can affect future decisions on developing CASE vehicles domestically and internationally.

**4- An Overview of Automotive Industry**

This chapter gives a global big picture of current positions of automotive industry and pressures to face transformation due to the shift to new forms of automobility, for example from the car as a personal commuting tool to the car as the basis of mobility-as-a-service. Challenges and competitions for new players and incumbents are varied, CASE has the potential to become a disruptive innovation to prevailing organisations. Hence, this chapter also presents an outline of boundary dissolution between the automotive industry and other suppliers, sectors and co-operators. This dissolution appears to be resulting in flatter, less hierarchal interacting networkers of business. The automobility transition pathways are also identified.

**5- Research Methodology**

This chapter represents the philosophical position for the research: the epistemology and ontology of the study in the broader context of the research background. A mixed methods approach dominated by qualitative methods, secondary resources, auxiliary qualitative interview primary data collection have been applied in the overview of automotive industry in Chapter 4 and Chapter 6 of case studies. Theoretical framing and concepts guide research methodology, and choices of how and why research conduction has been undertaken in the selected way. The account of methodologies also relates to the procedures of data collection both secondary and primary. Secondary data is obtained from historical and archival journals, reports, professional websites, news press releases, and other grey literature resources. Primary data is obtained from interviews for which this chapter shows how interview questions and procedures were decided, interviewees selected and the results recorded. Software used to help in data collection is also illustrated. Lastly, this chapter illuminates how cases were selected for the embedded case studies in Chapter 6.

**6- Embedded Case Studies**

This chapter gives a more detailed description of how different automotive corporations manage with pressures, challenges and issues faced when transferring to new forms of automobility. Cases also contain firms that outside of the automotive industry such as ICT suppliers and ‘tech giants’ to show the possibilities of participating in the emergent new form of automobility by other industries. Each case is representative in a region with a corresponding business model.

**7- Discussion**

This chapter firstly positions how each CASE fits with socio-technical transitions theory and where the current adaption positions and penetration so far can be understood as transitions stages. The chapter also covers the study conclusions and summarises the findings both from secondary archival documentary, cases on websites and primary opinions from interviewees. The chapter brings together the main relations, competitions, business models and choices from different automakers and technology players.

**8- Conclusions**

This chapter is the last chapter of the thesis, which covers conclusions for each of the research questions, contribution of thesis, relevance of thesis to the industry and policy and further research.

## 1.5 Summary

This research offers the contribution of combining STT in the context of the future of automobility and the automotive industry. It is innovation in framing automobility in these terms, and by bring insights from business models theory and network theory to illustrate the concept of multiple regime confluence that has not been undertaken previously.

# Chapter 2
# Regime Convergence and Coherence Under the Socio-Technical Transitions

This is a theoretical chapter which addresses 1) how Socio-Technical Transitions (STT) theory can be applied to understand the attainment of sustainable automobility, 2) how dynamically stable regimes may be challenged by pressures from top-down landscape pressures and bottom-up innovations, 3) and how previously distinct regimes may partially merge around new technologies. Further, this chapter introduces Business Model and Network Theory into Socio-Technical Transitions Theory based on the literature review, which is later applied to the cases studies (for details refer to Chapter 4 and Chapter 6). Hence, the chapter can be divided in four main sections after the Introduction (Section 2.1): Multi-level perspective and the regime change (Section 2.2); defining automobility as a Socio-Technical system (Section 2.3); business model innovation (Section 2.4); regime confluence (Section 2.5), and networks along with regime confluence (Section 2.6). Lastly, Section 2.7 concludes the theorical framing used in this research and how this framing contributes to the analysis of the automotive industry and the automobility regime.

## 2.1 Introduction

This Chapter demonstrates how the key theories used have developed and then links the research questions to the context. The theory of Socio-Technical Transitions (STT) used as a principal configuration across the entire thesis. CASE vehicles are one of the outcomes of highly developed technology to solve existing social issues, therefore, STT could underpin the CASE vehicle examples to further explicate the structure of the work from a theoretical perspective. The STT is broad in that it covers a general conception of change over time, while the MLP (Multi-Level Perspective) lacks explanation of agency acting to instigate or restrain change between each two levels. In consequence, Network Theory was chosen to provide a casual theoretical explanation. STT theory is a framework to explain the associations between social issues and technological innovations: how social issues are solved or helped by technological development and in turn, how technological innovation impacts on societal issues. This is a complex but well-structured theory that has been applied in different research domains.

STT theory is often presented using the concept of the multi-level perspective (MLP) in which there are three levels (macro, meso and micro). Change processes could be analysed from any one of these levels. A large volume of research has investigated the niche (micro) level of innovation i.e. micro-concentrated studies rather than the complexity of the bigger picture (Geels 2005a; Verbong et al. 2008; Nill and Kemp 2009; McCauley and Stephens 2012; ONeill and Gibbs 2014; Kivimaa and Kern 2016). It is understood that innovations in technology have been a feature of recent decades, but that niche applications may be fragile and easily to be destroyed by participants in the prevailing regime or other competitors, so that niche applications need more protected spaces (Smith and Raven 2012). Nonetheless, this bottom-up incremental process of niche innovation is vital because it lays the foundation and opens the window for the adoption of new technologies that have the potential to displace existing regimes, and thus, it is worth paying more attention to study. A successful or enduring niche could affect existing societal behaviours, industrial structure, markets, economics and business opportunities. Hence, it is possible that a niche can grow and it can even reconfigure the entire regime system.

In contrast, the study of the regime level (Raven and Verbong 2007; Papachristos et al. 2013) and landscape (Nadaï and Horst 2010; Marletto 2014; Morone et al. 2016) is far less considered in previous research. The regime level represents routine-based societal behaviours, activities and attitudes, and entrenched corporate structures and markets, all centred around pervasive and mature technologies. It has been described as “dynamically stable” in that it encompasses both challenges and opportunities for existing practices and innovative developments. When a new entrant breaks into a well-established territory, it brings some turbulence to challenge the prevailing ordering. The landscape, meanwhile, is an over-arching long-term stable context within which regimes exist including cultural practices, policy, the influence of the natural environment and other elements that usually do not change within a short period of time. The landscape level could create pressures change to existing organizations or offer opportunities to the latest entrants to help them enter the regime (Auvinen and Tuominen 2014). However, the landscape level can be shocked under circumstances of evolutionary-economic or social-institution interruptions (Geels and Kemp 2007; Sovacool and Hess 2017). A contemporary example of a rapid landscape change creating a shock to multiple socio-technical systems is the COVID-19 pandemic (Wells et al. 2020a). The COVID-19 pandemic can be seen as a quickly emerging, extreme shock from the landscape level, which impacts upon all socio-technical systems from the up-down. In turn, the landscape event becomes integrated into these socio-technical systems by instigating change processes, some of which may endure even once the initial shock has passed (Boons et al. 2021).

Organizations, institutions, policy actors and industry networks that constitute the socio-technical system's regime level have usually been considered as independent from other regimes without significant mutual interactions (Geels 2004). Later, alongside the incremental reactions between the isolated regimes, more researchers identified the possibility of interaction between one or more different regimes (Markard et al. 2012). This regime separation idea also could be found in the early application of the Multi-Level-Perspective (MLP), an agency to explain STT theory. The MLP describes the independence between two regimes and each regime is linked directly to its relevant niche components (Geels 2005a). However, with research continuing, it has been found that structures of regime boundaries may be blurred and overlapped. Within these intersections, either a new organization has emerged, or the overlapped part has been assimilated and adapted by both previous distinct and separate regimes (Raven and Verbong 2007; Papachristos et al. 2013). This regime confluence acted as to mediate socio-technical regime changes, and may in turn be enabled by novel business models.

The contribution of this chapter is to argue that innovative niches are not only generated from niche levels, but also formed from distinctive regimes. The new innovative regime can benefit from its parent regimes to better respond to any external changes.

## 2.2 Sustainability Beyond the Multi-Level Perspective and the Regime Change

Above all, socio-technical transitions theory is one that claims to embed transitions towards ‘sustainability’ from both societal and technology perspectives. Therefore, this is a theory which could explain what and how to transmit input information and output impact on society, technology, and sustainably. Social impact could directly or indirectly address issues which are relevant to our lives, while technology impact is focusing on the technological innovation and improvement. Apart from the theory, the practical domain of this research is in the automotive industry, which illustrates the themes of social issues and intensive technology change. Therefore, STT theory could perfectly address the issues in the automotive area.

Secondly, this work focuses on and expands the arena of automotive industry which allocates the topic within the context of transportation. Transportation, meanwhile, is one of the most important factors and has the closest relationship to our ordinary lives. It plays an essential role in the social system and can profoundly impact the quality and the living patterns in a tiny change, such as an increase in the price of bus or train tickets. Similarly, there are many other social situations which are capable of antagonizing us, for example rising fuel prices, which directly impact on personal travelling patterns. In recent years, it is impossible to move without cars especially in rural areas with a disadvantaged transport system. So our life, or we should say our ‘car life’, is socially oriented.

Additionally, in respect of the automotive industry, this research will allocate more specific categories which are technology-based autonomous and connected cars. It is not a novel conception, but over recent years, it has been increasingly applied in practice. Different types of companies have been involved: traditional car manufacturers at the heart of the automotive industry such as BMW and Audi; some newly invented car companies such as Tesla; even IT companies like Google and the Chinese searching engine giant Baidu. Evidently, outsiders such as mapping companies HERE and Sygic have also played a part in this area and have built a close cooperation with car makers. The innovation of autonomous and connected vehicles breaks the boundary of the traditional regime of the ‘automotive’ industry, thereby allowing a point of entry for new participants.

Therefore, the socio-technical transitions theory is used in this work. This approach focuses on how innovations permeate and interact with society.

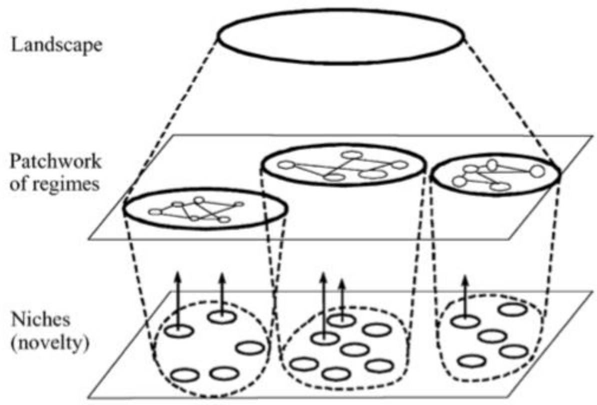
However, STT theory as a framework is not sufficient to explain all changes due to the lack of agency. Agency refers to the ability to make changes occur. STT is largely descriptive of change processes happening over a long timeline, but does not provide detailed explanations of how events happen. There is a general explanation of change based on technological determinism, but this needs to be supported by more detailed theoretical accounts of agency in making change occur. Firms are presented as social agents, actors that are able to make change occur. Therefore, network theory has been chosen to explain the relations among all mechanisms. This could make up for the weaknesses of STT theory. Network theory defines a phenomenon as a unit and uncovers the relationships between different constituent entireties in a network. For example, network theory explains how the vehicle industry interacts with other industries, such as the IT sector and electric industry in the form of micro networks.

Many automotive companies have declared that the networking or alliances in the automotive industry are essential and the industry cannot survive without them. Li Shufu, who is the largest shareholder of Zhejiang Geely Holding Group delivered a speech of why vehicle manufactures need partnership (Bloomberg 2018): "…But with challenges come opportunities. No current car industry player will be able to win this battle against the invaders from outside independently. In order to succeed and seize the technology highland, one has to have friends, partners, and alliances and adapt a new way of thinking in terms of sharing and united strength…".

### 2.2.1 A dynamic progress from multi-level perspective to socio-technical transitions

***Multi-Level Perspective (MLP)***

The Multi-Level Perspective (MLP) is a basic heuristic conceptual framework to show the relations between niches and regime mechanisms from multiple dimensions (Figure 2.1).



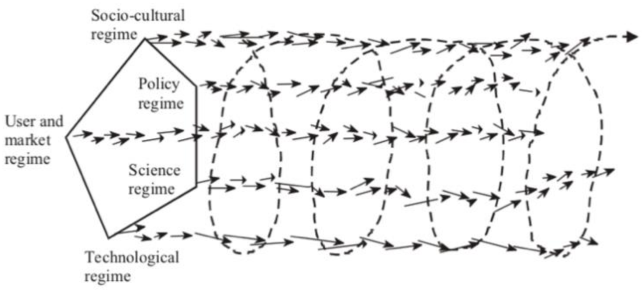

Source: (Geels 2002) p.1261

***Figure 2.1 Multi Level as a Nested Hierarchy***

Landscape as an external macro level contains heterogenous long-term stable essentials such as domestic / international economic growth, environmental issues, culture, demographic trends, policies and regulations. It could also be explained as basic infrastructure or city plan a complex system by which to keep city integrity and operation smoothly. Technically, the landscape level is usually understood to change slowly and meanwhile is rarely influenced by behaviour-based routine. It is a guidance and protective space for regime level and niche novelties to maintain the entire socio-technical system.

The meso level is in the middle, which encompasses several regime groups and each one has a clear boundary. Theoretically a boundary exists when each regime has been well-defined, but practically it may not be specified sufficiently. The concept of regime comes from varies of sources (Kemp 1994; Schot et al. 1994; Rip and Kemp 1998; Schot 1998). Previous research studies and theoretical concepts such as system innovation, evolutionary theory and long-wave theory lay the foundation to frame a regime. Regimes have been identified as an individual system such as “social regime” or “industry regime”, it can be more specified like “automobile industry regime” or “IT industry regime”. The factors in each regime have domestic linkage in terms of corresponding the endogenous identical standard and distributing common knowledge and rules. A factor could belong to two distinctive groups which links two groups by an overlap. This point elaborates later in this chapter in regime convergence and coherence.

The regime in the MLP is mainly dominated by engineering and technological mechanisms that triggered innovations and revolution from both the regime and niche level. Thus, this regime in MLP is also called technological regime. The concept of ‘technological regime’ comes from Nelson and Winter (1982) who portrayed the regime as a shared space between engineering and technologies. Rip and Kemp (1998) extended the engineering dominated regime and redefined it to include infrastructure and institutions. This regime has been described as a rule-settled cognitive oriented area where numerous distinctive independent groups exist at the same time. The engineering and technology groups are not the only restrictions characterised in this regime, relevant elements that influence or are influenced by them also belonging here, such as consumers, suppliers and researchers. The regime offers a protection for radical novelties from below and is subject to pressures or shocks from above to open a window. Each group in this level has a clear boundary while groups are mutually aligned. Elements in groups dynamically push themselves moving forward and spiralling over the time; this process is defined as an ‘ongoing’ process (see Figure 2.2). Geels socio-technical regime is wider and more comprehensive than previous work, which composes by five basic regimes. These five basic regimes are the constituents of societal concerning, pushing social practice functional and forwards. They are socio-cultural regime, policy regime, science regime, technological regime and user and market regime (Geels 2005b). Interestingly, economic regime is not presented as a distinctive regime. Based on Geels and others, elements of economy as an immanent concept laid behind each single concept and all levels (Geels 2011).




Source: Alignment of ongoing processes in a socio-technical regime (Geels 2005b, p.23)

***Figure 2.2 Alignment in a Socio-Technical Regime***

Niche level is more fragmented and contains innovation possibilities for business models, technologies, ideas and subcultures, emerging from bottom and growing up within the same system. These radical innovations are “precarious” and not guaranteed. Innovations may wander around rather follow the same innovation trajectory as previous novelties. Thus, originalities in this level are varied and non-stabilised. According to Geels, an innovation trajectory is an ascending process influenced by existing knowledge and rules in the regime and potentially growing to become a new regime. Niches are also influenced by the landscape because it plays a decisive role in the whole system. Thus, regime and landscape levels affect the direction of niches and could protect innovations. All three levels could be seen as a nested hierarchy and landscape embedded regime and regime embedded niche (Geels 2002; Geels 2005).

***<u>Niche innovation</u>***

Relevant research into niche innovation can be traced back to the end of last century (Abernathy and Clark 1985), it is furtherly applied in the area of energy, agriculture and others (Hargreaves et al. 2013). Niches could be self-generated alone, as a group, or can be an interrelated network (Verbong et al. 2008). They can be categorized as radical, incremental, regular, architectural, revolutionary and niche (Popadiuk and Choo 2006). Niche innovations thus have their origins, serendipities and specific opportunities, which influence the trajectory of their growth path (Geels and Schot 2007). However, niches are too fragile and vulnerable to failure and so need to be protected (Raven et al. 2010). Therefore innovations can be protected, oriented, selected and managed towards sustainable goals by political instrument and future benefits coincidence (Nill and Kemp 2009; Smith and Raven 2012; Berkeley et al. 2017).

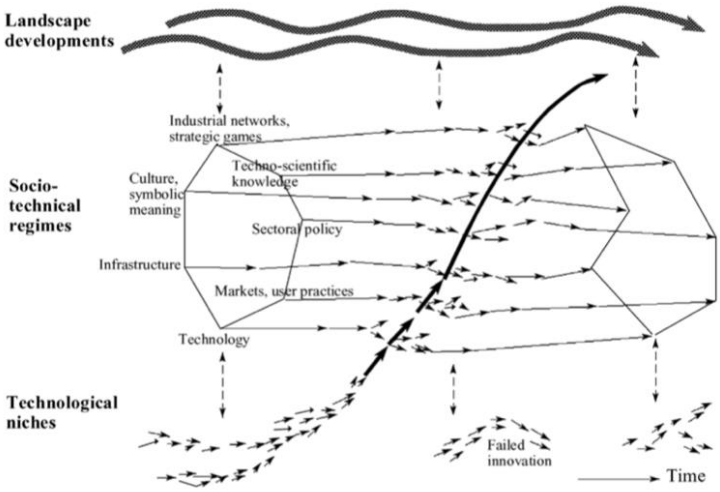
MLP is a simplified structure to illustrate functions of three hierarchies and content in each of them. Socio-technical Transitions Theory can be understood as a holistic version of MLP which contains more elements, complex structure and a timeline. In MLP, regime refers to technical relevant factors which is narrowed and limited. More studies since then broaden the technology-focused regime to a wider socio-technical concept.

***Socio-technical concepts***

Socio-technical concepts include many outcomes. The first one is *socio-technical system*. Socio-technical system illustrates how technology works under a sociology consideration. Technology is a tool to change/alternate social activities, nature and behaviours, thus to push societal development. Research to survey a socio-technical system is to divide the entire system into three different parts and consider how the most crucial one is working and interacting with other elements (Elzen et al. 2005).

*System innovation.* One of the arguments on system innovation is to regard system innovation as a ‘technology substitution’ which composes three steps: technological emergence, diffusion and replacement. Another debate is that it is not simply a substitution of technology, but a ‘coevolution’ mechanism along with technology and could change elements inside from the system. The third and more recent opinion is that system innovation is the ‘emergence of new functionalities’. If a radical innovation is compatible with special ‘properties’, it will be offered or enhanced as a more functional character (Elzen et al. 2004; Elzen et al. 2005, p.200; Geels 2005b).

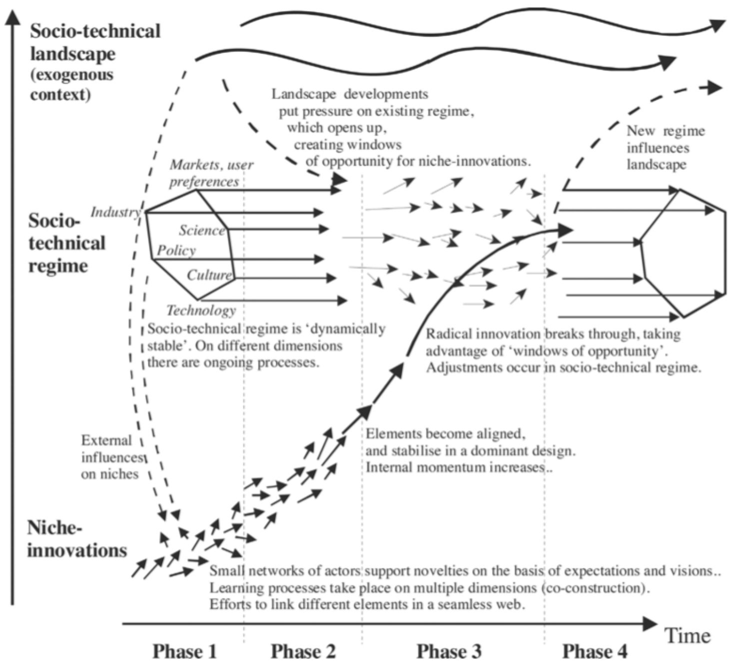
***<u>Socio-Technical Transitions theory (STT)</u>***




Source: (Geels 2002) p.1263

***Figure 2.3 STT in A Dynamic Multi-Level Perspective***

Then a more comprehensive Socio-Technical Transitions theory (STT) (Figure 2.3) was put forward by Geels and his colleagues (Geels 2002; Geels 2004) and developed by Geels and Raven (Geels and Raven 2006; Geels and Raven 2007), Elzen (Elzen et al. 2005), Kemp (Geels and Kemp 2007; Kemp et al. 2007a; Kemp et al. 2007b), Geels (Geels 2005a; Geels 2010; Geels 2011; Geels et al. 2012), Schot (Geels and Schot 2007). They added a nascent notion of 'transition' in socio-technical system, therefore it can dynamically show the interactions between each of the levels. This is an important shift, because it illustrated the trajectory of how a niche gradually becomes a part of obtainable regime, and how the three levels inter-change and influence mutually. Nonetheless, with the development of societal diversity, the socio-technical aspect is not confined the framework to the working group (Trist 1981), it contains supplementary fresh sections and puts them into many further areas. Correspondingly, here, a dynamic association and substitution always accompanies the process of reinventing a novel form and rule. The fragile innovations could fail or be replaced at any time or in any format. This theory is associated with Frank Geels who responded to flaws in previous work and sharpened the theory into being more precise and functional (see Figure 2.4) (Geels 2011; Geels 2018a). Along the theory updated, definitions of each level are rationalised. Landscape has less conversion, it keeps stable characterisation, impervious and stand-alone.




Source: (Geels 2018a, p.226)

***Figure 2.4 Multi-Level Perspective on Socio-Technical Transitions***

Niches as prior work defined, could emerge with the innovations and have possibilities to access the regime. While Marletto (2014) combined the work of Geels (Geels and Schot 2007) and Haxeltine (Haxeltine et al. 2008) and endowed the niche a new connotation: niche could be 1) one of the elements in dominant systems as a new adapted factor, 2) or replacement of similar actors in destabilizing incumbent system and thus become a new variable in the stable system, 3) or a creative destruction to totally displace the existing system and expand into a new system (Marletto 2014; Kivimaa and Kern 2016). Geels newest article (Geels 2018a) re-categorized the niche innovations as four phases from a small chaotic niche emerging, to aligned, stronger niche momentum to seek a right opportunity to squeeze in the regime level influencing the exist regime.

Geels's STT based on all theories mentioned earlier, becoming a broader but comprehensive detailed dynamic theory. The niches here refer to technological niches which are not much difference with niches in MLP. However, STT niches are showing a process of the niche innovation rather a still symptom. Niches are dynamically growing from disordered and protected novelties to stronger, cohesive, oriented power that could break though ‘dynamic-stable’ socio-technical regime. The disruptive innovations access the prevailing system and reorder one or more regimes, hence possibly to form a new regime alignment. A niche could fail when it grows during this time but it could be reorganized and converted to a preferable technique niche and over again. All these growths and co-evolutions are time-consuming, so the niche level could become a protective mechanism offer a shelter for those innovations when the novelties are venerable.

In the Figure 2.3, seven elements have been chosen to frame the basic configuration and become the socio-technical regime: industrial networks which operate at the strategic level, techno-scientific knowledge, technology, sectoral policy, markets and user practices, infrastructure and culture which represents symbolic meaning. All these elements are fixed during a certain period but can also be fluid and they can be intruded when a stronger violator breaks into the system. Each mechanism here is a group, as MLP showed, it has a complex inner system with some sub-elements sticking together to be a meaningful point. Those sub-elements may vary in circumstances and would influence the main point, even further to the entire regime. When some sub-points are weak, this may be an opportunity for niches to invade the system to replenish the weak components and reinforce it. What is more, elements could reorganize the entire system and re-establish the norm and regulation. That is why the socio-technical regime can be called ‘dynamically-stable’.

Other than five regime components have been defined in socio-technical regime before (Figure 2.2), infrastructure and industry network supplemented to enhance the socio-technical regime (Figure 2.3). Questions are, why did Geels insert two additional elements in the socio-technical regime and what is the difference? Are there any different definitions of remaining elements on the two versions? It is a weakness or a vagueness to define a boundary in the STT theory. For example, infrastructure can be clarified in the regime level, also could be in the landscape;

likewise, what is the right size of industry network to compose a regime? This is the same issue as Wells stated, is a city with over a million population belonging to regime or landscape (Wells and Lin 2015)? In China around 100 cities have the population over a million. The Talents Introduction Policy attracts more elites into these cities with a double population by 2025 (Haas 2017). Population in 13 mega cities are over 10 million, 30 cities are over 8 million by 2017 (Sina News 2017). Are they qualified as landscape demographically? However, geographically, only 1/6 cities are over million, so are they niche or regime? All these questions and previous studies help construct and refine the research questions and design. For instance, the electric bike case indicates that niche innovations could emerge without political support in the regulatory or legal sense, or indeed could emerge despite the opposition of the state. Hence in this thesis research has been conducted into the role of the state, which underpinned innovative technology developments. The unclear boundaries in STT theory have been identified later in sections 2.3, 2.4 and 2.5, additionally with the micro, macro and meso level identifications that located in automobility industry.

The theory is going to mature and become more detailed. Landscape not simply shows a short, direct interplay with regime (Figure 2.3), it is a soft, slow and dynamic pressure on the regime with the time going (Figure 2.4). Correspondingly, a dashed arrow from landscape downwards to niche level means that the long-stayed environment has effect to the niche innovation. The power to regime, however, are the thicker dashed arrow lines; it can be recognized this erosion is stronger than to the niche one (Geels 2002; Geels 2018a). From Geels' point view, the power to niche from landscape has less impact because it is indirect and far away from specific niche ideas. Hereafter, four points need to be noticed: 1) how to measure niche pressure acceptance from the regime and landscape level; 2) why do they have a same pressure both from landscape and regime to niche? 3) why in the Figure 2.4 there is the stronger impact powers in and out between landscape and regime than previous figures? And 4) niches are only the level accepting powers, so why not to have influence from niche to landscape? These questions can be solved in the rest of the chapter.

Owing to transitions being viewed from various levels, studies on transitions have different entry points and methods to expand their stories through STT theory. Case study is the most prevailing method to illustrate STT in the previous work. For instance, a case study of green energy and economy applied in Central Massachusetts in North Eastern USA, from a niche level explained how green energy has innovated and grown up (McCauley and Stephens 2012). A multi-case study was piloted in Brazil, Malawi and Sweden to investigate the application of alternative energy in the transport sector (Johnson and Silveira 2013). The food industry also has been examined by case study that is a local food systems exploration in Belgium at the niche level (Van Gameren et al. 2014). Lawhon and Murphy (Lawhon and Murphy 2012) accessed political ecology to understand sustainable environmental governance through the regime level. The studies above reconnoitred the relationships between society and policy, society and economy and the environment from a macro stratum. Semi-structured interviews have also been conducted to use STT theory which can be seen in offshore wind research in Finland (Verhees et al. 2015). Also more modelling approaches have adopted socio-technical theory (Vespignani 2011). STT now has a wide and vibrant research agenda (Köhler et al. 2019), to which this thesis contributes.

The STT, meanwhile, includes research on transport and sustainable mobility from the macro, meso and micro levels. For example, Schot has used evolutionary theory to illustrate how techniques in electric vehicles have been applied and how innovations incrementally developed under a guide of political, cultural and societal elements (Schot et al. 1994). This research aimed to examine sustainable mobility through elements of the STT regime and it was far before the STT system being established. Geels (Geels 2002) started this theory through a steamship case study and later he (Geels et al. 2012) illustrated sustainable mobility from a transition management viewpoint; Wells and Lin (Wells and Lin 2015) discussed electric bikes by interviews and questionnaires to test this theory in China and formed a new arena for e-bikes; Steinhilber evaluates barriers for electric vehicles in Germany and UK markets by transitions theory and niche management (Steinhilber et al. 2013). At the same time, works on autonomous and connected vehicles have been done in the engineering field.

Almost all topics centred on how the autonomous and connected cars work and manipulate such technique mechanism by different algorithms (Naranjo et al. 2008). Methods include to introduce new algorithms to lane-changing techniques (Choi 2014; Guo et al. 2016), or if environmental friendly investigated by Mersky and Samara (Mersky and Samaras 2016), or cognitive and psychology perspective of responding time tested by Morgan in typical age group (Morgan et al. 2018; Voinescu et al. 2018).

The difference between MLP and STT is, MLP is a heuristic approach to illustrate an existing phenomenon whereas socio-technical transitions theory applied a 'dynamic' method to elaborate how things change during the process. It is a way to see elements dynamically both vertically (interactions mutually) and horizontally (timeline). Hence, the most essential contribution of this theory is the 'transition' process, which is fluid, flexible, dynamic and transformed gradually. In addition, MLP has applied in not only through STT, but also could have an intertwined relationship with network theory (Brass et al. 2004) and this will be emphasised later in network theory section. Above all, STT is a functional and helpful theory that could explain most technology-related societal transformations. Nevertheless, most STT research programmes are single historical case study embedded. This thesis proves the STT theory under the future circumstances by dynamic data resources.

### 2.2.2 Transition pathways

To discuss regime transitions, two elementary stages are essential to clarify, one is bottom-up acceding process from niche to regime and another is downward from landscape to regime. These processes are known as 'transition pathways'. Pathways are defined as a method to follow the planned short or long term objectives (Smith and Stirling 2010). Different alignments of interactions between the three levels along with innate nature and time could form different pathways. The transition pathways are categorized to distinguish the features to approach the destination (Geels and Schot 2007; Marletto 2014) such as to subsidise the original innovation, to supplement the exiting features or to add new characteristics to the regime.

Owing to the technology's swift expansion, business models with and within an industry have to be changed to coincide with the technological innovation improvement trend. Technological growing niches are divided into two types which are market-derived niche and technological-derived niche. It means either industry revolution could commercial and expand niche technologies, or the demand derived from market niches could allow industrial expansion (Geels 2005b). The niches can also be classified as a 'fit-and-conform' niche which is competitive to the existing mainstream elements, while a 'stretch-and-transform' niche embraces a substitute to challenge current mechanisms (Smith and Raven 2012). Therefore, niche innovation can be analysed from diverse perspectives, recognizing the types of niches may help investment attraction, political adjustment and development and regime reconfiguration.

An on-demand niche market may or may not gain political supportiveness, the growth of electronic bike selling and production in China is a good example (Geels 2002; Geels 2005b; Wells and Lin 2015). E-bikes in China are not policy-supported, even the government banned the production once due to the view that their use jeopardizes both drivers' and pedestrians' health. However, the production and sales volume continued increasing dramatically over the preceding decades. Economically, it suits for a large group of people who cannot afford a car. Functionally, it is for parents who need an electric bike to send their kids to school and pick them up after school; it is also suitable for some modest daily shopping or commuting. The electric bikes function as a substantial transport between bikes and cars with a low price. It is also very convenient and flexible (Lin et al. 2017).

A technological niche is an industrial pushed technological evolution which can be found in each technological reinvention. For example, the discovery of electricity has changed many ways of life, one of them is light bulb adoption instead of the kerosene lamp. Another revolution is electric powered trams or buses instead of horse-drawn wagons. These examples show that technology innovation can generate its derived market. From a socio-technical transition perspective, earlier examples are new technology innovation on the stage of niche transforming to regime.

However, apart from the technological derived market and demand derived market, there could be one more niche market which is policy-driven niche market. This point can be verified on the example of electric vehicle market. Due to the immaturity battery technologies, electricity powered vehicles are not the primary choice either for commercial or private usage. Nevertheless, for coinciding with the Paris Agreement and the Agreements earlier (Paris Agreement 2016), most countries in the world signed the agreement to dedicate national ability to mitigate $CO_2$ emissions from many perspectives, automobility is an essential sector. From then on, the production of electric vehicles is growing rapidly so that almost every car manufacturer has at least one optional electric model. Additionally, political rules and regulations assist to build many other ways to encourage the usage of electric vehicles. For instance, London and Paris settled emission charge zones and zero emission zones (TfL 2008; TfL 2009); Shanghai and Beijing have limited licences for petrol fuel cars but not for electric fleets; intercity/city buses and coaches are gradually electrifying in Sweden; new taxis are forced to electrify since relevant rules released in Dundee. Correspondent public infrastructure and private charging stations are emerging in a reasonable planed mile, to make sure the normal operation. All these activities around the world accelerate the acceptance and usage of electric vehicles, they are policy derived.

No matter what reason niche innovations are derived trajectory pathways have shown similarly on the process. As table 1 exhibited, innovation trajectory can be considered to have four phases in which two appear in the niche level. These phases are unprepared, less competitiveness, multi-dimensional novelties. After breakthrough past the regime barrier, new entrants rewrite the existing orders or rules in terms of the innovations becoming stronger and invasive, to become established in the new regime. The last phase is the new restructured regime that tends to be stable. While the aftershock could influence consistently the landscape and thus gradually changing landscape until it changes (Geels 2018a).

***Table 1 Four Phases of Innovation Generation***

| Innovation Phases | State | Circumstances in this stage |
|---|---|---|
| Phase 1 | Weak and multi-dimensions | Actor networks are supporting niches, multi-dimensional innovations in a learning process |
| Phase 2 | Not weak and co-evolution | Gradually aligned and ‘internal momentum’ ascendancy |
| Phase 3 | Strong and aligned | Aligned innovation become a new force break into existing regime |
| Phase 4 | Strong and re-structured | Construct a new regime and have an influence on landscape |

Soure: (Geels 2018a)

Even though table 1 clearly shows all possibilities of an innovation generation and acceptance, it is not showing a clear boundary of being an ‘innovation’ or being a ‘regime’. From the definition of ‘regime’, the regime contains the essential elements that could support the system running correctly and smoothly, and it is one of members in the existing stable elements. The phase 4 innovations united with the regime level and have capability to challenge the landscape. In which, should it be clarified as ‘new regime’ or the ‘niche innovation’? Additionally, table 1 shows the process of an innovation to be a regime but lack of details of each kind of innovation. For instance, the innovations here are a collection growing supportively together, is it possible that a niche is growing alone to become a member of a regime? Or how to define ‘a’ niche or ‘a collection’ of niches? It is not clear in the theory. Several researchers have investigated around ‘innovation pathways’ but not under the condition of STT, so we are not discussing here (Robinson et al. 2013).

As declared before, ‘transition’ is an essential term to illustrate innovation growth over time. It is descriptive of innovation emergence from the bottom-up, where it is also understood as responding to the pressures from the top down. The transitions could be impacted under various circumstances, it thus has heterogeneous ‘pathways’ to interrupt and reform the regime. Geels has introduced the typology of transition pathways, in which transitions could be completed by both pressures from landscape and niche levels. It can be clarified that a success innovation should be completed to the end of a pathway. The pathways therefore are: transformation, reconfiguration, technological substitution, and de-alignment and re-alignment (Geels and Schot 2007; Verbong et al. 2008; Sovacool and Hess 2017).

Previous paragraphs have described Geels four phases of innovation generation, and transition typologies. Here, Wells and Lin (2015) ranked pathways from landscape pressures from P0 no pressure to P5 a disruptive shock, see the Table 2.

***Table 2 Different Pathways Under Distinctive Pressures***

| Level of pressure | Pressure from Landscape | Circumstances of Niche-innovations |
|---|---|---|
| P0 | No pressure | Keep original trajectory |
| P1 | Moderate pressure | (Innovations not sufficiently ready yet), mildly change direction |
| P2 | Large and sudden | (Innovations not completely ready), chaotic competition, one winner |
| P3 | Much pressure | (Developed), replacement |
| P4 | Reconfiguration | Re-organize/replace the (partial) original order |
| P5 | Disrupt pressure | De-alignment and re-alignment after a new transformation |

Source: Different Pathways under Distinctive Pressures (Wells and Lin 2015) based on (Geels and Schot 2007)

Regarding the landscape pressure and innovations, the opportunities to disrupt the regime and its consequences are as above. From the landscape/ambiances view, the new orientation of pathways is largely determined upon pressures from landscape and innovations’ perspective. If there is no pressure, the regime dynamic trajectory keeps the original pathway, nothing will be changed, and all business are running as usual. If a mild pressure from landscape, but innovation is too fragile to respond to the challenge, there is not much influence on regime. If a large but sudden shock splits the regime, luckily, innovations may be prepared but not fully complete, it may cause a chaotic competition among these innovation candidates, finally a winner will dominate in this condition. Suarez and Oliva

(2005) stated that environmental change or pressure from a superior level should be more clarified because the consequeces are varied if the definition of ‘environment’ is different. For instance, the environment may refer to ‘an industry’, in which pressure has treamendously changed the entire system, but from even broader view, this challenge has not impacted much on the landscape level. Therefore, what should the environment be defined as? What elements could be clarified as ‘landscape’? This is the same question we asked before. This brings an interesting option, under a societal context, which element has most powerful impact on car industry and which has the least impact?

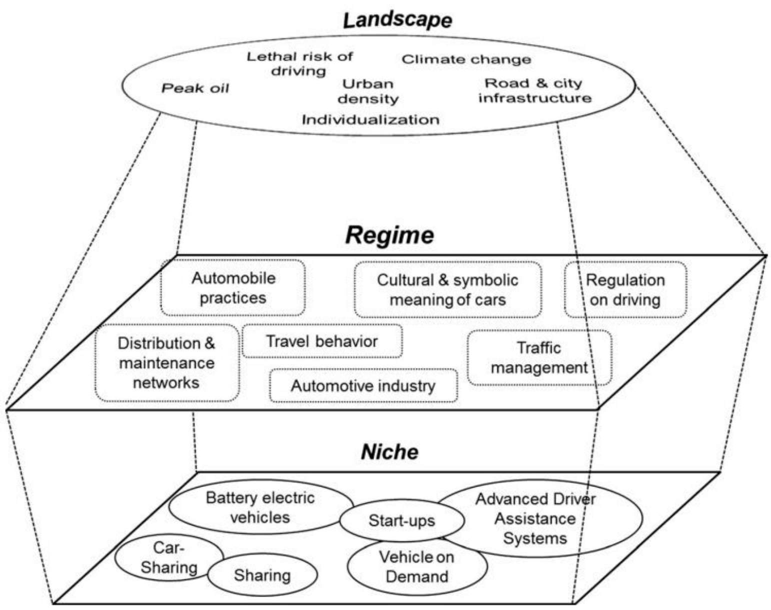
To summarize, pressures can be filtered in several categories, mild or heavy, sudden (short-term) or slow (long-term), frequent or occasional. These shocks more or less influence the regime and keep it unstable. Alternatively, regime stabilization measures may enable a return to ‘normal’ progress. Regardless, the innovation trends or pressures come from varied angles, and the regime changes over time. However, ‘pathways’ along with socio-technical transitions have been resulting in the monodirectional transformation result within a system: pressures and innovations open a window and provide possibilities to new entrants to destabilise the present system. Here there is less consideration about 1) incumbents at the regime level that could enact and participate as casual agents in transition (Ansari and Krop 2012; Bergek et al. 2013; Köhler et al. 2019); 2) the ‘whole system’ transition (Geels 2018b); and 3) dynamic mechanisms of interchange between system-to-system (Raven and Verbong 2007). Thus, the regime frame amendment is under a mutual action between landscape pressure and innovation growth and this has varied permutations and combinations. This point is further illustrated in the Chapter 4 scrutiny in the context of automobility industry Section 4.2. Additionally, the ‘internal’ system change has been less studied, the reactions of existing elements to new players need to be illustrated as an example in automobile industry in Chapter 6 Embedded Case study. Additionally, the dynamic interchange between systems illustrates later on network reconfiguration and constructions in this chapter.

## 2.3 Defining Automobility as a Socio-Technical System

A socio-technical system has three levels: landscape, socio-technical regime and technological novelties. In other words, this system can be understood as a long-term stable structure. The structure of the socio-technical system is defined by the core or foundational technology (in this case, the car), and by the resultant industry (in this case the automotive industry) which together from the basis of deeply embedded social practice (in this case, automobility). The automobility system is the one that can be identified as an individual socio-technical system as it has these characteristics. The interconnections in and beyond the automotive industry and automobility are managed using the approach pioneered by Vayda (1983) in a form of 'progressive contextualisation'. Precisely because the STT of the car, the in industry and automobility is potentially in profound transition it is necessary to be 'inclusive' in how the STT is defined.

The automotive industry has partly been guided by emergent policies from governments over a hundred years. The resulting automobility socio-technical system is stable, showing incremental innovation driven by road safety requirements, (WHO Road Safety 2015; NHTSA 2017), emissions regulation, and the governance of markets. Other regulatory controls over the production, and competitive pressures in the market. The cultural dimensions of automobility has been expressed and gradually formed by books, movies, fans clubs, songs and peripherical products, and is demonstrated in museums. Cars became a representative of a person's social status. Even more, automobility cultures around specific car manufacturers emerges as part of the industrial history of a country or region (Cohen 2012; Geels et al. 2012; Wells and Nieuwenhuis 2012). Correspondingly, it is highly relevant to daily lives so that the best-selling models in each country have traditionally symbolized the national character. Rules and regulations were therefore varied by country. Owing to the specific requirements in each country, cars were manufactured and adjusted to coincide with local context. This may drive different niche innovations in particular countries in different areas. Institutionalisation creates economic and social inter-dependencies that help stabilize the system (Carolan 2010). Over time, this pattern of 'national' industries and cultures has given way to international structures, driven by economies of scale and the increasing global alignment of regulations.

Automotive industry acts as one of the pillar industries in some countries such as Germany (Koptyug 2020). More than a simple company localized in a country, an automotive company involves the national economy by virtue of huge revenue incomes, on society by jobs creation and relevant innovative companies, and on the environment especially by its emission contributions (Nieuwenhuis and Wells 2001; Arnold 2019). The system has expanded through the deeper stemmed automotive culture which makes the automobility coherent with citizens' commuting and travelling behaviours. This forms a chain of transformation which adapts or is adapted by innovations e.g. prevailing sub-culture or technology (Schulze et al. 2014). The socio-technical regime can be deeply expanded from various perspectives (Smith and Raven 2012; Bento and Fontes 2015), particularly for niche emergence. This point can be found in 2.2.2 'transition pathways' that niches may emerge from an overlapped edge of two or more regimes. Innovation in business models will occur and this point will be further discussed in the next section. Thus transport system could be described as a large socio-technical system (Auvinen and Tuominen 2014, p.346), or macroscopically an automobile could also be a small socio-technical system (Carolan 2010; Fraedrich et al. 2015). The mobility socio-technical system shows as Figure 2.5 through MLP heuristic framework (Fraedrich et al. 2015).



Source: adapted by (Fraedrich et al. 2015)

***Figure 2.5 Mobility as a Socio-technical System by MLP Framework***

The automobility socio-technical system is a ‘self-reproducing or autopoietic’ system (Urry 2004) in which stable regime sustains system functioning well, possible novelties constantly are challenging the regime, stimulating system to keep autopoietic, political and infrastructure as a whole. In the automobility system, the core product is the car, but also the added value services and functionality of automobility are fundamental to the regime. It is the transformation from tangible products to intangible service (Godlevskaja et al. 2011) that is currently underway in the automotive industry. Services that are digitalized that could form a new ‘data-driven culture’ (Dremel et al. 2017). These services are added by platforms or agencies which take advantage of the products made by car manufacturers i.e. Uber. Platforms do not own properties while gaining a huge amount of profit through their application as intermediaries between those that own cars and those that want to be driven to destinations. It can be seen that a niche market is a virgin space which has not been shared, compared with being a traditional car maker where market is almost saturated (Basole and Rouse 2008; Statista 2019b; Narayanan et al. 2020; Wells et al. 2020b). Niche markets thus could be generated by traditional car makers through existing regimes or self-generated from the niche level itself. The value-added service is one of the changes in automobility system as an example. In terms of the comprehensive automobility socio-technical system, pressures and possibilities could be emerged in any levels and thus external aggressions invade to challenge regime are much easier. This point is proven in Chapter 4 under a broader context of the current automotive industry.

## 2.4 New Business Model Innovation

Business model innovation could have an enormous influence in a business network, it is potentially a powerful means to change the business social network, but the scope for this has been neglected in research (Mason and Spring 2011; Neumeyer and Santos 2018). The cause of such a literature limitation is that research studies are often investigated only under the solitary circumstance of business model innovation. However, the if literature on business models is integrated with socio-technical transitions it is possible to envisage business model innovation as an agency and heuristic device to analyse socio-technical transitions (Van Waes et al. 2018; Wesseling et al. 2020). Alternatively business model innovation can be explained as arising in the context of a socio-technical transitions (Sarasini and Linder 2018).

New business models are emerging from a convergent, competitive or overlapping point between regimes. Business model innovation may transpire on the edge of overlapped systems driven by a niche market, or within the regimes because inner regime has embedded an assortment of elements (Raven and Verbong 2007; Papachristos et al. 2013). Not only can the boundaries between regimes be intersected, but also be invaded and penetrated if divides are softer (Wesseling et al. 2020). The ‘softness’ can be defined as the culture, markets structures and user practices where the contents are more easily accessed, the boundary of these groups is easy to break and can be influenced by new entrants. In most cases, the cognitive and amorphous formed regimes are categorised as regimes with ‘soft’ boundary. On the one side, the regime boundaries are not unified solid, on the other side, regimes in between are collaborative but also competitive. The innovations may also be triggered or initiated by competition within a regime, but that tends to be less disruptive, and more incremental, as a part of ‘normal’ competition (Raven and Verbong 2007). Both ways act as enablers that collectively promote regimes confluence and new regime emergence. As parts of regimes gradually congregate and gradually overlap with others, new regimes come out from the edge of two distinctive regimes and it can be called a new regime or even niche if it is very rare and fragile.

It should be noticed that the above two-regime confluence processes are examples to illustrate how a new regime may emerge from the ‘parent’ regimes, the confluence could be taken by two or more regimes at the same time. It could also be an inequivalent permeation that the central regime may be more invaded than other peripheral organizations. For instance, in the automotive industry, car manufacturers are in the centre to dominate the entire operation of the industry. Therefore, at present car manufacturers are more overlapped by multi-functional regime groups such as ICT, chemistry, electricity production and distribution and housing. The peripheral organizations may not have many relations with other group clusters such as automotive parts suppliers, although this may develop in the future.

Interestingly, the new emerged regimes may encounter fewer problems in adapting to the surroundings because these fresh regimes are benefitting from both well-established original regimes. The new emerged cluster brings the innovative business models that could be embedded by the traditional businesses or could be distinctive business models which are superior all conventional business models. This sort of business has a higher starting point and some observable benefits compared with a pure start-up, even that may, or may not reward financial, technical, or political support. First, the new regimes are familiar with the role played in a certain arena, which gives confidence and experience to handle the sudden pressure or shock to the new area. In comparison with new regimes/niches that come out of regime level, niches face a long-distance battle to squeeze into the regime from the niche level; the process is time-consuming and unpromising. Therefore new business models offer opportunities to conventional business models which may make it easier to transfer to network embedded models (Nicolai and Faucheux 2015; Bankvall et al. 2017; Sarasini and Linder 2018).

However, the stereotypical incumbents are innately fixed in the regime level. They have been existing for a long period and may not (easily) change. The incumbents are also slower to respond to the prevailing trends because of their historic practices and embedded infrastructures. The new entrants have the same cliché that they belong to the niche level and need to be protected. The inherent attribute of new entrants is that they are disrupting the existing regime. However, the definition of ‘new entrants’ and ‘incumbents’ are relativistic. As mentioned in previous paragraphs, new business models could generate from the competitive regimes where the boundaries are soft and overlapped. The characters therefore are ‘new’ but ‘old’. It stemmed from the parent regimes but standalone for the new world. In this context, it very hard to define as a ‘new entrants’ or an ‘incumbent’.

Landscape pressure may contribute its effort to new regime confluence mediated by business model innovation. To accept the change whether mild or interruptive, the landscape level influences the existing regime circumstances. Pathways of incremental innovations are alternated by these effects, under the confluence of regimes there may be magnified levels of uncertainty over technologies, markets, etc. i.e. from landscape to niche level impact could be directly (Geels and Schot 2007). In addition, the uncertain pressure is a challenge to existing practices and its business models while it could be an opportunity to the emergent regime. The new product / service attributions, new cost structures, new competitors are all opportunities that worth considering. Hence, we can expect (propose) that business model innovation is an important mechanism in enabling regime shift.

Therefore, the new emerged business models in the automobility system are rooted in the convergence of vehicle automation, connectivity, electrification and sharing functions. These four elements are thriving in the automotive industry transition stage, aiming to address transportation sustainability issues while achieving corporate success. The sustainability performance can be measured in reduced damage and deaths, less non-renewable energy consumption, less exhausted gas discharge, less time lost in travel, and so on. Automation, electrification, connectivity and sharing could solve these issues from different perspectives to reach an overall balance of sustainability. To simplify, these four elements are not emergent under the same support, such as national government, but under the same pressure of bringing improved sustainability for the future transportation sector. Section 4.2 will scrutinise the status quo of the current automotive industry and the challenges it may face. In isolation or in combination, CASE technologies were expected either to bring new income streams, or to present new challenges for income and profits under the existing business model. So along with the technological innovation there has been a lot of business model innovation.

This is not only a challenge for existing automobility system, but also a culture and travelling pattern alternation. The new business models challenge the inter/national wide culture, users' attitude i.e. acceptance and adaption rate, experience, cognitive competence of new technology innovation. By which, if a creative concept would like to be advertised, it has to be clearly illustrated what the functions are and how it will change the current states. And that is why system upgrade is more acceptable than a new unknown notion. For instance, the research from (Auto Trader 2019) reported that the car system or technology upgrade is accepted by 72% car users with a better explanation. However, the semi-autonomous features are not clearly explained so that only 35% users would like to upgrade corresponding features.

## 2.5 Regime Confluence

Interestingly, the varied definitions of regime confluence have given rise to two distinctive concepts: multi system interaction diagnosed by Papachristos, (Papachristos 2014) while Raven called them interactions between regimes (Raven 2007). The difference between these two, are Papachristos clarified that 'systematic overlap' could be two integrated regime systems or the entire socio-technical system. Which means the world could be identified as many different socio-technical systems. The regime confluence is the consequence that two system interaction. However, Raven claimed from a different perspective. He regarded the entire society as a socio-technical system, all elements are in the world could find its position in this system. Regimes were isolated groups that all lay in the bigger context of socio-technical regime level, therefore, when two or more groups attract each other, confluence is occurred.

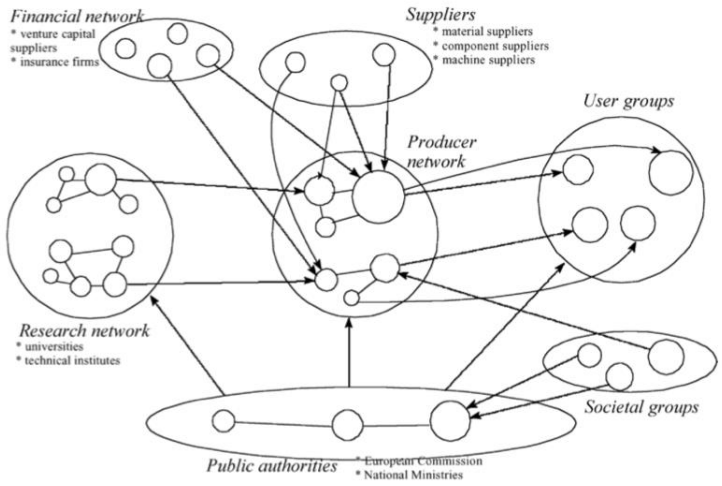
Regimes have been defined in varied ways, they can be categorized in Geels model (Geels 2005b) by a broad 'social' regime, 'political' regime or 'technical regime'. They can also be defined as more specific mechanisms such as the 'electricity regime', 'natural gas regime' or 'automobility regime' (Raven 2007; Dijk 2014). The regime convergence accelerated during time with more interactions and complexity in between (Raven 2007; Raven and Verbong 2007; Budde and Konrad 2019). The intricacy of the surroundings enable sector interaction and communication not only between regimes but also in the between of internal sectors within regimes. As a result, regime confluence enables niches innovation and emergence (Papachristos et al. 2013). The size of a regime does not matter. The regime is supported by many substructures and nodes. The size for the new innovative regime or a moribund regime may be smaller than an emergent regime, but it does not significantly affect the development of transition. Again, interactions between regimes can be multiple ties: competition, symbiosis integration and spill-over (Raven and Verbong 2007, p.503).

## 2.6 Networks Along with Regime Confluence

Regime convergence is multi-dimensional, both in the interior and on the periphery. The interior elements may be collaborative and competitive, as may the external elements (Raven and Verbong 2007). Through the collaboration and cooperation of con-joint work, the relations between elements may become a network. A network refers to any paradigm or system that shows the relations among members. This is the foundation of working together and so that networks are one of the outcomes from regime confluence and coherence.

In the socio-economic system, a few network research areas should be emphasised. Geels uses actor-network theory as one of fundamental theories of STT to emphasise that it could exist mostly in niche level (Geels 2002) as shown in Figure 2.6. In which, he expressed that the actors in a network denote its motives, resources and goals and cannot function without mutual action. The network could also be modulated during the accumulating process to create new linkages and in the diffusion stage to eliminate network components to keep the network functional, dynamic and flexible. His actor-network represents the dynamic relations within a regime. However, the accumulation process is far more successful than de-alignment because the network is the base building blocks for innovation. Especially in technology, "…new technology does not emerge in an empty world, but in a world that is already made up of existing networks…" (Geels

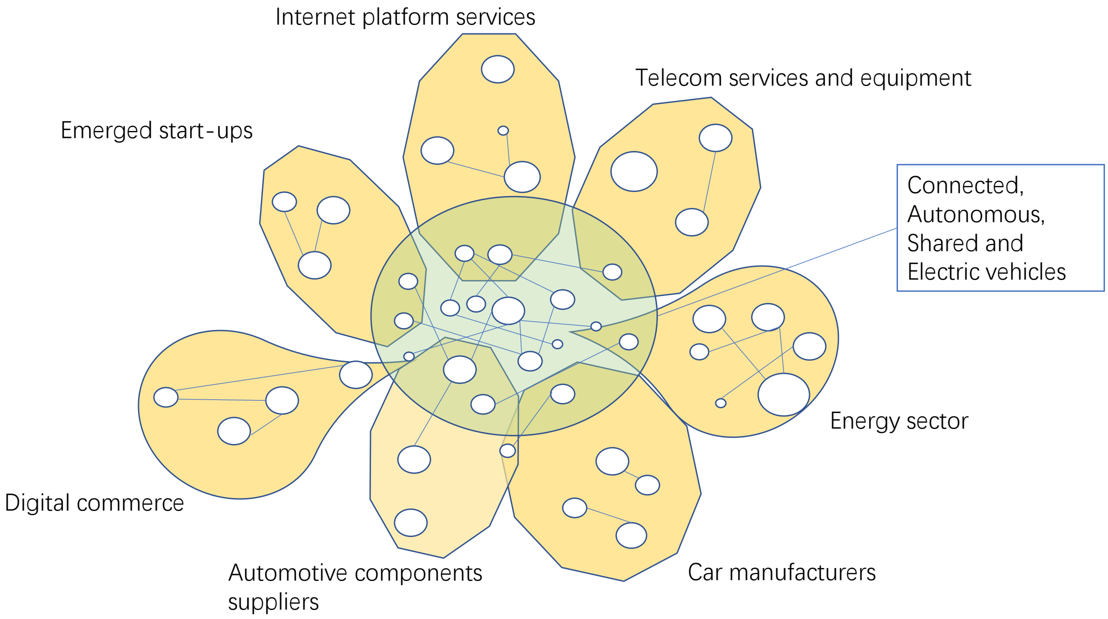
2005b, p.52). Therefore, he used actor-networks in the niche stage to explain the interplays in an existing network and with new technology innovations.




Source: (Geels 2002)

***Figure 2.6 The Multi-Actor Network***

Borrowing the conception of the multi-actor network from Geels (2002), Figure 2.7 shows the possibility of regime confluence and the role of business model innovation around the CASE concept of networks emerging. There are several regimes that are independent but collaborative under the socio-technical automotive system in which each regime defines the characteristics of inside elements. The fringe of each regime could be modified regarding the dynamic movement and extension from the inside elements. Therefore, the network relations both interior and exterior may vary over-time. The salient points to stretch to a novel territory could be very fine, partial or a large collection of the original section. These salient points are collectively intertwined so that they increasingly become a shaped (new) regime. In this case, the new emerged regime is triggered by the concept of CASE vehicle design and production. Each participant in the new regime contributes new elements but stems from the original regimes. It is worth remembering that the new shaped regime is stable-dynamic as the members and the relations in the regime are changing, but the general shape is kept from the initial conception.




Source: Author

***Figure 2.7 Regime Confluence and Business Model Innovations***

### 2.6.1 Network theory

To manage STT theory and the dynamic relationship networks in the business, the business ecosystem concept as an intermediate theory has been introduced. This ecosystem bridges across the multi-actor network in the STT niche level, the business regime confluence boundary in the regime level, the transitions to sustainability in the general socio-technical system level, and simultaneously, it helps to allocate environment in the automotive manufacturer context. The business ecosystem concept can be traced back to Moore (Moore 1993). On one hand, the business ecosystem notion contains all the elements businesses require e.g. suppliers, competitors, producers, other stakeholders, consumers, and new types of users (Jacobsson and Bergek 2011; Farla et al. 2012; Sarasini and Linder 2018). And on the other hand, it links the ecosystem concurrently at the other end of the relationship chain. However, the business sustainability transition cannot be achieved by single business alone (Lindgren et al. 2010). Business eco-system as an intermediate to bridge the gap between the transition and individual businesses (Lindgren 2016). This research, however, aims to study the collaborative and collective relationships between businesses (business-business network relationships) in STT transitions. The network theory has been chosen to identify the dynamic business relations in a general. It has been applied in the single-business centralised business clusters (core business cluster) and businesses between clusters. The core business clusters are demand-supply mode in that all businesses are around a single company such as in the traditional vehicle integration business (see Figure 2.8 a). However, suppliers may offer the products to several companies at the same time, this may cause potential links between two rivals (see Figure 2.8 b). This is an example of businesses between clusters. The main actors later may interact in between in a specific area, even though they were competitors. The autonomous vehicle is a typical example that all main competitors create a new area which attracts more actors in such area (see Figure 2.8 c). The arrows represent willingness directions to build a relation, and nodes are the joint where a new centre may occur. As the nodes grow, a giant network can be created regarding the more dynamic relations. The wider network and be a part of business ecosystem. See as Figure 2.9 which provides the inclusive relationship between these concepts.

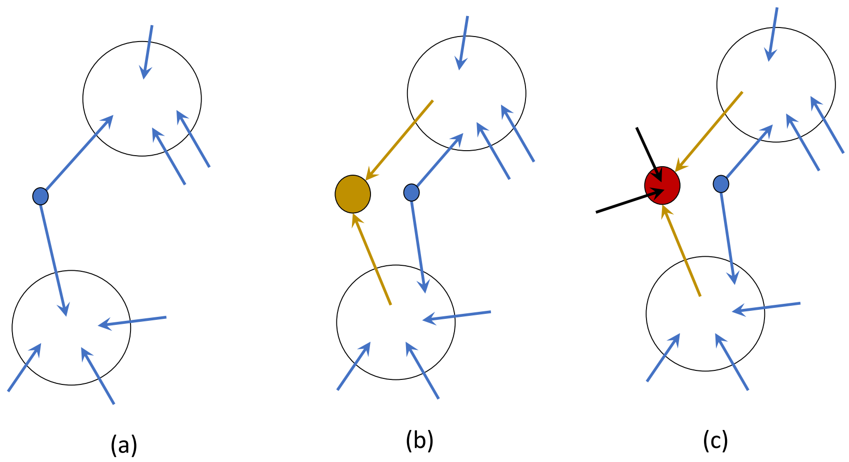
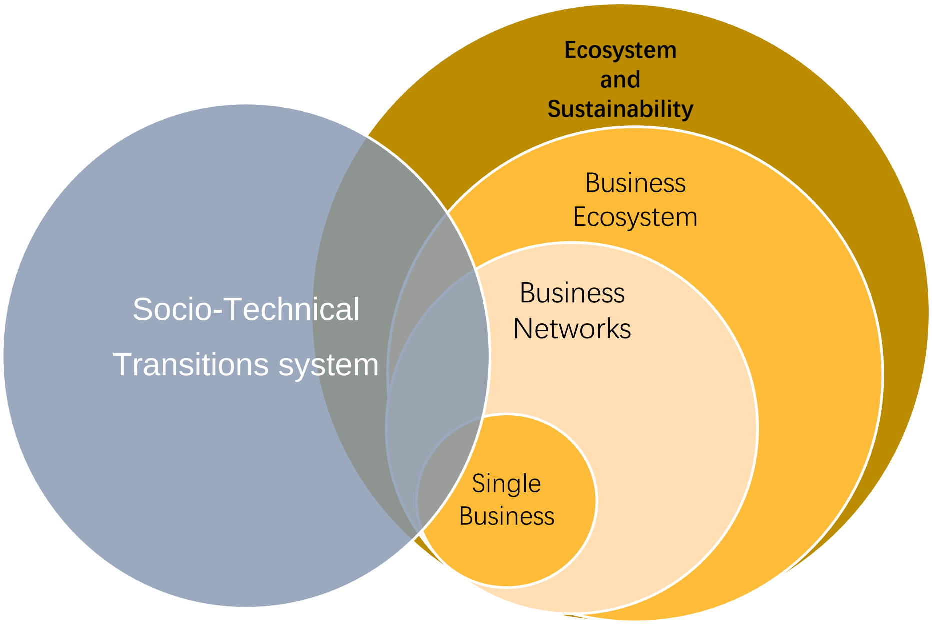



***Figure 2.8 The Relations Relation Clusters and New Business Network Immergence***

This study will illustrate the business ecosystem from a single viewpoint rather the global landscape which is from business-to-business network perspective. To allocate the collaborative and collective relationships between businesses (business-business network relationships) in the STT transitions is a new contribution in that few of studies have been done (Zott et al. 2011; Sarasini and

Linder 2018; Diepenmaat et al. 2020). Even though there is an overlap to achieve the sustainable business model (Stubbs and Cocklin 2008) and sustainable transitions, especially in the automobility arena. The characteristics of the business ecosystem is similar to the STT regime as they both are 'dynamically stable'. The relationships within business networks are evolutionarily changing over time, but generally keep the relations steady. Just because of the 'dynamically stable' characteristic, the system is updated, towards sustainability in a long term.




Source: Author

***Figure 2.9 The Relations Between Business Networks and STT***

Network theory crosses homogeneous subjects, ranging from engineering, biology, operations research, computer science, business studies, climatology to sociology including both natural science and social science (Provan et al. 2007). It is a bridge to connect components and clearly show the relationships in between. Network theory broadly focuses on two points: one is concerning network as an integration and another is emphasizing the nodes. If seen network as an entirety, network theory emphasises the integrity to the whole system and how this network works under a broader context. For example, the automotive industry is a network that involves components of suppliers, delivers, users, after-sale services and many other sectors. However, beyond these groups, the broader context is society, relevant policy, other interest groups and stakeholders, economic conditions, etc. How to handle a position in a such complex environment, therefore, becomes a key to survival for the automotive industry. If nodes are where more attention is concentrated, each node is vital and that is the key issue in logistics management for example. Lean operations require to simplify the route to eliminate redundant nodes. Nodes could be any points e.g. procurement, operations and management, sorting, packing, or delivering. It was introduced into logistics in recent years, having not such a long history as in sociology or biology. Since network theory has been included in logistics, it was highly adopted in route selection and optimization to reduce costs. If the network regarding as a whole network, the distribution of deliveries or warehouse selection relies on the entire network rather the single knot. There could be a key node that impacts the quality and stability of the whole network, if the core node suffers disturbances, the network might descend into failure (Cohen-Rosenthal 2000; Xiao et al. 2016; Harrison et al. 2018).

The network could work as three levels alternatively in terms of the size of the unit: interpersonal, interunit and interorganizational levels (Brass et al. 2004). Borgatti and Foster (Borgatti and Foster 2003) and Brass et al. (Brass et al. 2004) explored how to build, extend and develop an organization network. They investigated each level from many perspectives, such as: personality; the structure of an organization; job satisfaction and personal behaviours. It can be regarded as a micro transition theory that applied in the network bottom-up. The whole theory is based on a social net that illustrates from a working perception. It is a fact that we are living in a network society and each element may have a relationship to another one (Provan et al. 2007; Provan and Lemaire 2012). Here, the conception of organizational network theory in autonomous and connected vehicle industry could be borrowed and analysed from inner industry, intergroup and inter-organizational aspects. The socio-network and organization network are investigated more due to the clear hierarchy and configuration. It is easy to peal done and sort out the skeleton of entire institute. However, to format a new network and analyse it, is harder than comb an existing one.

Inter-organizational network provides an agency to illustrate conflicting or combing networks in many ways such as strategic alliances, partnerships, coalitions, joined ventures, consortia, agreements or even exchange relationships. Meanwhile, network theory provides the shared cognitive understanding and needs to agree on both the nature of the problem (in regime confluence). So, relationships in network clusters are competitive, conflicting and interest coexisting. Therefore, it creates a form of governance mechanism that seeks to reduce or spread risk and cost (Dickson and Weaver 1997; Podolny and Page 1998; Borgatti and Foster 2003; Brass et al. 2004; Provan et al. 2007).

Business network is stable but dynamic network which could be conversed in a moment, also could keep for a century. Öberg has evaluated the role of network and consequences of network in business innovation stage with its correlation of social ties and economic ties. Business innovations in her research have three types, incremental, radical and disruptive. In which, incremental innovations have strong ties with social and economic ties, and could absorb new ideas and link them to focal businesses. Radical innovations are aiming to change partners or compensate for business weakness with social and economic ties; while disruptive business innovations mean grafting a new business to an entity that is unable to create its own new business. Therefore, the author suggests that business should leverage the trade-offs between focal parties with new parties or obsolete, dissolved ties, to capture new value and enlarge business expansion (Öberg 2018).

Networks here are not randomly integrated networks, they refer to a shared interest, and ties that are beneficial to each other by way of alliances or collaboration, through which both sides could have a win-win outcome and where the network is tightly resonated in all stakeholders.

Theory combination such as business models with network theory, or social network with business models are more popular for the purpose of specifying and defining its effect. Neumeyer and Santos from organization (venture types and venture tenure) level and individual (network actors and demographic feature) level illutrate posibilities and challenges of transfermation from conventional business model to sustainable business model, combined with social network theory and business models (Neumeyer and Santos 2018). It results in conflicts that are observable between interest groups.

The reasons to use network theory rather social network or organizational network theory are various. The principal reason is that the unstressed network could cover wider a range of elements no matter the ‘nature’ of the elements rather finite on specified territory. In which case, an easier and better solution may be better to correspond with the STT theory. In addition, not all the elements in future cases (the future automobility industry) are located socially. The structure of future automobility is unclear. The dynamic nature of the partnership provides further non-determinacy beyond the social or inter-organizational network prediction. Another reason to choose network theory is that the conventional definition of network is nodes, ties and corresponding relations in between. Hence, the majority have one-to-one/more correspondence and vice versa. However, most of elements are unidirectional and these types of combination are covering all sorts of alliances, agreements, joined ventures, partnership. The relations are varied and fluid and not clear hierarchal. It is more likely to be called a network as a generic term. The last point is, it is difficult to tell the characters on each element, because they are organizational, business and sociality. Based on the above factors, the author would purify the interrelationship and network as purely ‘network theory’.

## 2.7 Conclusions

This chapter highlighted socio-technical transitions theory, the original theory, the pathways and its relevant other theories. Additionally, along with the regime dynamics collaboration, new business models and networks come from the interaction edges. We thus can see that in transition theory social systems are dynamic stable, but there are also mechanisms for change. All this leads to some research propositions. We can propose that:

a) Business model innovation is an important enabler of regime shift, despite some reservations e.g. very different time scales of analysis.

b) Competing inter-organisational networks of varying scale, exclusivity and resilience are likely to emerge in an attempt to manage uncertainty. Not all will be successful in this.

c) The resultant new regime may comprise incumbents from existing regimes and genuine new entrants to various degrees.

d) What is less certain is whether there will be a single dominant regime as an outcome… or when such an outcome may materialise.

# Chapter 3
# The Historical and Political Context

This research lies in the domain of the automotive industry, which is composited of three basic elements: users; infrastructures and vehicles. However, it is policy which is the mechanism that consistently impacts on all on-road users (Auvinen and Tuominen 2014). Connected, autonomous, shared and electric (CASE) vehicles are a new emergent vehicle group, which notably need the supportive regulations and government could play an active role in accommodating the long-term and short-term goals of the sector; this support is essential, especially in the transition stage (Rotmans et al. 2001). The chapter is organised as follows: it opens with a brief introduction (Section 3.1); this is followed in section 3.2 by a general background to the policy on vehicle emissions; an overview of actions taken in the European Union are discussed in section 3.3, followed by the policies of the UK, Germany, France and the US respectively (Sections 3.4, 3.5, 3.6 and 3.7). Whilst these countries play a more active role than others, the Chinese market cannot be ignored; therefore, this market is discussed in Section 3.9. It is important to consider that policies pervade to other sectors, such as the insurance, repair and finance sectors; therefore, this is discussed in Section 3.9. Lastly, there is a summation of the discussion and a conclusion in Sections 3.10 and 3.11.

## 3.1 Introduction

CASE vehicles with their nascent technologies could compensate for the numerous drawbacks of traditional vehicles. However, in terms of local culture, technological embracement and acceptance rates, relevant rules and regulations vary from country to country. Therefore, targets to integrate CASE vehicles also vary, with each country having a priority to promote one or more features to coincide with its domestic circumstances. Hence, relevant law has been correspondingly constructed federally and municipally. The proposed and published regulations have been thoroughly examined by researchers, producing reliable evidence, and in time, as has happened with emissions testing, more global standards in this area will emerge.

Car manufacturers often declare that future vehicle technology development aims to improve sustainability (Audi 2019; BMW 2019b; Volkswagen 2019; Volvo 2019a). This sustainability is achieved through using recycled materials, service-added value chain, alternative energy powertrain, in-car and inter connection, car sharing schemes and related innovations, either on their own or in combination. This discourse emerges as a response to ‘landscape’ pressures on the automotive industry, for example concerns over climate change, urban air quality, congestion, lack of parking spaces, deaths from car crashes. The discourse also allows the regime participants to lobby for resources (especially from government as in R&D programmes), and to improve legitimacy with investors, car buyers, and the public. Hence, vehicle manufacturers invest in, and make public relations announcements about, these technologies to show that they are doing something to make car use better, less harmful, or even more pleasurable.

Connectivity in vehicles provides entertainment, safety and comfort; this functionality has gradually become a necessity, for example to identify in real time the availability of a public electric charge point. Connectivity in this manner may lay the foundations for all the other three features. Enhanced technologies enable cars to be safer, so that autonomous vehicles will become latent lifesaving tools to all road users because driver errors are the most common cause of crashes. Therefore, ‘driver-less’ is one of the best solutions for safe driving in that it replaces the human drivers by computer systems with fewer crashes and injuries (Wells and Beynon 2011). Value-added supply chain is additional value obtainable from the vehicle manufacture viewpoint; it also shares the environmental burden to more end-users if vehicles are shared. The fleets-as-services could also help users to save maintenance fees, insurance and fuel charges, without having to worry about other issues such as parking.

All above CASE elements were identified and officially integrated as a concept by Daimler (2016). Daimler therefore acted as a leading company who lifted the CASE concept into the public discourse as a future transformation in the transport sector. Many other automotive companies have also been active in talking about and investing in the relevant concepts, as have many leading consultant organisations. The many efforts pioneered by the industry are explained later in the individual cases in Chapter 6 Section 6.2. These four elements are individually developed, while they are later gradually mutually helped and inter-supported. CAVs (Connected Autonomous Vehicles) as an example of a slightly different focus, as illustrated in Dan Sperling's book 'Three Revolutions' (Sperling 2018). Like Daimler declared, the CASE vehicle is evolutionary while the prize "lies in the interlinking of all of this" (Daimler 2016).

A general outlook of policy is discussed in this chapter. However, as the variety and the distinctiveness of policy is evident in different countries, several selected areas are discussed. These selected areas are representative of the range and scope of initiatives worldwide, for countries with a highly developed automotive industry and highly developed transportation sectors using CASE vehicles to reach sustainability. CASE vehicles are supported by either established regulations and rules, or other ways such as the newly established institutions and governmental funds. The selection of cases emerged out of the process of gathering information from the academic literature, secondary sources and the grey literature. In particular, the selection process focussed on those countries that had innovative policies and support mechanisms designed to assist one or more of the elements of CASE vehicles, usually with the premise that this support would also benefit the industrial base in the country concerned. Therefore, these countries were considered to be likely locations to lead innovation in CASE vehicle design and deployment, and be at the forefront of global changes.

The U.K. and the U.S. obtain political support for autonomous and connected vehicles, nationally and federally. The U.K. government established the Centre for Connected and Autonomous Vehicles (CCAV) in 2015, which comes under the domain of the Department for Transport and the Department for Business and

Energy & Industrial Strategy (CCAV 2015a). National legislation regarding autonomous vehicles in the US is a general guiding principle of the US Department of Transport (USDoT 2016). Meanwhile, the National Highway Traffic Safety Administration classifies the levels of autonomous systems and governs safety and performance (NHTSA. 2013). Also, ICT companies in Silicon Valley catalyse the integration of automation and robotization technology to mass-market commercialisation (Glade 2000). Germany is one of the cradles of vehicle production and consumption; thus, car manufacturers play an essential role in the integration of new features into new models and their penetration into the market. Therefore, the German car manufacturing industry has facilitated policy within Germany (Hetzner 2018). The EU has a joint commission where policies outlined in a general framework are to encourage member countries to contribute more to reducing $CO_2$ emissions. This includes measures such as charging station construction and renewable electricity generation (EU electric vehicles 2018). In contrast, China is more renewable energy focused, in their aim of reducing greenhouse gas emissions. Policies and regulations are detailed and localized to solve local urgent problems with long-term projects. For instance, the Beijing car-pooling policy aims to relieve heavy traffic congestion, emissions and improve air quality; Taiyuan, the capital of the Shanxi province which is famous for coal mining, has been encouraging electric taxis to replace traditional taxi fleets to create cleaner air condition (Asian Development Bank 2018).

Policy and regulations serve as a strong backup for new technology to boost end-user market growth methodically. Although they lay the foundation for better and safer on road driving surroundings, on-demand service may perform beforehand the rules and regulations, e.g. popularity of electric bikes/scooters in China (Wells and Lin 2015). Nevertheless, the on-demand service may create a niche market for potential technology and could be an extension of the current market. New technology permeates users' daily experiences to gradually challenge consumption behaviour and attitudes; potentially, it will establish new rules of behaviours and habits. Car sharing and pooling services could be paradigms that offer an additional means of transportation. As a value-added service for vehicle manufactures, sharing schemes offer the additional possibilities for vehicle use and reuse while the manufacturer retains ownership. For end-users, shared vehicles provide a wider selection of vehicles and more flexible options on travelling choices, often without the difficulties of maintaining the car, finding parking spaces, and related ownership costs. It potentially challenges the current transportation system, perhaps more so on the side of public mass transportation (Wells et al., 2020) and delivers a challenge for the future travelling culture. Thus far, car sharing has not generally been integrated into other transport systems, so the idea of cars within a 'mobility as a service' concept remains to be put into practice. At the moment, car sharing offers vehicle manufacturers a way of expanding the market, but is on a small scale. Hence, many relevant policies should be amended or added correspondingly e.g. car sharing and autonomous vehicle testing.

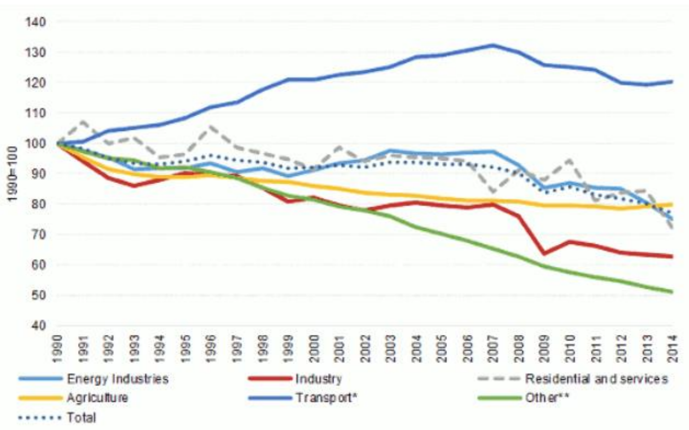
Overall, this chapter demonstrates the policy transition history by considering the following aspects of the autonomous vehicle sector: machinery connectivity; electric vehicles and relevant infrastructure promotion; car sharing, rental and pooling schemes (and its extension services), and the transformation of the technology industry. In order to provide supportive evidence, financial and societal impact are highlighted at the end of each section.

## 3.2 Background

Climate change has been a topic of discussion for decades, official and non-official organisations and institutions have allied to tackle the issues in an effort to prevent global temperatures from increasing by more than 2$^{o}$C. The United Nations Framework Convention on Climate Change (UNFCCC) was founded in 1979 when the first World Climate Conference (WCC) took place in Geneva. It was the most global and authoritative organisation to become responsible for encouraging all nations to deal with climate change. The Kyoto Protocol, the agreement followed by UNFCCC, which was settled in 1997. It aimed to decrease emission contributions by 5%, as compared with the level in 1990, with the participation of 37 countries and ended in 2012. The target settled upon in the Kyoto Protocol was completed successfully; notably, it was the UK which contributed to the highest emissions reduction (12.5%) (The CCC 2015; UNFCCC 2015).

The Paris Commitments is an essential milestone to decelerate global warming, which starts officially in 2020. This is the latest, and first-ever universal agreement, against climate change (although some key nations, such as the USA, did not agree to sign). Since then, every 5 years, all representatives will meet together to review the past years' performance and set new/higher targets for the next stages, as necessary, to reach the overall target by the end of 2050. It requires the member countries to minimise their emissions contributions from different perspectives, e.g. transportation and industry. Notably, the agreements set general rules for each country to coincide with its local circumstances (Paris Agreement 2016).

Although the total $CO_2$ distribution is decreasing, the transport sector contributes far more $CO_2$ than other sectors and has been averagely increasing since 1990 (Figure 3.1), the transportation sector here includes aviation and road transport; this not only means the overall miles of travelling are gradually increasing, but it also implies the travelling pattern may have been changing incrementally since 1990 (European Environment Agency 2016). This research examines the transportation sector's efforts to introduce CASE vehicles, one of the extensions to the traditional vehicle market. Essentially, this research addresses the changing patterns and new models of consumer behaviours.




Source: Global $CO_2$ contribution by sector (European Environment Agency 2016)

***Figure 3.1 Global $CO_2$ Contribution by Sector***

## 3.3 Actions in the European Union

The EU Climate Actions set in 1990 are the standard and the reference point for greenhouse gas emissions and atmospheric temperature reduction. Ideally, the action appealed to all countries to produce less emission charges to the air so that the temperature could be cut down, as much as possible, to the to the level of 1990. This is because since 1990, the average atmospheric temperature has surged rapidly, owing to the fact that human activity, movement and renovation technology have increased considerably. Targets have been set as ‘phases’ and are defined as each 10 years period: short-term (10 years); middle-term (20 years) and long-term (30 years), up until 2050. Before 2020, the EU appealed to cut 20% of total energy consumption and 20% greenhouse gas exposures, and a 20% increase in energy efficiency. The short-term target is to 2030: greenhouse gas emissions to be further cut by at least 20%, at least 27% of total energy consumption from renewable energy, and a 27% upsurge in energy efficiency. The long-term goal covers the period up to 2050: excessive exposure gas should be reduced by 80-95% compared to 1990 levels and to a half of 2010 levels (The CCC 2015; EU climate action 2016).

Reducing GHG emissions and reaching the agreed target at each phase will be a difficult task for all countries involved, notably for developing and economically disadvantaged countries. However, significant financial help is provided by the European Commission. The EU, as a united alliance, financially supports its member states by providing a funding injection of at least €200 billion during the period of 2014-2020: around 20% of the EU budget. In 2016, the investment was scaled up with a total dedication of €20.2 billion, which amounts to a significant increase that that of the precious few years, this figure is set to be met until the end of 2020 (EU climate action 2016; EU climate action 2017b). Various initiatives have also been created to provide funding for developing countries outside the EU. The Global Climate Change Alliance+ (GCCA+), another EU initiative, aims to support developing countries, and at the time of writing, has invested €450 million, covering more than 60 national/regional actions. The GCCA+ aims to support its EU neighbours and African countries with over €44 billion by 2020. Another initiative, the Green Climate Fund (GCF) is a universal funding body founded in 2010, which has been set up to support developing countries in their efforts to achieve a subsiding emanation charge. According to the European Commission, since 2014 the GCF has received pledges of USD $10.3 billion, the EU member states contributing almost half of this total, USD $4.8 billion. Its Horizon 2020 project has funded €1.6 billion in vehicle low emission projects. Further investment has been provided by the European Fund for Strategic Investment and the European Structural and Investment Fund €12 billion for low-carbon and sustainable urban mobility (EU climate action 2016; European Environment Agency 2016).

Countries in Europe are encouraged to green vehicle usages and behaviours. For instance, car users are urged to share and use low, or even zero, emission vehicles and to explore alternative fuel powered vehicles. To solve the low market penetration rate of electric vehicles in the market (5%), large investments are injected. Infrastructures are invested in government and car manufacturers, and shared electric vehicle schemes are encouraged (European Commission 2017; Daimler 2018; Matlack 2018). The EU is the second largest passenger car production community in the world, accounting for more than 20% of the global total in 2017 (ACEA 2018c). Therefore, effective control of emissions from passenger cars is vital. Table 3 lists the code and year of Europe emission standards; the initial limitation elements include CO, HC, $NO_x$ and PM but HC and $NO_x$ are calculated as a mixture. However, a year by year, more detailed and restricted evaluation to each element is needed. Since 2005, diesel particulate filters (DPF) are gradually introduced in diesel vehicles to further filter the exhaust soot that is discharged directly into the air directly.

***Table 3 EU Emission Progress***

| Code | Petrol | Diesel | Item |
|---|---|---|---|
| Euro 1 (EC93) | CO: 2.72g/km<br>$HC+NO_X$: 0.97g/km | CO: 2.72g/km<br>$HC+NO_X$: 0.97g/km<br>PM: 0.14g/km | Available for new cars registered after 1 Jan 1993<br>Ready for lead free gasoline and catalytic converters |
| Euro 2 (EC96) | CO: 2.20g/km<br>$HC+NO_X$: 0.50g/km | CO: 1.00g/km<br>$HC+NO_X$: 0.70g/km<br>PM: 0.08g/km | Available for cars registered 1 Jan 1997 afterwards<br>Decreasing all allowance emission quote |
| Euro 3 (EC 2000) | CO: 2.20g/km<br>HC: 0.20g/km<br>$NO_X$: 0.15g/km | CO: 0.64g/km<br>HC: 0.56g/km<br>$NO_X$: 0.50g/km<br>PM: 0.05g/km | Available for cars registered after 1 Jan 2001<br>Independent requirement for HC and $NO_X$ |
| Euro 4 (EC 2005) | CO: 1.00g/km<br>HC: 0.10g/km<br>$NO_X$: 0.08g/km | CO: 0.50g/km<br>$NO_X$: 0.25g/km<br>PM: 0.025g/km | Available for cars registered after 1 Jan 2006<br>Discharging of PM and $NO_X$, meanwhile introducing DPFs which capture 99% PM. |
| Euro 5 (EC 2011) | CO: 1.00g/km<br>HC: 0.10g/km<br>$NO_X$: 0.05g/km<br>PM: 0.005g/km | CO: 0.50g/km<br>$HC+NO_X$: 0.23g/km<br>$NO_X$: 0.18g/km<br>PM: 0.005g/km<br>PN [#/km]: 6.0x10 ^11/km | Available for cars registered after 1 Jan 2011<br><br>All diesel vehicles are compulsorily having DPFs, limitation also did for NG-DI engine |
| Euro 6 (EC 2015) | CO: 1.00g/km<br>HC: 0.10g/km<br>$NO_X$: 0.05g/km<br>PM: 0.005g/km<br>PN [#/km]: 6.0x10 ^11/km | CO: 0.50g/km<br>$HC+NO_X$: 0.17g/km<br>$NO_X$: 0.08g/km<br>PM: 0.005g/km<br>PN [#/km]: 6.0x10 ^11/km | Available for cars registered after 1 Jan 2015<br><br>$NO_X$ from diesel vehicles should be less than 67%, also have limitation of PM from petrol vehicles. |

Source: (Evans 2017; Autoevoke 2018; EU Emission Standards 2019)

Notes: all car manufacturers allowed to use Euro 6 two techniques for 1) using liquid catalyst transform $NO_X$ to hydron 2) exhausted gas recovery devices reduce the formation of $NO_X$. (Evans 2017; Autoevoke 2018; EU Emission Standards 2019)

The code acts well under the control of EU emissions. According to the research results from SMMT, since 1993, CO decreased by 82% and 63% for diesel engines and petrol engines respectively, and PM decreased by 96%. Since 2001, $NO_X$ has decreased by 84% and HC decreases by 50% in petrol engines (EU Emission Standards 2019).

The new regulations *Regulation (EU) 2019/631* were adopted and implemented from January 2020 for declining $CO_2$ emissions. The new regulation stipulated the manufacturer fleet average $CO_2$ emissions for passenger vehicles (95g/km) and light commercial vehicles (147g/km), with requirements from all manufacturers to meet the target by 2021 (EU climate action 2017a). Since 2020, the tighter target restricts the emission limits by attaching financial penalties: fines, vehicle emissions if higher than the standard set will be charged €95 per gram $CO_2$/km. In addition, a reward mechanism is implemented, when a vehicle emits a super-low emission discharge, i.e. $CO_2$ sub-50g/km, it will count as 2 vehicles in 2020 and 1.67 vehicles in 2021 (Middleton 2020).

Apart from the restriction on CO, $NO_X$ and PM discharges, EU members largely agreed to support alternative fuel vehicle promotion. Correspondingly, the infrastructure constructions are required to be sufficient. For instance, a recharge point should be offered for every 10 electric vehicles, and a fast charger station is needed every 40 km on the highway (EU recharging infrastructure 2018a; EU recharging infrastructure 2018b).

***Table 4 Targets Submitted by Member States***

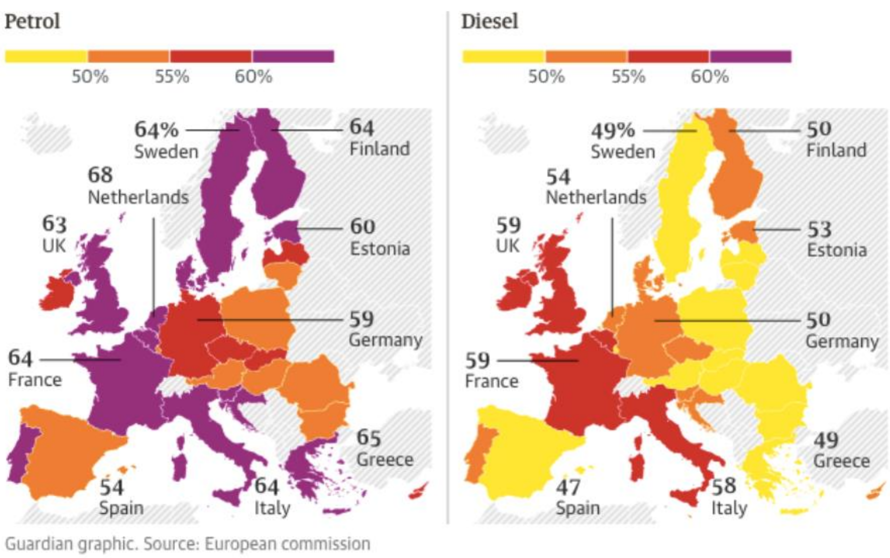
**Targets submitted by Member States** *(out of 23 NPFs)*

| | | CNG | LNG | LPG |
|---|---|---|---|---|
| Vehicles | 21 | 11 | 6 | 4 |
| Infrastructures | 22 | 21 | 19 | 4 |

Source: Targets submitted by Member States (out of 23 NPFs) (EU recharging infrastructure 2018a)

The Clean (2nd) Mobility Package was published in November 2017 to implement the transformation to low emissions. The Package proposed that Alternative Fuels Infrastructure (AFI) should be included in their National Policy Framework (NPF) to further replace the traditional combustion engine vehicles. In the AFI, it is suggested that each member country submits its NPF with an estimated target of infrastructure development recharging (electric), refuelling alternative gas (CNG, LNG, LPG) points and relevant automobility sales. Although not all member countries submitted their NPF, among the countries which proposed for their NPF (Table 4), the vehicle electrification transformation was given the most consideration. However, CNG/LNG/LPG are still given less consideration than vehicle electrification, both on infrastructure development and vehicle sales and improvement (EU recharging infrastructure 2018a). Nonetheless, in 2017, the sales of low or none emission vehicles were still much lower than the target (China Electric Vehicles 2018).

Except for the incentive mechanisms, governments in the Eurozone have endeavoured to increase petrol and diesel tax on crude oil in order to decline fuel usage to indirectly hit the target of $CO_2$ reduction. Figure 3.2 reveals the major fuel tax added by EU countries, labelled by percentage and colour from dark purple (highest) to light yellow (lowest). The tax added in the highlighted ten countries are: an average 62.5% on petrol and 52.8% on diesel.

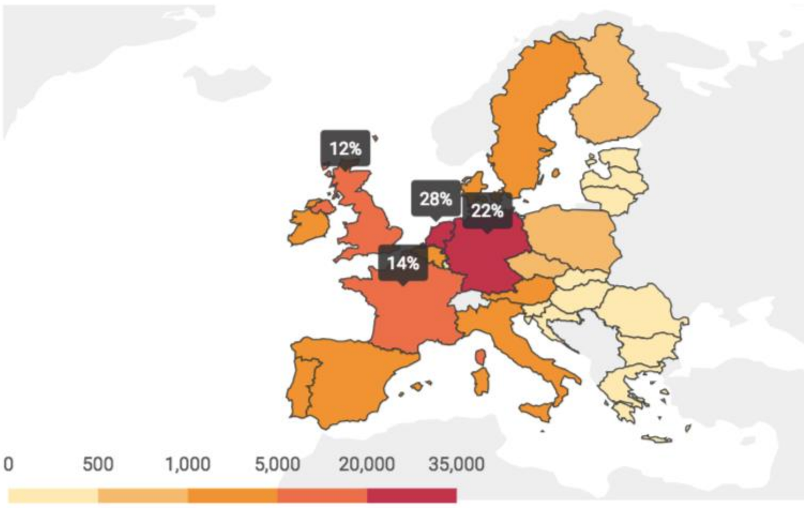



Source: (Jolly 2018)

***Figure 3.2 Maps of Fuel Taxes in the E.U. Area***

BMW, Daimler, VW, Ford have created Ionity jointly along with the EU to build a fast-charging network along the main high-speed motorways in Europe (Stumpf 2017; Tovey 2017). They propose the ratio of electric vehicles and charging points should be 5:1, with 220,000 chargers by 2020 (EU recharging infrastructure 2018a). Figure 3.3 shows the charging points map with the highest permeation among the EU countries, led the Netherlands and Germany: 28% and 22%, respectively. France and the UK follow, with half the rate of permeation:

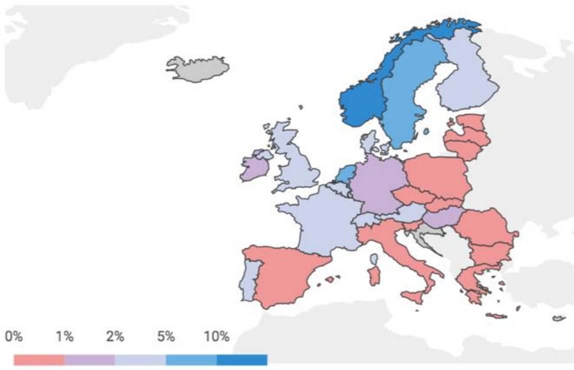
14% and 12%, separately. Nevertheless, these four are the highest countries that have over 70% of the electric charging infrastructure in the EU. The Netherlands, Germany, France and the UK are keen to push electric vehicle adoption through a high capability infrastructure, with 32,875, 25,241, 16,311 and 14,256 charging points available by the first half of 2018. However, the land area of these four countries only occupy 27% of in overall EU countries land area (ACEA 2018a), which implies that other EU countries have a huge potential to invest more in electric and other basic infrastructure construction. The numbers of charging points in these four countries are increasing, but the permeation has changed little over a year. By the end of the first half of 2019, the share of electric vehicle infrastructure is decreased in the Netherlands (26%) and Germany (19%), whilst France (17%) and the UK (13%) increased with over 5000 charging points having been established (ACEA 2019).




Source: (ACEA 2018a)

***Figure 3.3 EU Charging Points are Mainly Located in Just Four Countries***

However, the above charging points map does not include the data on Norway. Norway is the country which has the highest electric market share worldwide (49.1%). Figure 3.4 shows the EV market share in the EU and EFTA member states, in which, apart from the highest EV penetration Norway, Sweden (8%) and the Netherlands (6.7%) are the two countries at the top of the list. However, other than these three countries, all remaining countries have an EV market share lower than 5%, or say, even averagely less than 3% (ACEA 2019). France, Germany, the Netherlands and the UK are highly promoting the charging points, which strongly stimulates the adoption of such vehicles; nevertheless, the results are not satisfactory. Up until 2018, the UK had 2.5% electrically chargeable vehicles on the market, which included all types of electric powered vehicles (i.e. including hybrids). Notwithstanding, it is a good sign that some governments are helping with EV adoption, and it is these countries which will have a higher permeation ratio in the very near future.




Source:(ACEA 2019)

***Figure 3.4 Market Share of EV 2018***

The relevant incentives (both financially and non-financially) have been announced accordingly in the EU except for four countries (see Figure 3.5). This is the most direct and correlative method to encourage car users to purchase such vehicles, by offering lower excise duty, or other forms of enticements. For instance, in the UK, vehicle excise duty is free if the car has a zero discharge rate. Incentives differ greatly from the country to country, and types and usages of vehicles. In the four countries without EV incentives: Estonia; Lithuania; Poland and Croatia, the market penetration is low: 0.2% for the first three countries and Croatia is without data (ACEA 2018b).


Source: (ACEA 2018a)

***Figure 3.5 Incentives for Buying Electric Vehicles Per Country***

According to research in China (China Electric Vehicles 2018), $CO_2$ emission targets lead to increased employment; a 30% reduction in $CO_2$ could offer 5 times higher employment rates, compared to jobs lost: 22,000 gained and 4000 jobs lost by 2030. If emissions decreased by 40%, jobs creation would rise by approximately 88,000, this mostly depends on electric vehicle development e.g. the technological improvement of battery cells. Overall, $CO_2$ emission decline will have a positive impact on both the economy and the environment.

To summarise, the EU as a joint union, does offer many incentives, rules and regulations to achieve vehicle electrification, but there are no unified guidelines to push connected, autonomous and shared vehicle schemes. Vehicle electrification is agreed by all EU members while to achieve the CASE from all perspectives consensus is less possible. EVs have reached the point of deployment, so most action and support now is about regulation, standards (e.g. for charge systems), and funding for new investments in e.g. battery production factories. Connectivity is partly related to the roll out of 5G. Automation is still not market ready, so most initiatives are national in character (e.g. changing the law to make it legal; funding experiments), but also with some R&D at EU level (INEA 2015). However, several countries in the EU have published relevant protocols in autonomous, connected and shared vehicles to further vehicle sustainability, and additionally, towards the transformation of vehicle-as-a-service. The transport system in the EU is efficient and smart, and accelerates lower and zero emission vehicle adoption; relevant technological development therefore further encourages energy transformation. However, policy and incentives should not only be limited to the transition of emission discharges, non-emission travel such as cycling and walking should also be encouraged by municipal government. Public transportation and car sharing/pooling/rental scheme should gradually be normalised and integrated into the current transport system, all of which would make transportation run more smoothly and efficiently (European Environment Agency 2016; European Commission 2017).

## 3.4 The UK Policy

The UK has contributed a significant portion in the process of decreasing gas emissions around the world. A government report shows that it strictly followed the track of the given target for carbon budgets (Figure 3.6). Indeed, up to 2016, UK greenhouse gas emissions were reduced by around 42% compared to the level in 1990, and it achieved its goal in advance of the target date (CCC Carbon budgets 2017).

| Budget | Carbon budget level | Reduction below 1990 levels |
|---|---|---|
| 1st carbon budget (2008 to 2012) | 3,018 MtCO2e | 25% |
| 2nd carbon budget (2013 to 2017) | 2,782 MtCO2e | 31% |
| 3rd carbon budget (2018 to 2022) | 2,544 MtCO2e | 37% by 2020 |
| 4th carbon budget (2023 to 2027) | 1,950 MtCO2e | 51% by 2025 |
| 5th carbon budget (2028 to 2032) | 1,725 MtCO2e | 57% by 2030 |

Source: (CCC Carbon budgets 2017)

***Figure 3.6 UK Carbon Budgets***

*Funding*

CASE elements are strongly addressed separately through funding injection to reach the general goal of sustainability and de-carbonisation by the UK

Government. Investments are in the power sector, buildings and transport that will be scrutinised in later sections. The UK government has funded investment over £30 million, with 21 research projects in 2016, £93 million in 25 projects and £102 million for four Testbeds in 2017, and more investments from diverse sectors involved later. By 2021, £200 million has been invested in CAV projects by the government; vehicle manufactures and technology companies also inject the investments into autonomous vehicle R&D with additional £300 million (CAV projects 2018; Trueman 2019; CAV projects 2020; Cruse 2021). One of the merits of the smart grid is that it could autonomously adjust charging time to avoid electricity peaks, which relieves the pressure on electricity demand (DfT (V2G) et al. 2018).

*Projects*

Other than investment in the smart grid, a connectivity and autonomous vehicle centre has been established to promote the usage of new technology (CCAV 2015a; CAV projects 2018). This centre is studying, investigating and applying the autonomous and connection technologies into the latest circumstances to help test if it reaches environmental sustainability. With government support, a three-phase project was proposed from 2014 to 2018 with £120 million government investment and a £68 million contribution from industry. The UK government has partnered with automotive manufacturers, high-tech companies, research organisations, insurance sectors and universities: involving over 70 projects and more than 200 partners.

The first phase (CAV1) ran from 2014 to 2016, it was the pilot R&D phase before the establishment of the Centre for Connected and Autonomous Vehicles (CCAV). Connectivity, autonomy and customer interaction were the main themes of the first stage investigation. The second phase (CAV2) started in November 2016, which provided solutions that offer a better transport system to road users. In this stage, autonomous vehicles are required to reach level 4 autonomation, which means highly automated vehicles, enabling vehicles to be operated in various environments. Meanwhile, connected and autonomous control systems are required to improve the efficiency of energy usage and thus, new business models are generated to deal with supply chain relationships around the U.K (CCAV 2015a; DfT 2018).

From July 2017 forwards is the third phase of CAV projects. In this stage, projects are more focused on business development and practical solutions to customer's problems, laying the foundation to the further core technology development from 2020 to 2025. This stage involves more on and off road testing to solve the issues on SAE level 4 autonomous vehicles (CAV projects 2018). In July 2018, the UK government outlined a picture for future transportation for which £12.1 million funding is offered for a further 6 projects. These projects highlight the benefits, coinciding with the cleaner environmental protocols which promote the autonomous, connected, electric and car shared schemes to reshape customer attitudes, travelling patterns and the emergence of new business model (DfT 2018). In 2018, the government announced that future mobility services in the UK will become the best transport service in the world (DfT 2018).

Relevant protocols and codes have been published to support the above activities. The Code of Practice was declared in 2015 and updated in 2019 to help and guide both technology developers and testers to build a better and safer system for autonomous vehicle driving and testing. It was affirmed by the government that the UK has such ability and possibility it is possible to build and develop a better automobile system (CCAV 2015b; CCAV 2019).

*General impact*

To further address the safety issues and reduce emissions, vehicles are sold with enhanced features. More than half of vehicles sold in 2015 were equipped with an assistance system, limited automation and/or connected safety features, and the number is steadily increasing. Based on the research from the SMMT, the advanced features on vehicles will impact significantly on the UK society, economy, industry and the environment in the long term. By 2030, about 25,000 additional jobs relevant to automotive industry will be created. Economically, a £51 billion societal value is added annually on the basis of 2014 prices (Figure

3.7). More importantly, 2,500 lives would be saved, and 25,000 serious incidents would be prevented in the period between 2014-2030. Autonomous vehicles are being tested in selected region, for example in Bristol, Milton Keynes and West London. Also, fuel consumption, exhaust discharge diminution, cleaner mobility, traffic congestion and motorway efficiency are significantly influenced (SMMT 2018).

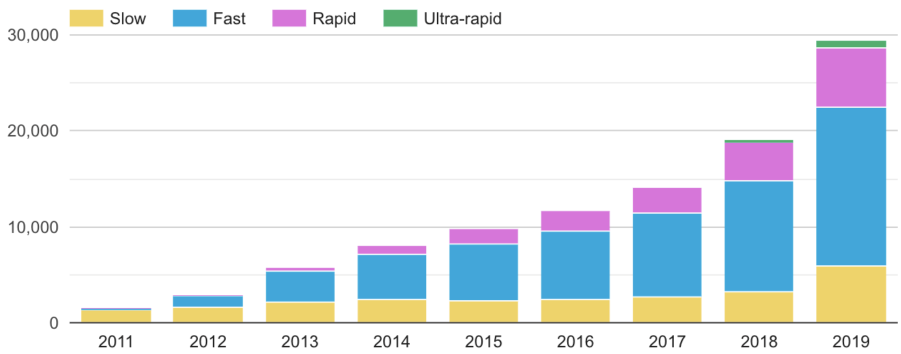

Source: (SMMT 2018)

***Figure 3.7 UK Economic Impact of Connected and Autonomous Vehicles 2014-2030***

*Electric vehicles*

As one of the main targets for de-carbonisation contributors in the EU area, electric vehicles also have been seen as the most accessible alterative to petrol and diesel fuel consumption. Authorities work with other stakeholders to support electric vehicles' buying, selling and recycling in different ways, such as lower tax or no taxation on EV selling, establishing the zero emission zones, and rapidly constructing charging point networks. EV sales in the U.K from September 2018 to 2019, saw the market share rise, especially in battery electric vehicles (BEV): from 0.6% in 2018 to 1.3% in 2019, followed by hybrid electric vehicle (HEV): from 3.5% to 4.2%. However, diesel- and petrol-powered vehicles still seized the largest share of the UK market: 25.8% and 65.4% respectively. Nonetheless, total sales in the UK dropped by 2.5% owning to less diesel and plug-in hybrid electric vehicle (PHEV) sales (Kane 2019c). The registration of electric cars were on average 1,000 higher per month in 3 consecutive years, with the number of just under 4,000 monthly in 2017, to just above 5,000 in 2018 and 6,100 in 2019 (Lilly 2019).

By the end of 2019, there were 265,000 plug-in vehicles in the UK, plus 8,7000 plug-in vans, but only 29,514 public charging points by the same date (Figure 3.8). The lack of charging points is a common issue worldwide. As discussed, (see Figure 3.3), the charging point installation rate in the UK is at second place in the EU. The result can be seen in Figure 3.7, which illustrates that the charging market is growing, especially over the last two/three years, led by the fast charging and rapid charging types (Lilly 2019).




Source: (Zipmap 2020)

***Figure 3.8 Charging Adaptors by Type***

*Infrastructures*

The 5G Internet network is imbedded in the strategy of next-generation digital infrastructure development, selected by the government's industrial strategy with funding of £1bn. In late 2018, 5G hubs (or a 'Smart City Mobility Centre') has been announced, it is to be established in the West Midlands with £50 million in funding support, from which £25 million came from local and regional sponsors, the rest was supported by the Department for Digital, Culture, Media and Sport (DCMS). Warwick University campus, one of the test pots for autonomous, connected and electric vehicles, is also in the 5G network trial basement. This university works along with the British car manufacturer Jaguar Land Rover, exploring capabilities of the next generation digital revolution in transportation and its potential benefit to the economy, working flexibility and life convenience (UK Government 2018; WMG News 2018).

### 3.4.1 The London municipal government

London is the capital of the UK, with one of the highest population density cities in the Europe area, in the top 4 in 2020 (Statista 2020b); it also has the most mature and complex on/under-road transportation system. The public road system is under great pressure, London lacks a strong cycling network and culture to apportion pressure. In addition, petrol- and diesel-powered vehicles are restrained in the London emission zone. The constrained land use, complex transport system and highly demographic is helpful for developing CASE vehicles.

London has established ultra-low emission zones, low emission zones to green the city centre environment (TfL 2008; TfL 2009). The congestion charge fee (£12.50 at the time of writing) for all higher emission vehicles is charged to restrict polluted vehicles to enter the centre of London. As well as a 15 pence “Clean Air Fee” that is charged per mile if in the limited “clean zone” area. In the long term, the UK policy will ban all new petrol and diesel vehicle sales including hybrids after 2035, ahead of rules as applied in other EU countries such as Spain (Jolly 2018). In catering for London municipal policy, Uber plans to invest more than £200 million to enact a “Clean Air Plan”. 20,000 drivers are encouraged to drive pure electric vehicles by 2021, and by 2025 Uber will run all its vehicles as electricity powered (Pyper 2018a; Stumpf 2018). Additionally, traffic congestion and the complex road conditions provide the possibility that traffic issues may be encountered; thus London has been selected as one of the test areas for autonomous and connected vehicles. The vehicle sharing and hailing scheme also aims into London market regarding its vast mass base. UBER, the US leading ride sharing platform, is changing its market positioning to recall all drivers to adopt green vehicles so as to coincide with local municipal rules (Pyper 2018b).

Above all, to address the environmental issues, autonomous, connected, electric and shared vehicles are good choices that should be promoted in London.

The Bromley and Croydon areas of West London were selected to test autonomous and connected vehicles for a 10-month trial which ended before

Christmas 2018. This autonomous vehicle trial with a driver auxiliary is the data collection procedure that is mainly led by the FiveAI company. The project lays the foundation to further aggregate and share transportation data to produce General Data Protection Regulations (GDPR) (Bernal 2018; Hamill 2018). Another project was launched in London regarding the robot taxi in Oxbotica around 2021, led by Oxford University and partnered with a local taxi company, Addison Lee, share not only the data, but also autonomous vehicle services. The onward autonomous vehicle test will be a practical on-road service, specifically, a driverless bus service from Forth Bridge to Edinburgh. All these continuing advancements in programmes have been practiced and learned to further enhance the accessibility and feasibility iteratively. The autonomous and connected vehicle and its relative services may be worth £28bn by 2035 in the UK (Bernal 2018; Khan 2018). Further, it incentivises the local and national economy (more than £41.7 billion) and jobs creation (more than 40,000 jobs in England) (Cruse 2021). The investigation shows that the CAVs have a huge potential to stimulate the local economy and release transportation pressure. These trials help further develop CASE capabilities and offers practical experience for the future possibilities.

Additionally, several projects tackle the practical issues with short/fixed routes. The Millennium Dome and the Greenwich Peninsular are the test pods for the GATEway programme, which has provided more than 100km of data. Government and municipal officials are not the only funders to support autonomous vehicle testing. Car manufacturers, such as Jaguar Land Rover and Nissan Leaf, have also tested their autonomous vehicles, with strong navigation and voice control systems, in East London's Beckton (Burgess 2017; Burgess 2018). Ocado has tried 100 delivers in two weeks by driverless cars in a fixed 3 km route with a low speed of up to 5mph. Nonetheless, Ocado is not the first retail company to deliver trials with robotic devices. Startship’s autonomous vehicles are equipped with cameras, sensors and auditory sense system that can detect surroundings and voices before making choices. By 2015, Startship had engaged over 40 cities in trials of their autonomous vehicle delivery service, cooperating with Just Eat and Hermes in the ‘Last Mile Delivery’ service. (Wade 2016).

## 3.5 Germany

Germany was the first European country to legalise highly autonomous driving on public roads with a licensed driver in July 2017; however, both data recording devices and a well-trained driver are required during the test process to ensure safety and minimise accidents. The federal government there aims to construct a new traffic infrastructure system, with 5G mobile networks which could offer better conditions for fully autonomous and connected vehicles (Hetzner 2018). However, along with regulations relating to permission for the on-road testing of autonomous vehicles, ethical issues have to be considered; the German Ministry of Transport has proclaimed that autonomous technology should programme human beings before property and animals (Sheahan 2017).

Nevertheless, the German government strongly supports this new technology. The reason for this may be that the automotive industry is one of the dominant industries in this country, generating over €400 billion in production value from vehicle sales each year (Arnold 2019; Koptyug 2020), and the update of new technology will keep this industry viable. Stuttgart is one the cradles of the German automotive industry and where Daimler has its headquarters. However, Stuttgart is also the city that is most severely afflicted by vehicle pollution; therefore, the local government is determined to reduce emissions and improve air quality in their city. One of their efficiency measurements is to ban diesel vehicles from entering the city centre. Following the VW diesel scandal, the supervision and threshold on diesel vehicles was increased; furthermore, diesel-powered vehicles are gradually being banned in city centres throughout Germany to control nitric oxide discharges, for example in Munich, Hamburg, Stuttgart and Berlin (Cremer et al. 2017; Schwierz 2017).

Car manufacturers are focused on diversifying their businesses to achieve sustainable operations. For instance, MIOA, one of the subsidies in VW, tested electric ride shared vans in Hamburg at the end of 2017, it ran around 100 vans in April 2018 and gradually expanded to 500 in twelve months, with additional

1000 job creation (Hampel 2019d). Later in this work, more cases are illustrated in an embedded case study (see Chapter 6).

## 3.6 France

The French environment minister announced, in July 2017, the banning of all petrol and diesel vehicles by 2040 (Chrisafis and Vaughan 2017), this intention was reiterated in 2018 by President of France Emmuanuel Macron, declaring: " We have to tax fossil fuels more in order to fund our investments in renewable energy…" (BBC Europe 2018c). This coincided with general EU policies (Figure 3.2) that all member countries are increasing the tax on petrol and diesel fuels in order to control consumption; however, this caused anxiety for citizens, especially those who live in the suburbs and rely heavily on vehicles for their daily commuting. Taxes on petrol and diesel increased by an average of €1.51 (23%) from 2017 to 2018 (BBC Europe 2018b). French citizens were reported as taking 'drastic action' regarding this issue (BBC Europe 2018c; BBC Europe 2018a); indeed, France suffered sustained, sometimes violent, protests by the 'yellow vest' movement ('gilets jaunes'). This protest ended with the proposed bill being dropped from the 2019 budget.

The French government has phased out coal as a source of electricity generation, turning to support renewable resources and nuclear power. Meanwhile, electric vehicles are encouraged by, for example, increased infrastructure construction (Figure 3.3) and shared vehicle schemes. Carsharing technology and platform application in France are more advanced than in many other countries (China Electric Vehicles 2018). The Autolib electric car sharing scheme in Paris is a good example which helps to remove both cars and emissions from roads. This project was funded partially by municipal government, and to a large extent it was seen as a successful example of official embracement of the new technology. Although, this scheme ended with the failure of the operational strategy and maintenance, it offered opportunities to citizens to become familiar with such a scheme in order to change their attitudes and travel behaviour (Platiau 2018).

France does not limit its vision of sharing schemes to vehicles, but it also encompasses bikes and e-scooters (BBC News 2019).

The automotive industry heavily relies upon the global market and supply chain, which is easily affected by geo-political issues and global trends; the current coronavirus pandemic being a contemporary example. To save the French automotive industry, the French government aims to launch on the market one million ‘clean cars’ within five years as a part of an ‘aid package’. (Hampel 2020). Whilst the effects of COVID-19 are a major shock globally, suddenly halting global demand and supply, it also provides an opportunity to incentivise the EV market.

### 3.7 The United States

Following the famous Paris Agreement reached in February 2019, the Green New Deal, a USA congressional resolution that proposes a plan for tackling climate change, has been proposed by Democrat Representatives in America. It appeals to workers, communities, investors, and policy makers to address the climate change issue. It declares that the climate issue cannot be solved by a single community or an organisation; if all nations not currently involved in this campaign agreed to meet the target of slashing $CO_2$ emissions down to 90% of the 1990 level the result would be incredible. Therefore, it appeals to all Americans to co-contribute their power, it argues that Net-zero emission should be encouraged and a renewable energy economy system should be built (Green New Deal 2019; Wolf 2020).

The territory of the United American embraces the most mature and complex inland transport system in the world and has a strong demand for vehicles. The busiest and thriving road network, however, witnesses a high car crash rate and many fatalities. In 2017, 37,133 people lost their lives on US motorways, including 10,874 deaths owing to drunk driving and 3,450 deaths due to driving distractions (NHTSA 2017). America remains highly car dependent, with a strong pro-car culture. However, at a regional level (and notably in California) America has also nurtured the electric vehicle market and is, of course, the domestic market for Tesla.

*Autonomy*

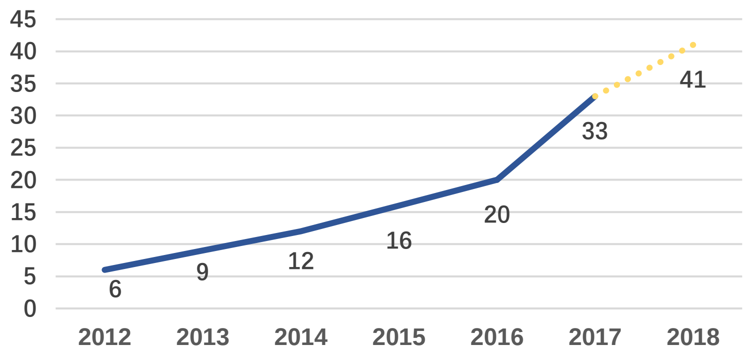
The National Highway Traffic Safety Administration (NHTSA) is responsible for US national road safety, it has frequently upgraded the standards for in-car safety facilities. Since before the end of the last century, seat belts, cruise control and ABS systems have been required on all vehicles and new advanced features are added each time the system is upgraded. Moreover, upgrade time has been shortened to keep up with the pace of new technology. Five eras have been clarified on the safety feature renovation, as shown in Table 5. Partially automated features, such as Lane Keeping Assist and Adaptive Cruise Control will be gradually adopted by the future generation vehicles to ensure vehicle safety. Features shown in the table below are those identified by NHTSA, which indicate that vehicle automation structures will be essential to vehicle safety in the near future.

***Table 5 Five Eras of Safety in the U.S.***

| Year | Features | System embraced |
|---|---|---|
| 1950 - 2000 | Safety/Convenience Features | Cruise Control/ Seat Belts/ Antilock Brakes |
| 2000 - 2010 | Advanced Safety Features | Electronic Stability Control/ Blind Spot Detection<br>Forward Collision Warning/ Lane Departure Warning |
| 2010 - 2016 | Advanced Driver Assistance Features | Rearview Video Systems/ Automatic Emergency Braking<br>Pedestrian Automatic Emergency Braking<br>Rear Automatic Emergency Braking<br>Rear Cross Traffic Alert/ Lane Centering Assist |
| 2016 - 2025 | Partially Automated Safety Features | Lane keeping assist/ Adaptive cruise control<br>Traffic jam assist/ Self-park |
| 2025 + | Fully Automated Safety Features | Highway autopilot |

Source: (NHTSA 2017)

In 2011, Nevada was the first state that accepted and authorised autonomous vehicle testing, the number of states to pass/consider the legislation/executive orders has been steadily growing annually since then (Figure 3.9). From 2012 on, 6 states have allowed autonomous tests in their areas, the figure reaching 33 states by 2017, and the number is still growing. In 2016, the NHTSA updated its guidance, based on the 2013 guide, which illustrated the levels of autonomous vehicles and its latent benefits. Furthermore, an approximate $4 billion budget will be invested in automation safety systems in the coming 10 years, according to statements made by the government in the North American International Auto Show in the same year. Hence, more states are aware of the potential benefits arising from autonomous technology when active legislation and executive orders are carefully considered. The executive orders have been updated and permissions expanded, providing more detailed guidance on automobiles with pilot and automation driving systems. At the beginning of 2019, the NCSL established a special website in which users are able to track the statements and processes of the bill on autonomous legislation and orders, state by state, between 2017 and 2018 (NCSL 2018; NCSL 2019).

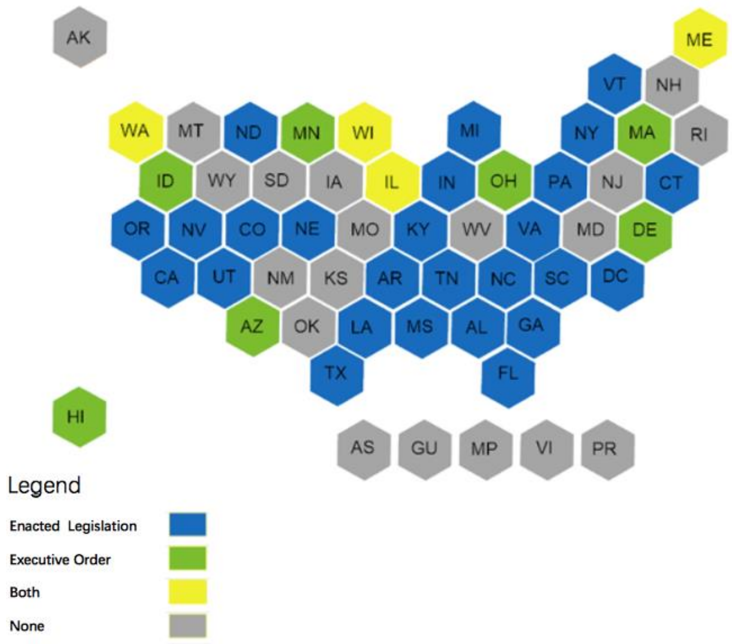



Source: (NCSL 2018)

***Figure 3.9 Numbers of U.S. States Considering Legislation and Orders Related to AV***

Figure 3.10 provides a map that shows the legislation and order status of each region up to 2018. Almost the half of the country's states (46%) have enacted legislation, whilst the second largest number of states are those which have neither considered or enacted legislation, nor executive orders (34%) (NCSL 2018). Some states have an executive order in place, but have not developed further. For instance, Arizona has an executive order in place, but it does not span their technology in the second half of 2017, Kevin Biesty from The Arizona Department of Transportation explains: "…One of the reasons we did not step forward and regulate is because the industry is changing so fast and what you release today might become obsolete in six months…" (Bellon 2017). However, it was assumed that if the penetration of the autonomous vehicle market share reaches 10%, the economic growth would add up to $25.5 billion per year in the

US; but considering the broader benefits and higher market penetration, the benefits would add up to around $450 billion annually (Fagnant and Kockelman 2015). ICT companies ally with conventional automotive manufacturers to contribute towards efforts on autonomous testing and promotion. For instance, the city-wide autonomous vehicle test which was launched in Boston by NuTonomy's parent company Aptiv (Lagnemma 2018).




Source: (NCSL 2018)

***Figure 3.10 States with Autonomous Vehicles Enacted Legislation and Executive Orders***

*Connectivity*

The NHTSA also supports vehicle to vehicle (V2V) technology, which helps to alleviate potential vehicle crash fatalities and damage. Crashes can be detected, and alerts sent to other vehicles through the shared system. V2V is capable of estimating a vehicle's average speed and making a diversion to avoid potential crashes and sudden stops before a crash happened. All transport commuting tools could carry V2V technology, from trucks, to public buses and motorcycles for commercial use, on public facilities and in private travel tools. As reported by the NHTSA, 6.3 million motorway crashes happened in 2015, while 615,000 crashes could have been avoided if they were using V2V technology and 1,366 lives could have been saved. This number is rising continually year by year, something which offers a promising prospect from using the V2V technique (Stevens 2016; Batelle Memorial Institute 2018; NHTSA V2V 2018).

To be cleared by the NHTSA, it has to be guaranteed that personal data would not be shared through V2V technology; so, the V2V communication platform is only for receiving and sending “standard messages”. The NHTSA, US federal government and the Department of Transport have funded several projects to test the safety of V2V technology, including: V2V on heavy-duty vehicles; commercial use vehicles; forward collision/crash warning applications; intersection warnings; blind spot/lane change warnings; emergency electronic brake light warnings by one or more vehicles ahead and cyber-attack protection by a high-assurance parser (Howe et al. 2016; Stevens 2016; Guglielmi et al. 2017; Batelle Memorial Institute 2018; NHTSA V2V 2018).

*Electrification*

In the EV Everywhere Grand Challenge Blueprint 2013 (U.S. Department of Energy 2013) it was stated that pure electric vehicles will become the dominating vehicle type, with the plug-in electric vehicle being used in the transition stage in the short-term. In 2016, the U.S government published a project to accelerate and promote electric vehicles and established The Corporate Electric Vehicle Alliance in which companies range from the energy sector, delivery companies, electric business sectors to ICT companies. A further planned investment of $45 billion to enlarge the electric vehicle fast-charging network are on track (Ceres 2020; Cosgrove 2020).

The US, as one of the biggest EV selling markets, has devoted itself in many ways to encourage local car retailers to trade electric vehicles, such as by providing tax exemptions and credit promotions. The tax credits vary from $2,500 to $7,500, based on battery capacity and gross vehicle weight. The more a manufacturer sells, the lower the taxes that need to be paid. For example, 200,000 EV was settled on as the baseline, if the same quantity of vehicles were sold in the next six months, the credit halves; then, the credit is cut to half again if the same quantity is sold during the next six months. The credits paid to the manufacturers reduce if sales consecutively remain at the same level, eventually falling to 0 (Lu 2018).

California is recognised as a famous multi-cultural, liberal, and inclusive State in the US and one that has historically been associated with high levels of motorisation along with the environmental consequences. It also is therefore one of the earliest States to pursue relevant regulations in for example the Zero Emissions Vehicle with Advanced Clean Car Regulations mandates of the California Air Resources Board into the States' policy (California ZEVs 2012; CNN 2020). In 1992, the state government of California declared a low-emission regulation and zero-emission vehicle mandate. It is a paradigm that served both environmental protection and technological innovation (Brown et al. 1995). In later years, this state continues to stimulate users to purchase electric powered vehicles. They offer rebates to light-duty zero emission vehicles and plug-in hybrid electric vehicles (PHEVs). In addition, families are offered an extra $2,000 allowance if their incomes are lower than average (Lu 2018).

*Shared schemes*

The US has a strongly embedded car mobility system. The US also has a long history of vehicle sharing dating back to the end of last century (Stone 2013).The previous lessons have been learned by the next generation of vehicle sharing companies as to what are the successful business models, adequate markets, and the level of financial support needed. The future of vehicle sharing disabled transportation, therefore, has to follow the population trend such as vehicle electrification, flexibility, platform applications on the mobile phone etc. This also excludes for the persons who are not phone enthusiastic and physically disadvantaged. However, it is a good situation for ride hailing start-ups because of a) a strong motoring culture and infrastructure, b) a highly developed tech sector with widespread affinity for the use of mobile phone apps, and c) a comfort with the on-demand economy of use rather than ownership. These incentivise ride sharing and hailing.

Uber is one of the originators of the car hailing scheme, it is now the leader in this realm around the world, with over 80% of the car sharing market share in America. It began operating in 2009 and was originally called UberCab, it later expanded to New York City in 2011, then began to spread worldwide, notably to capital cities, such as Paris and London in 2011 and 2012 respectively. Uber has since entered over 600 cities; 50 million active users hailed a car through the Uber app in 2016, stably growing to 75 million in 2017 and 100 million users in 2018. In the US alone, over 45 million adults use Uber (Smith 2018; Statista 2019b).

Despite this success, Uber suffers pressures in many cities. This is because Uber runs what may be called a 'subversive' car hailing scheme, heavily impacting on the business of the traditional taxi industry. Uber does not own any cars; it offers a platform for all capable drivers in a flexible manner; nevertheless, they have encountered resistance, indigenous local car sharing drivers have boycotted Uber out of their market in several areas, such as in China, Paris and Madrid. Eventually, Uber sold its Chinese business to DidiChuxing, a local Chinese car hailing company. In Paris, Uber drivers were regarded as Uber employees rather self-employed, meaning that Uber would have to pay the higher tax rate (Orihuela 2019; Rosemain and Vidalon 2020).

With over 300 rental companies, the American Car Rental Association represents 98% of the market, it aims to promote and support the car rental industry at state level. Five items of legislation on automobility rent transition in 5 states were highlighted because they transfer traditional vehicle rental methods to private, peer-to-peer rental (Table 6) and vehicle hailing and rental companies have been protected by corresponding laws (ACRA 2018).

***Table 6 Transitions of Traditional Vehicle Rental to Private Rental***

| State | Bill and Number | Subject | Requirement | Laws relevant |
|---|---|---|---|---|
| Idaho | House Bill 517 | Private motor vehicle rental programme | Competitive but fair | Insurance safety technology development |
| Illinois | Senate Bill 2641 | Personal and peer-to-peer rental | Stop the financial and law disparate treatment | Insurance traffic and vehicle tax |
| Maryland | Senate Bill 573 | Car rental company | Cost shift on renter's behalf | Insurance coverage |
| New York | Senate Bill S427 | Car rental company | Consumer protection Local other markets protection | Any ethical discrimination Insurance Local taxi market erosion |
| Utah | House Bill 429 | Car rental company | Stop the financial and law disparate treatment | Insurance traffic and vehicle tax |

Source: (ACRA 2018)

However, not all member states have implemented an agreement about environmental sustainability effectively. US President Donald Trump announced that America's withdrawal from the Paris Agreement from June 2017 (Shear 2017); this declaration has a huge impact on automotive industry, and it may go further by releasing or even deregulating from administration.

### 3.8 China

China is market independent, as-a-whole, whilst it is also intertwined with the markets in the rest of the world. To coincide with and contribute to efforts to the appeal of declining GHG emissions universally, China started a green transport network in both private and public transport. Basically, the green vehicles (i.e. electric buses and hybrid taxis) are mostly used in public transport (Zhang et al. 2014; China Electric Vehicles 2018; Stanway and Anantharaman 2018). Even though the relevant policy and regulations have been established to encourage in using alternative fuel powered vehicles, private use passenger vehicles are still very limited. The way China plans to deal with carbon diminishing is by using renewable energy to power vehicles, such as solar power and electricity, instead of traditional fuels. Further, to relieve congestion and reduce car consumption, car sharing and pooling are becoming more popular (Asian Development Bank 2018). In Oct 2010, China published its first item of legislation: "Decision of the State Council on Accelerating the Fostering and Development of Strategic Emerging Industries"; this decision added renewable energy powered vehicles as a part of the national strategy and pledged to accelerate its relevant production and research investment (State Council 2010).

*New Energy Vehicles*

Since then, it has not only encouraged domestic car manufacturers to develop relevant products but has also attracted foreign investments from Europe and America. For instance, EU car makers invested 7 times more on electric vehicles in China than they did in EU region in 2017, with a €21.7 billion investment in China and €3.2 billion in Europe, respectively. EU investments are injected into local automotive manufacturing, with an alliance or a joint venture to co-produce the products (Table 7). The EU manufacturers include Daimler AG, Volkswagen and Renault. Combined with NEV, the extended features of electric powered autonomous vehicles have been tested in many cities, such as Beijing, Shanghai, Chongqing and Guangzhou (China Electric Vehicles 2018).

The Chinese government is aggressive on EV policy; EV purchasing tax was exempted during 2014 and 2017 and extended until 2020. A subsidy scheme is also very successful in motivating users to own a plug-in electric vehicle (PEV) or pure battery vehicle (EV), in 2010 ranging from RMB 4,000 ($635) to RMB 50,000 ($7,941) for PEV and from RMB 4,000 ($635) up to RMB 60,000 ($9,530) for EV, respectively. This subsidy is offered for up to half of the total price. However, the subsidy rate has been decreasing on PEV and EV since 2010 and will be phased out in 2020. China plans to build 12,000 charging nodes by 2020, which could sustain 5 million EV (Lu 2018). China seeks to inject 5 million in electric vehicle production by 2020 which requires a 40 percent increase each year (Cheah 2017; Lim 2017a; Lim 2017b; Kwang 2018).

*Table 7 Electric Vehicle Production Investment June 2017- June 2018 in EU and China*

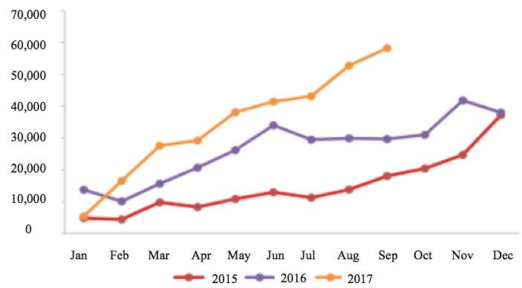
| Investments in the EU | | Investments in the China | |
|---|---|---|---|
| €1b | Renault second EV production plant in Douai, France | €10b | VW-Anhui Jianghuai venture for NEV production |
| €1b | Volkswagen Zwickau e-mobility production plant, Germany | €8b | Nissan 2022 plan to introduce 20 EV models |
| €500m | Daimler Hambach plant extension for EV production, France | €1.6b | Daimler-BAIC venture for new production site |
| €300m | BMW Leipzig plant extension for EV production, Germany | €670m | Volvo (Geely owned) for EV production |
| €200m | PSA-Nidec venture, Tremery plant EV production, France € | €650m | Ford-Anhui Zotye venture for EV production |
| €200m | BMW Munich battery production centre, Germany | €480m | PSA-ChangAn venture for CAPSA EV production |
| Undisclosed | Daimler Sindelfingen plant for EV production, Germany | €200m | Renault-Brilliance venture for NEW LCV production (EVs included) |
| | | €67m | Daimler-BYD venture for Denza EV production |
| | | Undisclosed | Renault-Nissan-Dongfeng venture for EV production |

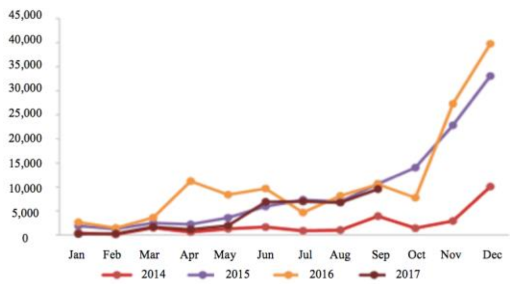
Source: (China Electric Vehicles 2018)

The promotion of electric vehicles requires a higher battery production capability; however, to reach sustainability, the new generation of EVs should consider not only the emission issues, but also after-life battery recycling. SKIO, a Chinese new energy automotive company, will launch 30,000 battery swappable NEVs over the next 5 years and over the past few years has already shaped a nation-wide network (Shiny 2018). The new energy policy impacts on the electric powered vehicles, both within China and on the world supply chain. At the beginning of 2019, Jaguar Land Rover announced over 5,000 layoffs in the UK; this is partly attributed to the collapse in the sale of diesel vehicles in China. To address this, JLR has built a battery factory in Warwickshire that produces for the electric vehicle market (Jack 2019; Mullen 2019).

For the conventional vehicle market, a similar pattern is appearing in the rest of the world, sales in China are still currently dominated by petrol and diesel vehicles. The emission standards in China follow EU emission standards, from

Euro 1 (EC 93) to Euro 5 (EC 2011), individually named from G1 to G5. The latest standard, G6, varies according to the rapidly developing context and its inequivalent environmental situation in China. As policy is becoming tighter, the sales of renewable vehicles are growing. Figure 3.11, see below, shows the sales of renewable vehicles for passenger cars (left) and commercial use (right). It shows that the commercial use vehicle sales are growing steadily each year, but the sales of passenger cars have increased dramatically since 2015. The average sales of passenger vehicles are increasing more than those designed for commercial use. An interesting point is that, at the end of each year (October to December), the commercial vehicle sales have gradually increased, peaking in December (Vehicle Industry 2019).




Source: (Vehicle Industry 2019)

***Figure 3.11 Sales of Renewable Passenger (L) and Commercial (R) Vehicles by Month***

However, with market expansion, the electric vehicle manufacturers and market are at overcapacity, meaning that there is “blind” growth of electric vehicles, owning to the encouragement from governments. The vehicles powered by electricity, hybrid, plug-in, and other power engines comprise over 350 modes with over 100 operators. To respond to these issues, the Chinese government aims to lift the threshold on electric vehicle manufacturers and improve the surveillance of the supply chain (Stanway 2018).

*Vehicle sharing*

Following the popularisation of the sharing, led by Uber, Airbnb and Didichuxing (Autocar 2016; McLellan 2018; Li and Srinivasan 2019), mobility sharing and pooling mechanisms are now supported by governments; with China being the second biggest car sharing market that benefits from its demographic and fast developed mobile phone applications (Schmitz 2017; China Electric Vehicles 2018). The vehicle sharing schemes are incredibly expanded in China. By 2030, China would be the largest car sharing market in the world (Zhang 2020). On one side, it is caused by the petrol vehicle restrictions and license plate restrictions in China so it is not everyone who could own a private vehicle especially in cities like Beijing and Shanghai. On the other side, the smart mobile phone equipped majority functional applications including the online ride sharing and hailing which enhances the connections both potential drivers and users. The online car-hailing and sharing platform shorten the distance of private drivers to be a 'ride hailing driver' regarding to share their properties flexibly: the work time, guests and destinations can be chosen. For users, it shortens waiting time as well as the vehicles type can be selected. The first draft legislation on online taxi booking published in 2016 was titled: "Interim Measures for the Administration of Online Taxi Booking Business Operations and Services" and was a collaboration by the following government departments: the Ministry of Transport; Ministry of Industry and Information Technology; Ministry of Public Security and the Ministry of Commerce and State Internet Information Office (Ministry of Transport 2016, p.21); up until September 2018, it had been upgraded more than 9 times.

Electric vehicle companies are also taking part in this competitive, expanding field of business; for example, SKIO owned a vehicle sharing platform named Blue Avenue, and has signed agreements with the Chengdu Government to share electric vehicles, this was its 13th city to adopt EV sharing schemes. In addition, Blue Avenue are in cooperation with Didi Chuxing and Dongfeng motors to operate EV sharing schemes (Shiny 2018). Basically, the Chinese government both legally and practically support autonomous, connected, electric vehicles, as well as car sharing schemes.

*Autonomous vehicles*

China banned autonomous vehicle high-way testing before relevant legislation was released (Zhang 2016); this was a nation-wide political decision which all local authorities should follow. In addition, China published the “Guideline for Developing National Internet of Vehicles Industry Standard System (Intelligent & Connected Vehicle)” at the end of 2017; this guideline requests the improvement of both the technology (connectivity and autonomation) and supporting facilities (Internet) to match the expansion. Intelligent and connected vehicles, therefore, as a national strategy, is to be developed (Ministry of Industry and Information Technology 2017).

On 1st March 2018， the Shanghai municipal authority issued their first administrative methods regarding public autonomous and connected vehicle testing (trial) in China. Cars with ‘trial’ licence plates were launched in Shanghai on a dedicated part of the road. This is a relatively safer, lower risk road at an overall length of 5.6 km (see Figure 3.12). Following an official assessment, partial roads in the Jiading District have been chosen for first stage trials. The trial road consists of three parts: two parts on the Boyuan road; (Moyu South road to An’yan road at 2.7 km long and the An’hong road to An’zhi road at 0.9 km) and the third part on the North An’de road (An’li road to An’zhi road) at 2.0 km long. The test area includes 200 smart test scenarios, it would be a nation-wide powerful test platform until 2020; after this trial, autonomous on-road testing is likely to be allowed on more roads. The official requirements for test vehicles in this program include: 1) to be equipped with Remote Data Monitoring and Controlling System; 2) a third-party data platform; 3) traffic accident liability insurance at a minimum of 5 million Yuan (around £450,000) and correspondent insurances on the test vehicles; 4) drivers are obliged to have at least 50 hours driving experience of automatic systems (Mydrive 2018; Shanghai Municipality 2018; Sina News 2018).

(1)


(2)

(3)

(4)

(5)

(6)

(7)

Source: Author

***Figure 3.12 Shanghai Autonomous Vehicle Test Roadway***

The author visited the selected area and checked the test conditions, as shown in Figure 3.12. The selected area is located in a new rural area, very rarely do vehicles travel on this road. Most of the nominated roads are straight (5,6,7 in Figure 3.12) with mild bends or turnings (1,2,3,4 in Figure 3.12); therefore, the road condition is better than that of most of the existing roads and there are fewer obstacles, and all road signs are clear and visible.

In time, further, supplementary areas will be permitted to test autonomous vehicles for both passenger and commercial vehicles. Inception Technology has been authorised to run autonomous trucks on open roads in the Baoding Autonomous Driving Test Service Centre that includes five motorways. It is the first company to target to L3 and L4 level inter-city autonomous trucks that claims to operate 'Logistics as a Service' (LaaS) in China (G7 Networks 2018).

By the end of 2018, 14 cities issued 101 special 'autonomous vehicle' license plates that were obtained by 32 companies: Beijing has 56 plates, followed by Chongqing with 11 licenses and Shanghai with 7. The company which has the greater number of licenses is the tech giant Baidu, with around half of the total license plates (Fan 2019).

Comments made on China, by Klaus Froehlich, the Head of Development of BMW are (Coppola 2018): (China has) "… good companies, software, hardware companies; they are expanding to very powerful chipsets, and there's a political will, it's very clear…" … "…On electrification, they were also quite late; now they're the lead market. It will be the same with on-demand mobility..."

## 3.9 Other Relevant Sectors: insurance; repair; maintenance & finance

To deal with the coming changes in the automotive industry, many coordinate sectors will need to recalibrate their roles, strategies, structures and relations with car owners and drivers; in, for example, the insurance, repair, maintenance and finance sectors. The automakers will need to deploy safer, more reliable and comfortable driverless vehicles. In insurance, current business principles will be challenged, i.e. how, to who, holders of responsibility and relevant interests; these changes in insurance will lead to the alteration of corresponding policy. According an investigation by Deloitte, due to autonomous vehicles' ability to technically guarantee the creation of safer cars, the insurance industry may lose most of their current business, or even disappear. Conversely, it could add new fractions on insurance that could be based on levels of autonomy, such as the sensor network, levels of mapping, algorithm design and personalised requirements (Matley et al. 2016; Xu and Fan 2019).

Insurance for autonomous or semi-autonomous vehicles are a means of protection by keeping the system updates and transfers. In relation to this aspect, bill was proposed in 2016, led by the Centre for Autonomous and Connected Vehicles in the UK (Palmer 2016). In this proposal, the government appears to cover the vehicle and the third party's insurance in the mobility transition stage. Mr. Channon, Dr. Bugra, Dr. Noussia and Professor Merkin QC claimed jointly that UK car insurance should be removed from the driver and placed on the car itself. It also suggested that insurance should embrace continuing technological transformation, including ADAS, to fully self-driving vehicles and all road users. The proposal is hard to achieve because the subject of the proposal (autonomous vehicles and highly automated systems) are not available on the market yet. Autonomous cars drive according to the coded programme; therefore, insurance would no longer be relevant to drivers. Under traditional insurance methods, the concept of the 'driver' would not exist in autonomous vehicles. Thus, the bill proposed shifting from driver insurance to motor insurance (Palmer 2016; Channon et al. 2017; Lawyer Monthly 2017).

Additionally, vehicle electrification simplifies the process of repairing and maintenance; thus, indirectly changing this portion of the cost. Cars are used less than they are meant to be: within the EU it is estimated that up to 90 percent of time they are unused, each run carries one and a half persons on average, an average €6,550 annual maintenance fee and extra congestion fees will apply up to €100 billion per year. This economic loss and inefficient usage can be reduced to a minimum; if petrol and diesel vehicles are replaced by electric powered vehicles, maintenance fees will be much lower (EU car sharing 2017).

Congestion and inefficient usage could also be relieved by car sharing and pooling schemes. Apps could group people going to the same destinations, taking them to the nearest drop off points; they would benefit further by sharing the cost of the journey (EU car sharing 2017). Car sharing/rental/hailing schemes are a group method of taking rides collectively, similar to taking taxis, but without a condition of employment. This form of travel directs the insurance sector and finance strategies in a new direction. Some claim that car sharing/rental schemes are unregulated and substandard (Elliott 2018). However, insurance that targets such new schemes gradually tend to systemise and normalise. Insurance coverage, even fully comprehensive coverage has already been introduced for Zipcar and Drivy (Wells et al. 2020b).

### 3.10 Discussion

Electric vehicles will be taken up not just from policy pushing and car makers' encouragement, but also platforms which provide accessibility to enrich users' experience. For instance, Uber launched UberGreen in Amsterdam, Paris and London to coincide with local policy and broaden its local market share (Manthey 2019).

For the transportation sector to reach full sustainability, policies will play an essential role. The establishment of relevant rules and regulations are necessary to ensure that both users and technique enthusiasts are legally protected. Additionally, the relevant societal and economic benefits would be legally generated. The selection of the countries highlighted in this chapter is based on their positive drive towards autonomous, connected, shared and vehicle electrification. Owing to international position and domestic surroundings, point of political emphasis vary from country to country; some are more technologically aggressive, such as the USA, while nations in the EU are more practical and moderate in their development of green vehicles. China is hugely politically driven, where policy is highly focused on vehicle electrification, both in the public and private transportation sectors. Compared with vehicle electrification, sharing and automation schemes are lacking in policy bolstering.

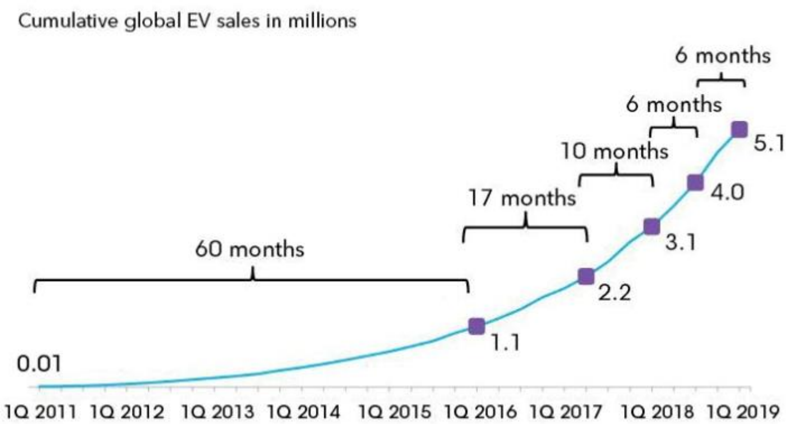
Table 8 below, shows a summary of the political support given to CASE in the selected areas; it demonstrates that vehicle electrification and connectivity are becoming the global trend in the effort to reach sustainability. One of the reasons for this is that the rapid development of corresponding technology maturity is capable of satisfying requirements from various perspectives. For instance, the sharing scheme in the UK is not supported officially and in Germany and China they are authorised locally; vehicle sharing schemes in the US are also supported by states rather nation-wide, but the appearance of Uber has boosted the circulation of ride/hail share. However, capital and demographically intensive cities have their own vehicle sharing platforms, such as: the London-based Drivy; Paris-based Autolib; Car2Go in Germany; DidiChuxing in China; Zipcar and Uber in America (Car Sharing Startups 2018). Whereas, in the UK as a whole, the concept of vehicle automation seems to be attractive to UK citizens: more than half of UK residents said they would accept a vehicle with an autonomous driving system (Manufacturer News 2018).

***Table 8 Relevant Policies and Regulations Has Established***

| | Autonomous | Connectivity | Electric | Sharing |
|---|---|---|---|---|
| EU | | Yes | Yes | |
| UK | Yes | Yes | Yes | |
| Germany | Yes | Yes | Yes | City-based |
| France | | Yes | Yes | Yes |
| US | States-based | Yes | Yes | Yes |
| China | Regional | Yes | Yes | City-based |
| Singapore | Yes | Yes | Yes | Yes |

Source: Author

Electric vehicles around the world are gradually becoming more acceptable, albeit with some potential downsides. Government and car manufacturers endeavour to build a better and smoother driving environment for drivers to achieve a better driving experience. EVs hit the car market and ramped up around 2010 to 2011, since then, global sales have increased dramatically. As Figure 3.14 shows, it was five years before EV sales reached the first million sales, but the second 1 million only took 17 months (Pyper 2018a; Wilde 2018); however, by the end of August 2018, the sales of EVs had reached 4 million, at a speed of 150,000 per month. It is expected that a million EV sales per six-month period will be achievable in the near future.

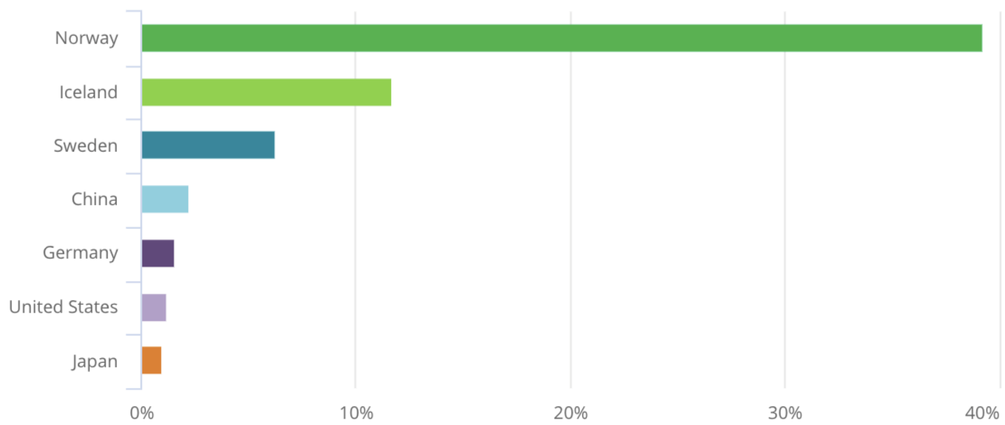



Source: (Pyper 2018a)

***Figure 3.13 The Time to Sell a Million EV is Reducing***

Looking at the individual country scale, China has a large demographic, while it only possesses 2.2% of the EV market share. In contrast, Norway has the highest electric market share in the world: just under 40% (Figure 3.15). Nonetheless, the Chinese market is seeing rapid growth, with 0.65 million sales in 2016 and 1.23 million in 2017. Moreover, European countries maintained constant expansion from 0.1 million in 2013 to 0.82 million in 2017, with an annual growth rate of around 0.2 million cars (The International Energy Agency 2018).

Electric vehicles are highly recommended in the UK and charging points are being added to cover a wide range of the road area. Even though more than half users in the UK currently do not consider electric vehicles as their second vehicles, advertisements and positive policy support stimulate this market to a positive increase (AutoTrader 2018). In their research, AutoTrader found The trend in attitudes towards electric vehicle has changed, the willingness of those questioned to buy an electric vehicle as their next car increased from 25% in September 2017 to 71% in the following two years: users who believe in and use at least one autonomous feature regularly increased up to 71% in 2019; however, 17% of users did not believe in the availability of such technology within their lifetime and 49% of people indicated no interest in this technology (AutoTrader 2018).

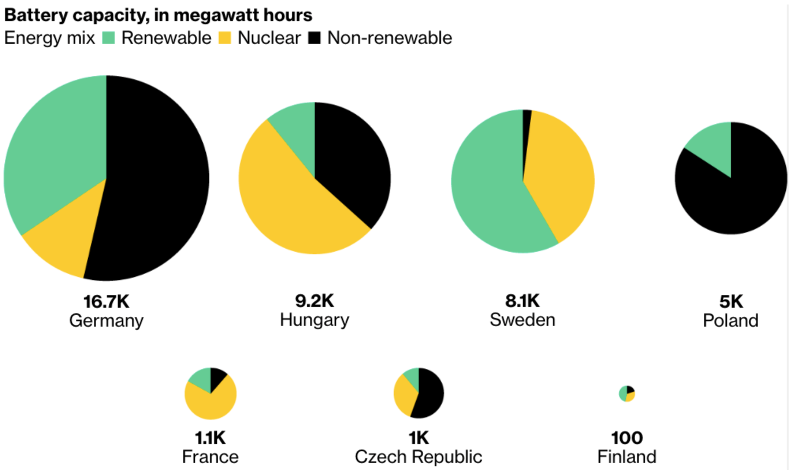



Source: (International Energy Agency 2018)

***Figure 3.14 Electric Car Market Share in 2017***

The plug-in vehicle is a transition bridge which links traditional fuel powered vehicles and electric powered vehicles. It is regarded as a buffer zone for adapting the pure electric vehicle, something for which sellers of plug-ins are grateful. Again, China is at the top of the list with 192,000 sales in the first half of 2017, surging up to 394,000 sales by the end of the year: over twice the proliferation (Irle 2018).

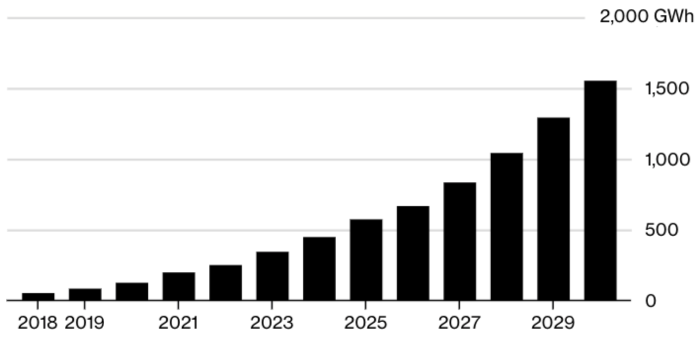
However, the barriers for electric vehicles exist. From the root, the greenness of electric vehicles has been doubted. Electricity that is generated by coal and other non-renewable resources does not coincide with the concept of sustainability in automobility. In most countries, electricity is still generated by non-renewable resources, such as in the EU countries: Germany; the Czech Republic and Poland, and in some cities in China and America (see Figure 3.16). Nuclear is another resource used to generate electricity, this is mainly used in Hungary, France and Sweden. Battery recycling is another grey area, 'afterlife' life-cycle emissions should be considered, as well as resource generation issues. The battery revolution e.g. lithium technology and higher capacity are just some of the things to consider for electric vehicles, but many other issues are waiting for attention (Rolander et al. 2018; Stringer and Buckland 2019).




Source: (Rolander et al. 2018)

***Figure 3.15 The Battery Sustainability on Electric Vehicles***

However, along with the roar of the electric vehicle demand that is being pushed by governments, the requirement for electricity is also growing; it is forecasted that this will increase by geometric progression. Electric cars will become the normal commuting tool in the coming decades, they could be owned privately, semi-shared privately or used publicly. Figure 3.17 illustrates the expectation of electricity demand for passenger vehicles; in reality, the number is likely to be larger (Rolander et al. 2018). At this time, the current electric grid may not satisfy the growing demand for electricity, the smart grid therefore would become one of the solutions to solve this insufficient capacity. It may require connectivity features to adjust the inequivalent demand of electricity at peak and off-peak times between vehicles and the smart grid.




Source: (Rolander et al. 2018)

***Figure 3.16 Passenger Car Electricity Demand***

Additionally, the main barriers from end users still remain including range anxiety, battery capability, battery stability such as in Iceland (Lin and Sovacool 2020), and the purchase price which is the most considered factor such as in less developed areas and countries (Adhikari et al. 2020). A relative lack of choice of vehicle brands and types is also a factor, as is uncertainty over the direction of technological change (Manzetti and Mariasiu 2015). In some case, dealers have been dismissive and deceptive about electric vehicles (Zarazua de Rubens et al. 2018).

Technological issues are sometimes intertwined with corresponding regulations and rules. Owing to an unclear definition of ‘autonomous’, some serious crashes have occurred in the USA. Thus, policies have been created to request for car manufacturers to change vehicle features from an ‘autonomous’ to ‘auto-pilot’ or a driving assistant system (Brown 2019; Stumpf 2019). It is a responsible move for users and citizens, but at the same time, it is also a stumbling block for ongoing technology. Autonomous technology is mostly integrated with connected or other features politically and practically. The UK has the Autonomous and Connected Centre and China has the ‘smart and connected vehicle’ policy (State Council 2010; CCAV 2015a).

Vehicle connectivity is based on 5G ('Fifth Generation') mobile Internet, which offers a high data speed and bandwidth spectrum for data deferral (0.001s). Current infrastructures are 4G based, with 0.045s data and signal deferral. This delay could cause a serious crash if insufficient reaction time is available to the autonomous system. According to CoventryLive, the first UK 5G Internet will be in Coventry. In cooperation with the mobile network and internet provider EE, local government in Coventry, Birmingham and the West Midlands have proclaimed that £150 million will be invested in new 5G Internet trial networks. Crucially, compared with the unreliable 4G, the 5G network provides a more stable signal and network, as Andy Street, the West Midlands Mayor said: "For the driverless car industry we need that reliable 5G signal." (Hallam 2018; Kavanagh 2018).

From the STT perspective, policy is categorised as a "landscape", a guidance to shape the automotive industry and its markets. Accidents such as the Diesel Scandal are a shock, shaking the current stable landscape and putting sudden pressure on daily routines. The regime is interrupted to adapt such pressure to adjust correspondent regulations such as to lift the threshold of crafting diesel vehicles. These accidents could result in consecutive consequences, users will be reluctant to accept vehicles from car manufacturers involved, resulting in a loss of sales and a narrowing of the production line. Taking the example of VW, which is dedicated to orienting towards electric vehicles in the near future, this will result in a loss of over 14,000 jobs (Taylor et al. 2018). However, it could also provide a chance to make changes both in technology and business strategy to coincide with the future trend i.e. vehicle electrification (Hetzner 2016; McGee 2018). Brexit is will also have an impact on the landscape, similar to that made by the Diesel Scandal.

## 3.11 Conclusion

Policy and regulation, most of the time, lag behind expansion, especially in the emergence of innovative technology. Thus, policy and regulation generally play a role of creating ‘norms’ rather than being a ‘guider’. This fact means that it has fallen upon a rudimentary market to protect the news while in some way, it would be a hinder for niches to grow freely and thus the space shrunk.

All features of CASE are more or less intertwined politically and practically. Autonomous vehicles are proposed as a national programme to gradually benefit both the nation and private users; however, the legalisation of this technology still has a long way to go. It has led to many technological and ethical problems; in addition, too much unclear jargon and protocol which cannot be fully accomplished and explained. New techniques innovation, such as electrification and automation, may reduce some jobs, e.g. in engine maintenance, but it may also create additional jobs, e.g. IT services. The automotive trade is important to import and export, for national and international economy. Whilst innovation will be a revolutionary shock for stable policy, it also offers challenge, pressure and opportunities to the automotive industry. Overall, the patchy regulations on transportation need vehicle manufacturers to dedicate more effort in the pushing of new technology (Rauwald 2019).

# Chapter 4

# Contextual Framing of Contemporary Automobility

> *"There is not just one company that can do everything. You can follow that approach, but it will be expensive and risky,"…"We learnt how to work in a network, to manage that network of different partners, and to integrate that into the car, a product or a piece of software. "* Thomas Müller, Head of development for autonomous driving at Audi (McGee 2019).

The theoretical frameworks have been introduced in Chapter 2 argue that automobility could be defined as a unique socio-technical system. This socio-technical system is subject to pressures and innovations that could stimulate the entire system into instability and become transformative of the socio-technical system. The innovations emerge at the niche level as well as in the regime level owing to the competitive and collective convergence in the regime. In this chapter, all the theoretical concepts are applied to the automobility socio-technical system to illustrate the pathways of transition, the challenges and pressures for the automotive industry, as well as the overall responses of vehicle manufacturers. The structure of the main body starts with a general background of contemporary automotive industry and its pressures (Section 4.2), including the challenges and responses from the industry, then the industry boundary dissolution and reintegration are interpreted in Section 4.3, therefore the distinctive industry transition pathways represent in Section 4.4. To illustrate in more detail, network reintegration among the organizations is described. Before the main body, an introduction is given at the beginning (Section 4.1) and the chapter is ended with discussion and conclusion (Section 4.5 and 4.6).

## 4.1 Introduction

Sustainability is a process of being more sustainable (Wells 2013). This process can be adjusted to coincide the preponderant scenarios by transformation, evolution and substitution. Socio-technical transitions include long-term changes and short-term interruptions where new technologies may permeate into society alongside structural changes in any perspectives such as production, consumption, regulatory frameworks and interventions, and social behaviours and attitudes (Roberts and Geels 2019). Particularly, sustainable transitions focus on how changes are orchestrated to enable desirable outcomes. Current research links STT agency with everyday experiences to explore how transitions happened.

Transitions in automobility happen when technical novelties tend to address societal issues. Transition is derived from the growing application of such concepts as autonomous driving, connectivity features, big data mining, platform based online vehicle/ride sharing/hailing, pure or hybrid vehicle electrification, and in-car infotainment communication. Each element could be an opportunity to contribute to the process of transition.

A transition normally requires that it is supported by national or international rules and regulations (Auvinen and Tuominen 2014), or it is autopoietic without any sustenance. Vehicle manufacturers explore new markets and enhanced revenues through innovation aligned to national regulations and rules. Collective and accumulative evidence indicates that an expanded niche market could emerge as a combination of product innovation and new business models. Typically, the pyramid of 'hierarchical suppliers — integrator' pattern is progressively replaced by 'lateral co-operators'. This trend is not merely limited in the automotive industry. Accordingly, thresholds for getting into the automotive industry are relatively lower for both new entrants and incumbents. The automotive system therefore becomes de-centralized but more competitive. In the era of Industry 4.0, tech giants, ICT companies and traditional car manufacturers are taking another race.

## 4.2 The Contradictions within the Contemporary Automobility Industry and the Pressures for Change

### 4.2.1 The contradictions

In the current stage, the automobility industry face four pairs of contradictions. The first one is between classic economic growth and environment. Even though the electric vehicle revolution addresses aspects of environmental deteriation and may enable technological innovation to stimulate econmic growth, it is still the case as discussed in last chapter that the market penetration of electric vehicle is far short of sustainability (International Energy Agency 2018; Rolander et al. 2018; Stringer and Buckland 2019). Vehicles are still mostly powered by traditional petrol or diesel which discharge toxic gas and carbon into the air. To boost revenue growth, ‘more sales more gains’ is the traditional strategy for automotive manufacturers but it conflicts with sustainability in many ways. Less activity should be encouraged, at least on less vehicle usage and production. But again, this pair paradox seems never to be solved until vehicles are effectively used and the production process are simplified, through in the longer time period it is possible that the circular economy will contribute to resolving this contraditction.

The second dilemma is between the environmental issues and personal requirements. The vehicles are an integral part in our daily lives. It is essential to create innovations to serve people. The primary consideration for users to buy a vehicle therefore is not the environmental impact of this production, it is the conveience and safety while achieving mobility. Manufacturers therefore to produce vehicles that reconcile the environmental appeals at the same time as functionality and cost. The electric vehicles ideally are environmentaly-friendly, affordable and safe. But to date higher cost and reduced convenience make electric vehicles less attractive compared with conventional combustion engine powered vehicles. Government therefore plays a mediating role between the users and manufacturers to balance the users’ requirements and environmental sacrifice. Electric vehicle is an epitome of technical innovations. In the transformation stage, the vehicle is changing its role from a product to a service tool. It is not only a challenge for the car manufacturers, but also the challenge for people to accept the new travelling modes.

The thrid is the business context that conflicts with the traditional business model in automobility industry. The traditional business model is no longer compatiable to the fast-changing technology and customer demands for differentiation. This compels the traditional automotive providers to extend their roles to be service value added providers synchronously to capture additonal value. The customization of mobility thus is required. Drivers and passengers tend not to treat the vehicle as a tool, but as a common relaxation space to chat and share experience. For instance, Blablacar aims to create a relax atmosphere between drivers and sharers, or autonomous vehicles require more space for passengers and more functions of infotainment.

Last, the entry thresholds to be an automaker are lower owing to the industry 4.0 smart digitalization, at least in terms of manufacturing. Technological development and environmental appeals necessitate that traditional vehicle manufacturers simplify production via common architectures and pay more attention to vehicle customernization and connection. This complex system could not be completed by a single car company, it requires a lot of technologies from other partners. For example, to create an autonomous vehicle at least needs the support from a car company, a map company, a navigation company, a sensor company and ICT company. The most important point is that the core of autonomous vehicle is not ‘vehicle’ but ‘autonomous’. Because the vehicle can be simplifed to electricity powered but the system of automation is far more complex. Therefore, every company in this project has an opportunity to step into the automotive industry to be an ‘automaker’. The threshold of being an automaker is not as high as it used to be, but the competitiveness among all players are more severe.

### 4.2.2 The pressures for change

To understand the pressures for change in the automobility regime it is possible to employ a regime-based typology of market evolution as proposed by Dijk (2014): The Regime Evolution Framework (REF). In this case, the understanding of change does not just rely on the 'internal dynamics' of a socio-technical system, but also draws on the idea that two or more regimes may be interacting. In turn, this means the analysis is concerned with the boundary conditions of socio-technical systems. In Table 9 the boundary conditions are proposed for three different conditions located in micro, meso and macro levels.

***Table 9 Overview of Socio-Technical System Change in Different Levels***

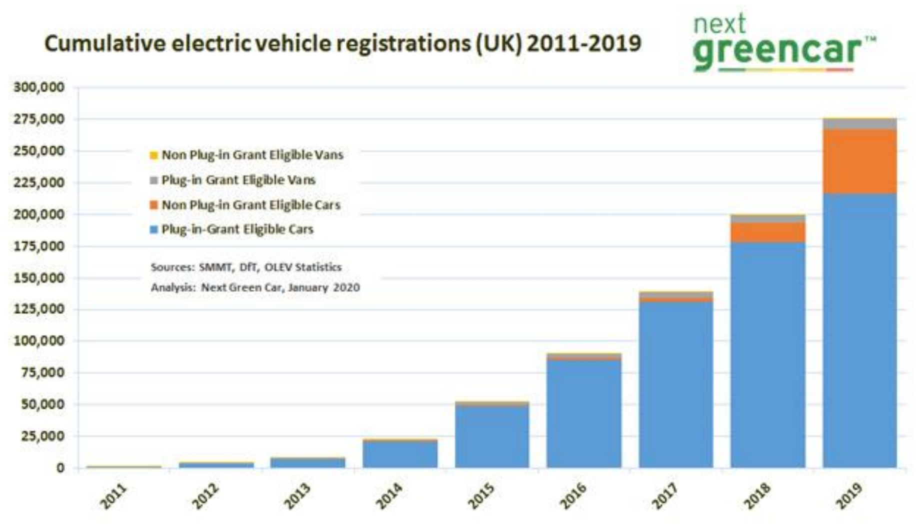
| System Level | | Patterns of change | | |
|---|---|---|---|---|
| | | Maintenance | Change | Disruption |
| Corporate Innovation Strategy | Micro | Business as usual | Competing differently / competing better | Beyond competition |
| Regime | Meso | Regime reproduction | Regime reorganisation/ Regime amidst diversification | Magnified transition pathways |
| System Boundary Conditions | Macro | Impermeable | Porous/ Fractured | Disintegrating |

Source: (Wang and Wells 2020)

The direction and scale of change depends upon the different system level under consideration, and the forces that instigate patterns of change. For instance, if a mild disturbance presses on the micro level where all innovations are competitive and yet to be formed as a collective group, competitiveness will take the form of normal competition. But if new innovations are integrated into an established or incumbent business entity, the changes are more radical. Again, the boundaries between each of two systems are conceptually impermeable, different socio-technical systems may be complementary but independent. However, if a shock or a sudden significant pressure squeezes into the systems, the boundaries between systems are disintegrating to offer a chance to change the current condition completely.

Note also that in socio-technical systems there is also a fractal element in that just as the system as a whole exhibits distinct boundary that define what is in, and what is not in the system, so too do the constituent elements. Hence, a vehicle manufacturer is a distinct element within the automobility system, and as a business it has defined boundaries. As with the entire socio-technical system, the boundaries of elements within the system need not be entirely static or fixed, but also show a dynamic stability over time. So, for example, vehicle manufacturers have over time reduced levels of vertical integration from the early days of the Ford manufacturing system to the contemporary neo-Toyota Production System approach of having tiered or layered supply chains.

The pressures of change in the automobility industry therefore from a several streams (i.e. political, demand-driven or potential benefits driven), and different elements distributions (CASE). Policy-derived niche such as electric vehicles could gain additional assistances e.g. via accelerated infrastructure establishment and services provision. Positive, supportive and effective policy could heighten the EV adoption rate from many perspectives such as users' awareness, businesses expansion and infrastructures utilization (Bakker and Trip 2013). In the UK, the policy on EV concentrates on financial support, inspiring electric vehicle sales, registration and usage by grants (Mazur et al. 2015; Lilly 2019). For example (Figure 4.1), a quarter-based year-on-year electric vehicle registration in the UK demonstrates a strong growth. Especially from 2014, this growth increased from over 20,000 EVs to almost 275, 000 vehicles by the end of 2019. Over 10-fold increase in registrations was achieved in only six years. In which, plug-in-Grant eligible cars are taking the largest collection over 90 percent that meant a smaller clean vehicle is the priority.

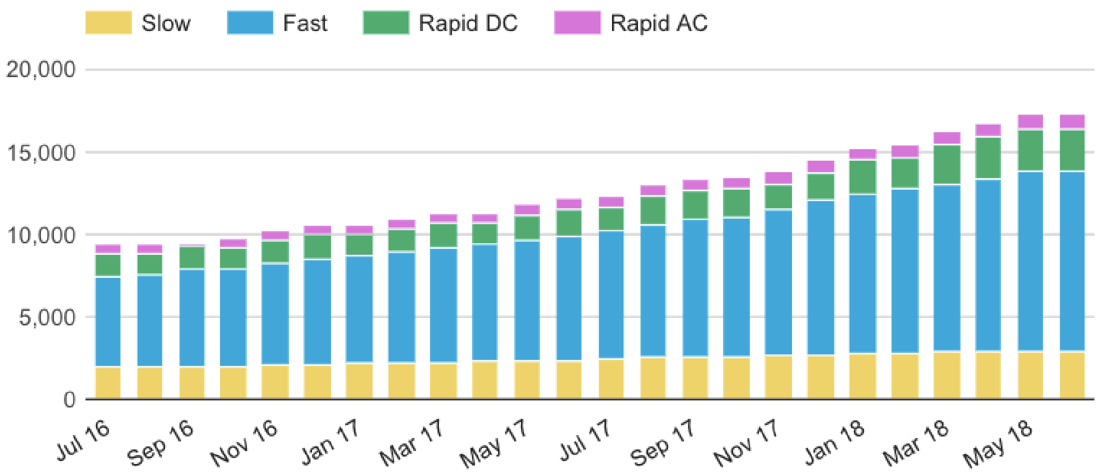



Source: Cumulative year-on-year electric vehicle registrations (UK ) 2011-2019 (Lilly 2019)

***Figure 4.1 Cumulative Year-on-year Electric Vehicle Registrations (UK)***

Policy helps individuals to inform a “greener” behaviour by various methods also with different ways to help car manufacturers. It accelerates businesses expansion in the UK but new technology adaption in the Germany. Therefore the former relies on global supply chain adaption to reach the $CO_2$ emission target while latter controls car market for a long term but may not meet the global emission target in a short time (Mazur et al. 2015). However, experts say that EV market extension is constrained because the technology is underdeveloped. Although numerous investments have been injected in both technology and market, the users’ experiences are not ideal or competitive with petrol/diesel vehicles (Huebner et al. 2018).

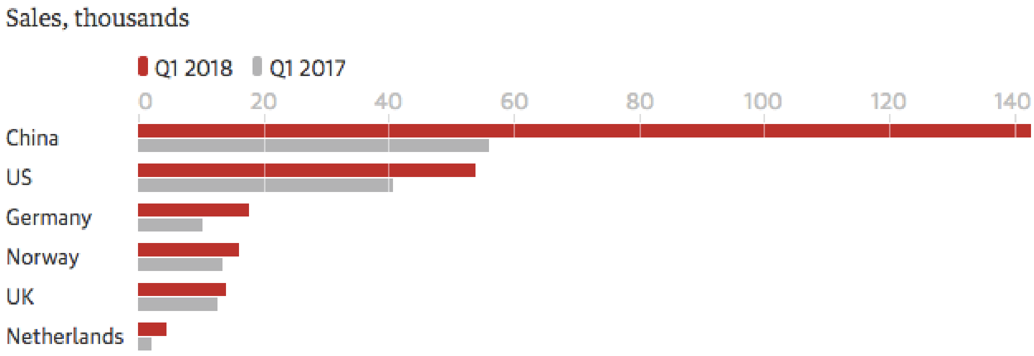
In turn, infrastructure development such as charging points construction is growing steadily since 2016 which has stimulated electric vehicle sales and usage in the UK (Boffey 2018). As Figure 4.2 displays, the fast charging points are on the top of ranking, from around 5,000 charging points in July 2016 to over 10,000 points of charging station available in June 2018. The number doubled only within a short 2-years (Zap-Map 2018; Lilly 2019). Charging points’ availability and capability have solved the major problem of the vehicle travelling length. The UK government invested £4.5 million for home and street charging and extra grant rates up to £4,500. The EV purchase growth stimulates the UK citizens involvement in cleaner environment revolution, government therefore sets a target to end of selling fossil fuel powered cars and vans in 2040. 115,000 ultra-low emission cars and more than 11,500 public charge points have founded by national government in 2017 (DfT et al. 2017; DfT (Charging points) et al. 2018).




Source: UK charging points by charger speed (Zap-Map 2018) adopted by (Lilly 2019)

***Figure 4.2 UK Charging Points by Charger Speed***

China is in the similar scenario. Official regulations support electric vehicle selling which makes China becoming the largest EV market in the world (Stanway 2018). Numbers of EV sales was more than doubled in the first three months of 2018 compared with a year earlier, which is a huge jump compared with other countries (Boffey 2018). Particularly from Figure 4.3, it shows that Q1 EV sales in China 2018 were far more than Germany, Norway, the UK and Netherlands those countries that are highly embraced the EVs. Of course, large population base counts for a momentous matter.




Source: (Boffey 2018)

***Figure 4.3 Comparative Sales of Electric Vehicles 6 Countries Q1 2017 and Q1 2018***

***Table 10 Estimates of Annual Economic Benefits from AVs in the United States***

Estimates of annual economic benefits from AVs in the United States.

| | Assumed market shares | | |
|---|---|---|---|
| | 10% | 50% | 90% |
| *Crash cost savings from AVs* | | | |
| Lives saved (per year) | 1100 | 9600 | 21,700 |
| Fewer crashes | 211,000 | 1,880,000 | 4,220,000 |
| Economic cost savings | $5.5 B | $48.8 B | $109.7 B |
| Comprehensive cost savings | $17.7 B | $158.1 B | $355.4 B |
| Economic cost savings per AV | $430 | $770 | $960 |
| Comprehensive cost savings per AV | $1390 | $2480 | $3100 |
| *Congestion benefits* | | | |
| Travel time savings (M hours) | 756 | 1680 | 2772 |
| Fuel savings (M gallons) | 102 | 224 | 724 |
| Total savings | $16.8 | $37.4 | $63.0 |
| Savings per AV | $1320 | $590 | $550 |
| *Other AV impacts* | | | |
| Parking savings | $3.2 | $15.9 | $28.7 |
| Savings per AV | $250 | $250 | $250 |
| VMT increase | 2.0% | 7.5% | 9.0% |
| Change in total # vehicles | −4.7% | −23.7% | −42.6% |
| Annual savings: Economic costs only | $25.5 B | $102.2 B | $201.4 B |
| Annual savings: Comprehensive costs | $37.7 B | $211.5 B | $447.1 B |
| Annual savings per AV: Economic costs only | $2000 | $1610 | $1760 |
| Annual savings per AV: Comprehensive costs | $2960 | $3320 | $3900 |
| Net present value of AV benefits minus added purchase price: Economic costs only | $5210 | $7250 | $10,390 |
| Net present value of AV benefits minus added purchase price: Comprehensive costs | $12,510 | $20,250 | $26,660 |
| *Assumptions* | | | |
| Number of AVs operating in U.S. | 12.0 M | 45.1 M | 65.1 M |
| Crash reduction fraction per AV | 0.5 | 0.75 | 0.9 |
| Freeway congestion benefit (delay reduction) | 15% | 35% | 60% |
| Arterial congestion benefit | 5% | 10% | 15% |
| Fuel savings | 13% | 18% | 25% |
| Non-AV following-vehicle fuel efficiency benefit (freeway) | 8% | 13% | 13% |
| VMT increase per AV | 20% | 15% | 10% |
| % of AVs shared across users | 10% | 10% | 10% |
| Added purchase price for AV capabilities | $10,000 | $5000 | $3000 |
| Discount rate | 10% | 10% | 10% |
| Vehicle lifetime (years) | 15 | 15 | 15 |

Source: (Fagnant and Kockelman 2014)

The economic saving from autonomous vehicles is significant as Fagnant and Kockelman (2014) claimed (Table 10). They extract a few obvious elements to measure the overall costs and benefits from autonomous vehicles. They propose the economic benefits from three different levels market penetration of AV: 10%, 50% and 90%. It shows the higher the market penetration, the lower total price cost per person and congestion cost, and the higher time, fuel and crashes saving. In this context, local municipals and vehicle manufacturers are potential impulse for autonomous driving innovative technology expansion.

Sharing schemes are also increasing rapidly while from another dimension. Without a clear political supportive background, the membership of vehicle sharing schemes and fleets increased by 50% 2012 and 2014 (Shaheen and Cohen 2016; Shaheen et al. 2020). A study from (Narayanan et al. 2020) stated that the literature on sharing vehicles has developed with analysis more focussed on the sharing perspective rather vehicle automation. Wells and his colleagues have described the different business models of shared mobility which has varied impact on society (Wells et al. 2020b). These sharing schemes are putting pressure on conventional vehicle manufacturers, the taxi industry and car renting/hiring companies (Dowling and Simpson 2013). Therefore the traditional car companies especially such as Daimler, are launching a challenge to these platform-based new industries (Green Car Congress 2012; Nicola 2016; Automotive News Europe 2017a; Daimler 2017b; Lunden 2017a; Reader 2017).

It is notable that the CASE concept includes the most elements of transformation, but it does not include other pressures such as the Circular Economy, Industry 4.0, Big data analytics and other new concepts. Even though the CASE aims to improve sustainability, there is less the consideration of the circular economy. CASE sees the ‘process to sustainability’, is a unidirectional process to achieve the goal. It lacks the thoughts of reverse flow of materials. There is limited research to predict the future trend on circularity (Land Transport Authority 2014; Marletto 2014), even less use the reversal thoughts to plan the future (Auvinen and Tuominen 2014). Industry 4.0 is the catalyst to achieve CASE vehicles, but it is not included. Equally, big data analytics includes the methods which may use data collection and deciphering for vehicle connectivity. CASE vehicles refer to the private or commercial cars, thus some new concepts are not included such as electric scooters and bikes.

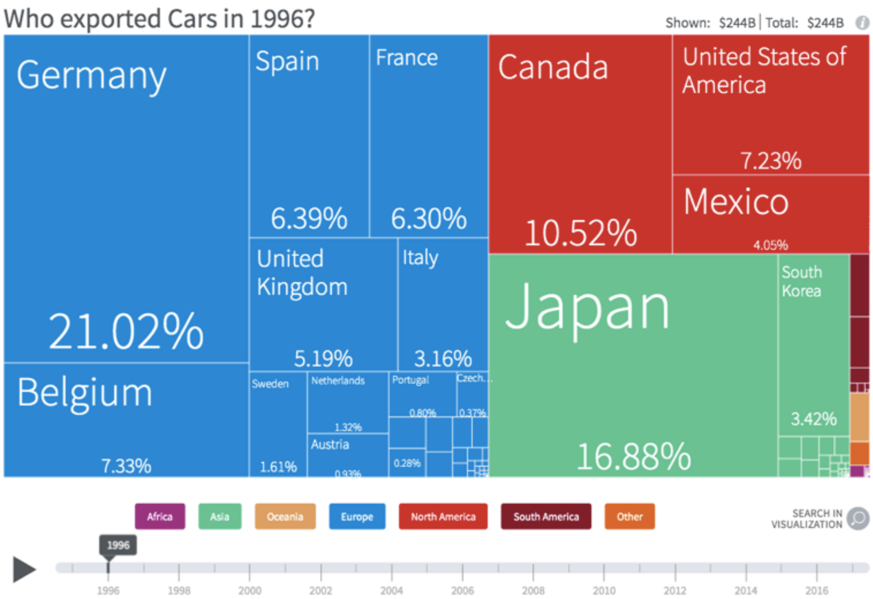
### 4.2.3 Normal competition within automobility industry

In principle, there should be a relationship between changes at the level of the socio-technical system, and changes at the level of the constituent elements (Bidmon and Knab 2018). Incumbents can be important as sources of change; just as new entrants can be. Equally, incumbents may need to react to external pressures and changes going on around them within and outside their socio-technical system. That is, vehicle manufacturers will face the ‘normal’ pressures of competition and market change within the automobility system. These normal pressures are significant because they act to restrict profitability in vehicle manufacturing and thereby give impetus to collaborate restructuring via mergers and acquisitions, to constant efforts to increase productivity of capital and labour, and to the quest to expand markets in line with low-cost manufacturing locations.

The demand for new cars was strong and is still likely to be strong in future years, it results in the current competition of physical car selling within the traditional automotive industry still furious. In the years 2010-2018, an average of 70.6 million cars were sold globally, with 78.9 million units in 2018 and 75 million units in 2019. It is predicted that the figure would slightly drop, but the basic demand of vehicles keeps strong (Statista 2020a). The big car manufacturers who dominate the whole industry are Volkswagen (12.2% global market share), Toyota (11.4%), and Renault-Nissan alliance (10.9%) in 2019, who took overall around 35% market share of the light vehicle market (Focus2move 2020). The automotive industry is very competitive, General Motors was the world leader before 2010, however, Toyota took the position and became the leader for a while. Ford once was on the list of top five, but it drops down in the past a few years.

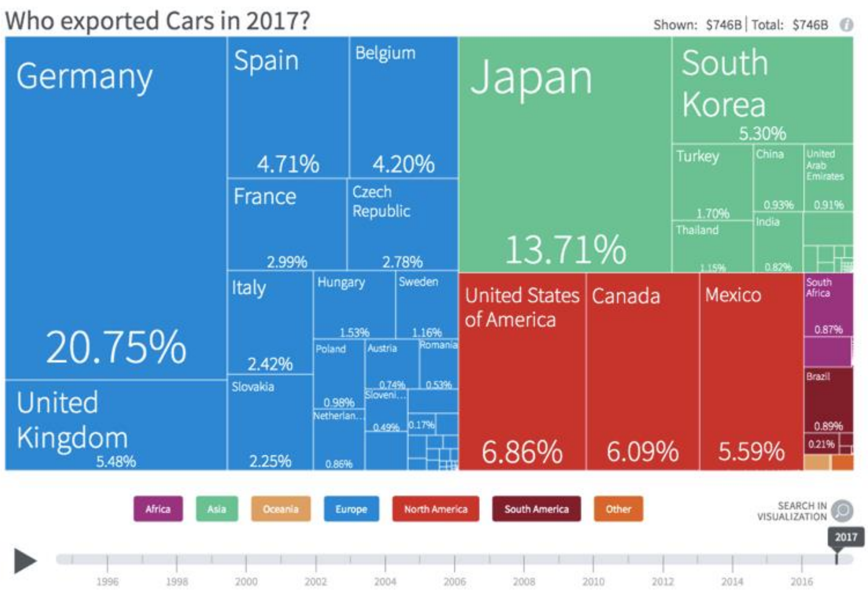
Europe is the biggest car export area which takes around half of the exportation in automotive industry, which means automotive enterprise in the Europe may be challenged more. The car export value in EU is increasing from $126 billion in 1995 to $408 billion in 2018 (HarvardGrwthLab 2018). Followed by North America and Asia, which each take just less than a quarter. The Figure 4.4 and 4.5 show that although the general pattern for each area is not much changed (in 1996 and

2017 respectively), they are more fragmented with more countries involved in over 20 years. Germany takes the largest collection with 20% of exports in the world, Japan is the second largest car export country with 16.88% in 1996 and down to 13.71% in 2017. The third country was Canada in 1996 which took over 10% while in 2017, four countries were shared the third place with around the same figure ranged 5%-6% (HarvardGrwthLab 2018).




Resources: (HarvardGrwthLab 2018)

***Figure 4.4 Countries Exported Cars in 1996***



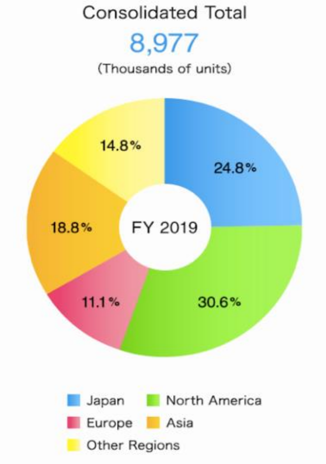

Resources: (HarvardGrwthLab 2018)

***Figure 4.5 Countries Export Cars in 2017***

It is worth noticing that in 2019, Renault-Nissan alliance took the third place. The configuration of the alliance gives higher opportunities for infiltration crossing countries and culture. It helps both manufacturers to understand the reciprocal markets to permeate quicker, also helps to share the data and technology to reduce the unit costs. However, the crisis with Ghosn also exposed the risks of such alliance structures. Other alliances attempts such as that between of FCA and PSA (Piovaccari and Jewkes 2020) show different risks, in this case with regulators concerned about a potential EU monopoly position on light vans. The traditional M&A has long been viewed as a method that allows a company to grow faster and stronger in a short time, but it is difficult to achieve all the synergies hoped for. This is a trend among big car companies which are willing to extend their businesses in a short period such as Daimler acquired the car sharing platforms (Reader 2017). These acquisitions and mergers make company internationally involved by which the companies could fulfil the local market requirements with lower risk.

The new emergent alliances and acquisitions are international, often driven by developing countries e.g. China and India. The similarity between these two countries are both demographic and economic. The potential large user market and capital investment give impetus to acquisition strategies. The typical examples are the Tata acquisition of JLR and Geely of Volvo. Over 20 % of Volvo sales are in Sweden, and EU is the largest sales region for Volvo, followed by China and the US (BBC News 2017; Volvo 2019b). The successful penetration by Volvo in the Chinese market may partially be due to Geely acquiring Volvo.

However, the automotive industry is not a ‘global’ industry, it is still regional in character. Toyota is one of the top selling companies, with 24.8% market shares in the Japan while 30.6 % in the North America and 18.8% in the Asia (Figure 4.6) (Toyota 2019a). Toyota is highly produced in Japan and sold domestically but with a very small market share in EU. Even within China, a local car company has many challenges to overcome (e.g. with policy barriers) when selling its products in another province, especially when they have local brands.




Resources: (Toyota 2019a)

***Figure 4.6 Toyota Sold by Region***

### 4.2.4 The new challenges to traditional automobility industry

However, automotive manufacturers also face the ‘abnormal’ challenges in transitioning to automobility by two sources. First, the fundamental innovative technologies call for the tremendous transformation of traditional automakers to incessantly develop new capabilities. To achieve this new form of automobility requires conventional automakers both strategically and practically to embrace these competencies. Second, the automobility transition involves many new entrants which may compete against with traditional car makers, often with innovative business models and customer propositions that are not easily replicated.

When entering the Industry 4.0, automotive manufacturers may try to turn their role from product providers to service suppliers, which requires them to challenge and compete in areas where they never extended previously. In these areas, automotive manufacturers are not the dominant entities, they are participants who play an auxiliary role. When a vehicle becomes as a service tool, the feeling of involvement may be more important than the driving experience. To maximize the experience, intelligent mapping and navigation are essential and the extension of connection from phone-to-vehicle to vehicle-to-everything is inevitable. Be smart, be intelligent, and be selective are the central principles for a service tool. This is the new challenge to automotive industry to compete with the ‘native players’ who are ‘native’ in this area such as Ericsson and Bosch.

However, the autonomous vehicle contributes a unique and new arena to all potential market participants. To build this product is a challenge for all players because none of them have made it before and none of them could complete such a project exclusively. However, this race to bring product to the market is fast and unpredictable, and expensive. It was declared by the CEO of Transit, Sam Vermette: "New modes of mobility are entering the market at record speeds. It took decades for car-sharing to catch on. Now, e-bikes and scooters are being rolled out in weeks *"* (Automotive News Europe 2018b).

The innovative niche market is even broader. E-scooters are easy, portable and can be shared. In some degree, e-scooters are an extension of electric vehicles because they share similar networks to gain the user adoption (Toll 2018). It is the same principle for the electric bike niche market. Additionally, varied new energy powered vehicles are prevailing and could be commercialized in the markets very soon. Toyota, for example, has raised solar cells mixed with other power functions to extend the vehicle range and be totally clean without worry under any weather conditions (Sensiba 2019).

Traditional car manufacturers tried to develop autonomous vehicles independently, but had to acknowledged that an autonomous vehicle is not merely another type of car, it requires higher coordination and cooperation with varied parties (Sigal 2018). As BMW finally admitted, they need help from outsiders rather take all techniques and integrate in one (Coppola 2018). Therefore, a successful transition is required on traditional carmakers for example Toyota invested $500m in Uber’s driverless taxi programme (BBC News 2018b).

However, many respects the negative externalities of automobility are not new, they are just more intense than previously. They include 1) carbon emissions, decarbonisation and climate change, 2) road traffic deaths and injuries, 3) air quality, 4) noise, urbanisation and stress, 5) congestion and the environmental burdens of infrastructure, 6) the geo-politics of petroleum supply and demand, 7) inevitable resource consumption.

***Table 11 Issues and Benefits from CASE Vehicles***

| | Connectivity | Autonomous | Shared | Electric |
|---|---|---|---|---|
| Carbon emissions | Less stop and start could decrease emissions | Effectively vehicle usage, averagely decrease the emissions | Should be less, if shared more | Yes, lower or zero |
| Decarbonisation | --- | --- | Yes, if shared more | Yes |
| Road deaths and injuries | Yes, should be less, as all surroundings are predictable | Yes, it designed as low or zero deaths | --- | Not really, they are operated manually |
| Air quality | Indirectly improved | Yes, vehicle efficient usage could improve air quality | Yes, if on-road numbers of vehicles are less | Yes, as they are zero or less emissions |
| Noise | Less, for less start and stops | should be less | Yes, but less | Zero |
| Urbanisation | Could be more, expanded to rural areas | Yes, it can go anywhere without hassles | Not sure, it is better to share in a high motorway developed area | Not currently, range anxiety |
| Congestion | Yes, congestion should be predictable | Yes, congestion should be predictable and avoidable | Yes, as less vehicles on road | Not really, they are operated manually |
| Environmental burdens of infrastructure | Yes, needs more | Yes, needs even more | Not much | Yes, charging stations but less than connectivity and autonomous |
| Geo-politics of petroleum supply and demand | Not sure, depends on the powertrain | Not sure, depends on the powertrain | Not sure, depends on the powertrain | Independence from geo-politics of petroleum |
| Inevitable resource consumption | Yes, rare metals inside of sensors and other parts | Yes, rare metals inside of sensors and other parts | --- | Yes, a large amount of copper and lithium required |

Sources: Author

From Table 11, we can see that the trajectory of CASE seems path dependent, it is somewhat coherent and will create further lock-in tendencies. None of the elements individually could fulfil all the requirements and tackle all the issues. Therefore, CASE should be the best solution to address all issues and derive maximum advantage from each element. In the automobility socio-technical system, the automotive industry is the one still to play the essential role at the heart of integrating CASE technologies.

## 4.3 Boundaries Dissolution and Reintegration in Automotive Industry

Under multi-purpose actions (i.e. political, geographical, market, and environmental), CASE dissolves the boundaries between conventional automotive industry and many other industries, and meanwhile enables multi-layer wider network crossing-bounded reintegration.

### 4.3.1 The dissolution of industry boundaries

The terminology of ‘industry’ clearly draws a boundary for products and companies to identify which categories they belong to. Each industry has norms to evaluate the performance for all participants if they fulfil the requirements. The industry is constructed by a relevant stable network with dominant core players and auxiliary participants. The position of each element within an industry is varied by the definition of this industry. The automotive industry for instance, is an automaker dominated field, in which parts suppliers are playing a supplementary role.

Within an industry, the measurement of being a contributor could be various. In the traditional automotive industry, performance could be measured as the volume of sold cars per annum, or the earned profit per annum. The traditional automotive industry is defined as a dynamically stable whole with settled structure in which car manufacturers are at the core of setting the norms and expectations. While as technology and notions change, some endogenous or exogenous forces may cumulatively undermine the dynamic stability through business expansion and extension. We frame this process as a transition by which traditional automotive industry is transferring to the automobility industry with additional service added. This intangible service could not be measured by ‘sold units’ per annum. The above analysis indicates that services and new technology bring revolution to the entire industry fundamentally.

The transition gives a window to new entrants which benefit with technology or heuristic concept to invade into the current automotive system to substitute and even to subvert the stable but dynamic whole. In terms of such new transformation from automotive industry to automobility industry, the boundaries are not clear to show which is the main-force or dominator. The outcomes will be contested and emerge as a product of the actions from companies, governments, consumes, regulators, and others. The service platforms offer another capability of automobiles while car makers could be more than a product provider. It is the same for the technological-intensive sectors in which tech-giants could provide higher performance vehicles rather a pure vehicle. Therefore, the individual vehicle is not the focal point in autonomous technology. The thresholds of being an automobility manufacturer therefore are lower for tech giants and service providers. Even though some struggles happened, for instance, Dyson announced to build electric vehicles while later they abandoned their plan to enter the EV segments (Dyson Automotive 2019). Again, this suggests that outcomes are not readily predictable.

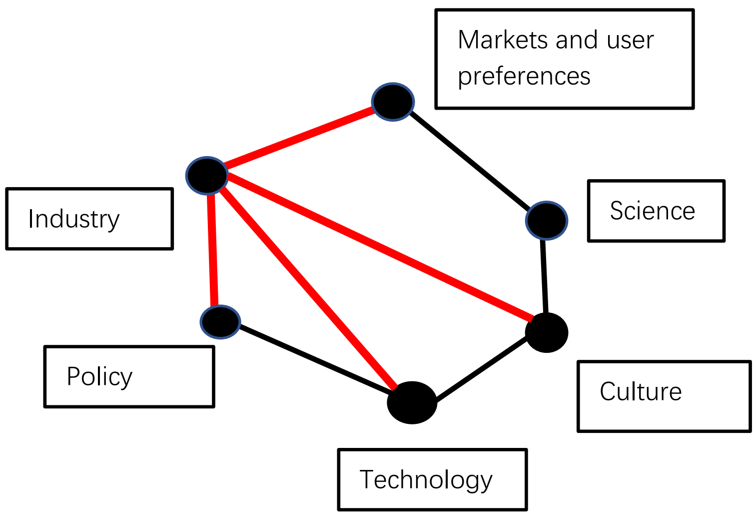
However, for either service creation, innovative technological carrier, or traditional car makers, this emergent automobility arena could be said to be 'new' to all players. In another words, the thresholds are the same for all players as each of them holds partial of essences. Of course, each player comes with a distinct set of assets and competences that may enable or restrict their ability to participate in future automobility.

To create new portfolios, traditional vehicle manufacturing will face two-extreme tensions between the standard competitiveness. They may be vertically and horizontally integrated to those which used to be suppliers to diversify the supplementary range to irrelevant domains. The areas may extend to where they never been or deepen to a field they may never have thought to enter, competitors or those that used to be opposite to this domain. 'Collaboration-integration' (Pinkse et al. 2014) is a strategy described by Pinkse et al. but companies may lack an understanding of how to achieve this balance. How to maintain the existing business (invest in new plants and models; close down plants no longer needed; manage existing supply chains; retain brand positioning, etc.) while simultaneously deciding how far to proceed with these burgeoning new requirements that come with the transition to this new form of automobility, with whom, where, and on what basis?

New portfolios of competence and business model innovation will be required, both from traditional automotive industry players and new entrants, with considerable scope for synergies (Wells and Wang 2017). Experienced automotive industry players that understand the cost pressures in the industry are often best placed to leverage new technologies into mass production, but may need to access new skills and assets in these technologies through acquisition, alliances or organic growth. It is argued that one consequence is that traditional strategies of vertical or horizontal integration within an industry are of decreasing utility. In effect, automobility services built around electric, connected, shared and autonomous vehicles demand and arise out of the confluence of two or more industry sectors as the industry boundaries dissolve. In this sense themes such as autonomous cars are not simply definitions of a product, but also a process which can be understood as seeking to bring together disparate entities. One way of managing this process is to create diagonal relationships across industry sectors. Thus, diagonal synthesis may be defined as the direct acquisition of new competencies in any part of the emergent automobility services ecosystem.

QDI is thus one mechanism by which network innovation may be achieved. Quasi-diagonal integration (QDI) may be defined as the less stable, more expedient (and possibly lower immediate financial risk) version in that the amalgamation process falls short of outright ownership but is more than the mere purchase of components or services. It can be seen at the beginning of the stage of network achievement.

All relationships emerge out of and are part of the process of creating shared cognitive framings of emergent phenomena and may be expected to be more prevalent when new contexts or requirements are present. Which may direct to further cooperation and network integration. The cognitive framing for emergent technologies such as those required for the autonomous car, or shared car, or even electric car, is thus understood as the mechanism by which innovation can be orchestrated within a network through the medium of QDI relationships. Figure 4.7 is a diagram to show how the QDI in current automobility industry for developing autonomous, connected, shared and electric automobility. The Figure 4.7 displays the regime network of the automobility industry which contains the six most representative areas (the black nodes). The lines join two neighbouring elements to frame a general outline of the regime. CASE vehicles, however, extended connections of the automotive industry with more than one area in the regime (the red lines radiate from automotive industry to other areas). This action therefore initiates a network that partially serves vehicle connection, or vehicle electrification, or autonomous vehicles or for vehicle sharing. Eventually, this frame will become a complex network in that all sub-nodes will entwine together. The Figure 4.7 model can be treated as the cross-boundary relations from an industry perspective; or it also can be represented as an individual car manufacturer to extend the business to various area. The data collection procedure is illustrated in the methodology section in the next chapter, more detailed cases are in the Chapter 6 to scrutinize the selected companies as examples.




Source: Author

***Figure 4.7 Automobility Regine Network to Build an AV World***

Boundaries' dissolution seems to inspire the latent possibility for new cooperation relationship and to extend the existing cooperation circles. From vehicle functionality perspective, the car is designed to maximise service for improving driving experience enjoyable. In turn, skilled driving experience and license required are finite the capabilities from drivers. The immergence of network is a process of complexity for both users' adoption and industry change (Amuzu-Sefordzi et al. 2018). This network is growing to be an interacted network when industry boundary dissolution. Without boundaries, networks become bigger and wider, powerful and influential. The networks changed from dot-to-dot network to network-to-network, it is a process transferring from original regime to a new generated regime.

### 4.3.2 Network reintegration

The automobile industry has been systematically changed to consecutively adapt the new innovative knowledge and disseminate it. Establishing alliances and sharing common knowledge help traditional car makers improve current states. Alliances are more possibly successful if they have absorptive ability and capability to accept new knowledge (Schulze et al. 2014). Since the boundaries have been broken and collaborative relations accumulated, wider networks are gradually reintegrated for reconciling with the state changing.

Automobility industry has developed from a single organization-controlled supply chain to a multi-tier participated round network, the system is dynamically stable but more complex due to the multi-partnering change (Mena et al. 2013; Elvers and Song 2014). Not only the way of network integration has changing, the goal of being partnership are also varied from mass-market standardisation to tailored personalisation. Alliances are transferring from production-based to service-oriented business strategy after 2000 and until now the increased revenues are generated by value-added services. Brand sensibility and brand customization from automakers tailored to consumers self-design, from drivers focused to users' adoption if autonomous vehicles could embed more in the mass market. Physical products are measured by quality as well as service can be measured by customer valuable feedback (Godlevskaja et al. 2011).

The traditional automotive industry, at least on the concept level, is in an advantageous position to combine CASE vehicles. The reasons include: 1) the four concepts are emerging roughly at the same time, around 2007 to 2009, 2) the automotive enterprises are capable of conjoining CASE in a one vehicle, and 3) they are cars. Transitions in traditional industry have challenged the concepts from ‘automobile’ to ‘automobility’ to ‘mobility as a service’. The pattern thus is from ‘inclusive wider ICT companies’ to ‘exclusive all possibilities’ to embrace service platforms through mergers and acquisitions.

The network complexity in automotive industry refers not just to the relationship network erection between spare parts suppliers, ICT companies and automakers but also the service value network emerging between consumers and products. Further, as the additional proportion of participants are ICTs rather automakers, it results in the network inclination gradually towards to ICT based service value network (Basole and Rouse 2008).

## 4.4 Automobility Transition Pathways

Socio-technical systems are not entirely stable, being subject to short-term perturbations and long-term transition. Much research has been concerned with identifying the ‘pathways’ along which socio-technical transitions may be said to occur, or the conditions under which a system may be destabilised (Geels 2002; Fraedrich et al. 2015; Geels et al. 2016). Incumbents at the regime level act as an agency in the transitions (Ansari and Krop 2012; Bergek et al. 2013), in the context of ‘whole system’ transition (Papachristos et al. 2013; Geels 2018b; Köhler et al. 2019). However, the system-system interactions have rarely been captured (Raven and Verbong 2007).

The historical vehicle transition pathway could be illustrated by STT theory as well, it could date back to 1840s, when electric powered vehicles were introduced, overlapping the period when the horse powered wagon and electricity were applied practically (Geels 2005a). The electric vehicle was popular but suddenly declined usage due to the underdeveloped technology, narrowed consumer market, finite driving range and high cost of the cars. The electric vehicle comes back around a century later, when technology developed far better and policy became more supportive (Nieuwenhuis and Wells 2001; Geels et al. 2012). It went through the p1(moderate pressure with innovation not sufficiently ready), at a disordered and chaotic stage, the innovation niches were not well prepared. At this stage, electric vehicles serve simply as a symbol of social status rather a commuting transportation.

Then de-alignment and re-alignment stages came followed by the previous stage around beginning of the 20 Century. Petroleum vehicles penetrated the automotive market with a stronger power and longer travel range. Most importantly, since Ford settled assemble line production, the cost reduced dramatically. Hence, the vehicle is not a noble and expensive property, instead, it becomes a common but private travel/commuting tool. At this stage, the development of electric vehicles continued, but the market size shrunk. After 2000, it returns to our life because it is environmental friendly and diversified (Todorovic et al. 2017). Early corporate pioneers such as TH!NK failed to gain sufficient sales, and went bankrupt.

Vehicle manufacturers are gradually taking a pattern of ‘one car company + one other (e.g. ICT, parts suppliers) company’ alliance. In this phase, car companies are seeking the partnership to co-build autonomous vehicles. By the end of 2017, the car companies dominated alliances and made powerful IT/other OEMs realize their strengths and weaknesses in building autonomous vehicles. Therefore, in this progress the ‘outliers’ are trying to build autonomous vehicles themselves without car manufacturers’ support. So, in the years of 2017 and 2018, the alliances became more diverse taking more than a one-to-one pattern, rather to become a two or more car manufacturers to ‘multiple outliers’ pattern. New joint ventures, acquisitions and mergers, and new cooperation allow all participants to implement such collaboration continuously (see Appendix 5).

The boundary expansion and erosion has resulted in regimes that are increasingly intertwined and gradually networked. Elements in such partnership networks are integrated, broken, and reintegrated during 2014 and 2019. Because of the boundaries between industries have been dissolved, each stage may isolate or slightly overlap with another one. Mostly the classic integration trajectory in automotive industry can be identified as following:

**Stage 1**. Quasi-diagonal integration (QDI). This is the primary stage when traditional players tend to insert into the new market. This period is a very exclusive and independent stage, namely the vehicle manufacturers are in charge of the centralized network in which all suppliers are independent with each other. It flattens the structure from pyramid shape to a flat shape. QDI occurs in the rapid technological or market change which includes pressures and threats that are exogenous to the existing industry; Vehicle manufacturers will create portfolios of QDI relationships in order to accelerate the creation of the new automobility ecosystem. It is a part of the strategy of quickly gaining the additional essential resources by which vehicle manufacturers seek to differentiate and compete themselves, but this may mitigate against wider standardisation. Vehicle manufacturers may use QDI relationships to exclude other vehicle manufacturers from a resource or capability. Multilevel hierarchy relations gradually flatten due to the QDI relations are directly one to one.

**Stage 2**. Multi-diagonal integration. This stage is a developed version of QDI in which vehicle manufacturing still dominates the entire network, but within a small group, suppliers are slowly linked with each other rather completely isolated. Usually one or two car manufactures lead a small group with few suppliers around it. This is because the alliance is developing for a while and parts suppliers could do some work together not solely around vehicle development. Or, each company is responsible for its part but eventually all companies will be integrated in the future.

**Stage 3**. Verified alliance. Till here, car enterprises are still playing an important role but not essential; suppliers gently put more weight on its role rather everything around car makers. Or we can say, it is the transition emergence stage that from a pyramid team becoming a hub-and-spoke value chain (Weiss et al. 2015). This stage has two perspectives: one is that they may thrive due to the same goal achievement. For example, Ionity with other car makers to build electric charging networks along the main EU highways. Another is that traditional incumbent rivalries may be set aside to defend from new entrants and thereby the speed of incumbent erosion is reduced. For example, Audi and BMW joined to confront Uber (Taylor 2019a). Alternatively, the same story is in the case of BMW, Mercedes and Audi were co-purchasing Here from Nokia (Hillier 2015; Lunden 2015). The wider automotive industry has also built relevant infrastructures to attribute more practical experiences for users - for instance in 2017, Shell announced a cooperation with NewMotion, and Ionity (Shell 2017).

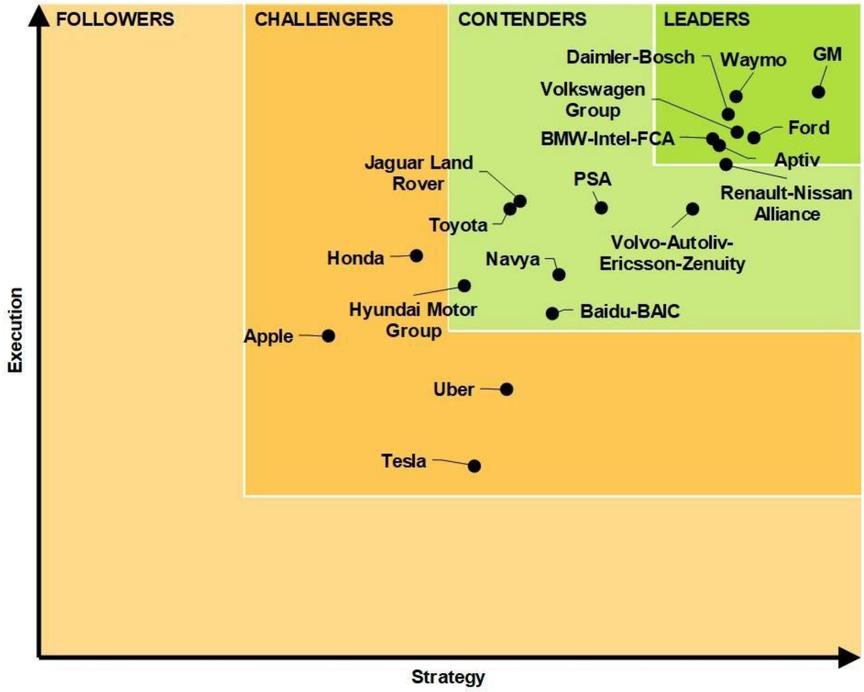
**Stage 4**. Platform-based diversification and expansion. Vehicle/ride share schemes turn competition towards mobility-as-a-service rather than to production of the physical vehicle alone. Additionally, vehicle driving and functionality are differentiated via new methods and features i.e. electrification and automation. At this stage, multiple players enter this vehicle revolutionary competition, thus the roles and participants became diversified. Autonomous vehicles are a springboard for companies that aspire to be an automaker or automobility service supplier. Vehicle manufacturers are not in charge of the network anymore, rather than that, other parts suppliers act more strongly. The most classic example is that Nvidia and Mobileye entered the automotive industry to build autonomous vehicles themselves (Korosec 2019; NVIDIA Newsroom 2019b). Suppliers such as CATL have signed several long-term contracts with carmakers to ensure the abundant supply of cobalt, the lithium battery and its components (Gallagher and Sarkar 2019; Randall 2019c; Yang 2019). Additionally, the products demand and business expansion of electric vehicles has accelerated dramatically and this has laid a good foundation for developing correlative functions such as connected electric vehicles and autonomous electric vehicles. The suppliers' cooperative actions are a great incentive for automakers investing more to weaken the competitiveness (Zhang et al. 2009).

**Stage 5**. Paralleled but unified network generation. In this stage, networks have been established among all players, these networks are intertwined while independent. Parts suppliers and car makers are no longer affiliated which means all participants are parallel without any hierarchy or centralized role to charge all processes. Decentralization and crossovers among all car makers and suppliers are the way to achieve a common future that driven by a same goal --- to build autonomous vehicles. This type of vehicles cannot be created by a single company but have to be achieved by several experts together. Additionally, it is ambitious to integrate CASE vehicles as a whole which is even hard to achieve by car manufacturers alone. This transformation in automotive industry is a revolutionary change that mixed the participants and to be treated equally. The networks are formed from small individual groups network to a numerous one and meanwhile it changes the automotive context from product producers to service providers (Allianz Partners 2019; BP 2019; Iguazio 2019; Soper 2019; ZF 2019).

The race gradually settles down in 2019 and frames a stable network to agree to build autonomous vehicles. Boundaries in individual car makers are broken, also the relations are shattered in superior and subordinate. Toyota and Honda, BMW and Daimler, Hyundai and Kia, VW and Ford all become a big winner in this year.

## 4.5 Discussion

However, tech giants such as google possess a controversial configuration that is upside to the traditional development trajectory. They directly aim to 'notion-based' technology which explores the level 5 ultimate automated functions and its service implication. The application scenarios of service are more likely to be connected for data sharing. Thus, efforts to integrate CASE vehicles have efficiently intensified.




Source: (Hanley 2018)

***Figure 4.8 2017 Autonomous Driving Report by Navigant Research***

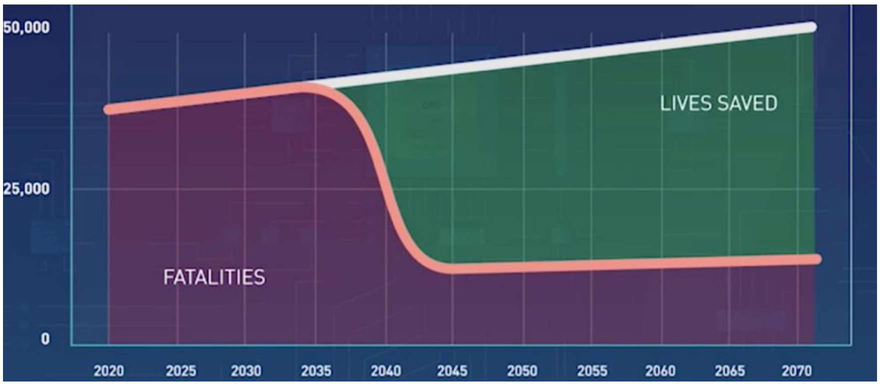
It is not surprising that even though ‘autonomous vehicles’ are the home field of ‘vehicles’, the leaders of the race are both automakers and non-automakers. The Figure 4.8 shows the position of each company that aims to build driverless cars by its strategy and execution in 2018. This stage is occupied by traditional car manufacturers still in the form of alliances such as BMW-Intel-FCA, Daimler-Bosch, Volvo-Autoliv-Ericsson-Zenuity. However, it shows the danger that of the ICT companies and tech companies are making the essential parts of autonomous vehicles as much as car manufacturers. It seems possible that these new players will take place of the traditional car makers if they do not change their business strategy and model (Taylor et al. 2018). This is why business models in car manufacturers are changing dynamically following the new polices.

All eyes are on the years around 2021-25. Many vehicle manufactures flagged their plans many years ago, that they intended to commercialize their autonomous vehicles gradually from the start of 2020. These companies include traditional car companies such as Volvo, BMW, Audi, VW and Ford, and more new accessories such as Delphi, Chinese Baidu, Google. However, the market for autonomous vehicles is unclear for a variety of reasons.

The principal reason is safety. It is an issue raised by users about the technology, the quality of the insurance coverage, ethics and other ‘in use’ issues. The issues have been partially resolved over time and with the maturity of relevant policy support and technology development. Insurance companies are willing to cover the premium on vehicle sharing and autonomous vehicles as discussed in Chapter 3, Section 3.10 (Palmer 2016; Xu and Fan 2019; Wells et al. 2020b). Foretellix, for instance, had series-A round funding with US$14 million and covering all driving solutions caused by autonomous vehicles from the beginning of 2019 (Foretellix 2019).

The tolerance of mistakes made by machine are relatively lower than the mistakes made by human beings because people believe that machines are defaulted as zero-mistakes and that is why we utilise such technology and trust it (Dietvorst et al. 2014). Even though machine algorithms are nearly perfect in that average safety performance robust, users worry about failure situations (Kalra and Groves 2017). Most drivers are confident with their own driving skills and have a very high sense of self-protection and considerate driving. But this cannot be applicable to all drivers, as the high rate of global deaths and injuries from cars illustrates.

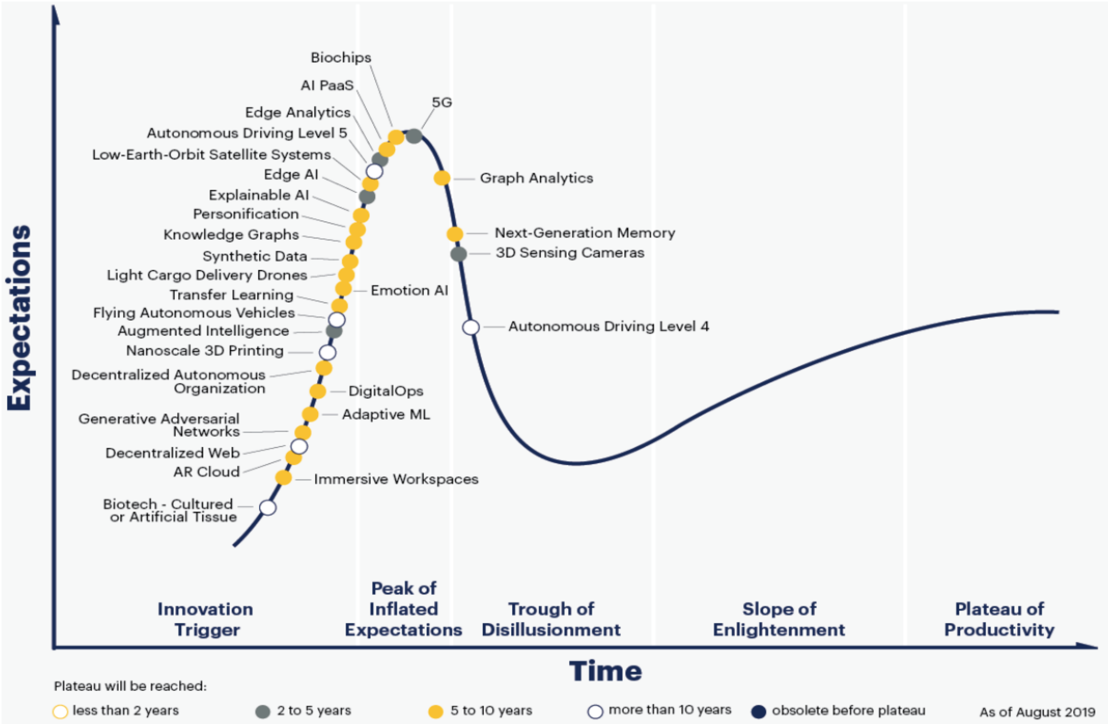
Therefore, Kalra and her research group suggested that the sooner the autonomous vehicles are introduced on the road, the more lives would be saved (Figure 4.9) (Kalra and Groves 2017). The white line is the annual deaths prediction based on the current data; the red line in the middle of the graph represents the fatalities when the autonomous vehicle becomes a practical reality. The death rate will keep the original line for a while because the technology until mass production is reached. After around 2035, the fatalities will decrease dramatically. Kalra also pointed out that the waiting time for the technology 'perfection' is barely possible based on the current on-road test-upgrade-retest mode, the fatality-proof autonomous vehicle will need a return distance to Neptune to prove the purely safety of the autonomous vehicle (Kalra and Paddock 2017).




Source: (Kalra and Groves 2017)

***Figure 4.9 Cost Lives Waiting for the Perfect AVs***

However, the trajectory may ignore the middle point when autonomous vehicles and conventional vehicles are concomitant which means a well-coded system will face possibly aggressive drivers. Or it does not account for fatalities while autonomous vehicles are introduced in such a chaotic circumstance. Further, the safety system and relevant policy are also upgraded for conventional vehicles, the performance and fatalities should not be calculated by the current level. Autonomous vehicles will go through the stages of 'introduction, adoption and improvement' by which, none of the stages are easily estimated (Kalra and Groves 2017).




Source: (Panetta 2019)

***Figure 4.10 Gartner Hype Cycle for Emerging Technologies 2019***

The trend of acquisition and merger are slowing down now, with less and less press release around. Gartner gives the answer that on the hype cycle (Figure 4.10), autonomous technology is on disillusionment period and will go downwards for a period of time. But it is claimed that L4 autonomous technology is leading the race of all niche technologies and it will take more than 10 years to keep stable. Meanwhile, Gartner also positions L5 autonomous driving almost on the top of the loop which refers to the peak of inflated expectations but it is doubted by the writer (Panetta 2019). This is a controversial discussion of the term ‘autonomous’. Even though the definition clearly explains L0 to L5 levels of autonomy from none to full autonomy, the word of ‘autonomous’ is very confusing as it defaults the function of no anthropological manipulation involved. In addition, autonomous vehicles are currently only tested in defined zones in which the complexity of the surroundings are not representative of reality. The pre-defined obstacles are predictable and the speed in the testing zone is much lower than real-world conditions (Kalra and Paddock 2017). How and when to achieve the real sense of ‘autonomous’ car is still unpredictable.

## 4.6 Conclusion

New technology opens a window for future automobility to contribute its efforts for cleaner environment.

It is too early to say CASE vehicles are the way to achieve sustainable transportation. A wide range of alternatives are offered in the automotive sector to improve the environmental performance of cars, such as hybrid, hydrogen, solar, and ethyl alcohol. The car per se, is a resource intensive structure from production to use, consuming a huge amount of resources. From this perspective, cars are never to be sustainable.

Again, if CASE vehicles code-driven, are programmers reliable? Are the machines being perfectly safe? Is there no paradox between being connective and private data abusively used? How could CASE elements resonate together? Research has lack of systemic thinking for CASE as a whole, all studied pieces are quite functional in isolation (Davies 2019).

# Chapter 5
# Methodology

Chapter 2 outlines the frameworks of applicable theories in the research; Chapter 3 portrays a general geo-political background in typical areas and Chapter 4 sketches the current competitiveness and cooperative situations in automotive industry. To illustrate further detail, this chapter scrutinizes the data collection procedure to lay the foundation to the entire thesis. Therefore, this chapter gives a guidance of ‘what’ the knowledge is and ‘how’ to find it. This chapter is divided into eight main sections: Introduction (Section 5.1), allocating socio-technical transitions theory to an ontology and epistemology (Section 5.2), methodology of this research (Section 5.3), secondary and primary data collection (Section 5.4), software that helped in data collection procedure (Section 5.5), the data interpretation and organization (Section 5.6). Lastly, Section 5.7 concludes with how the methodology applies to subsequent chapters.

## 5.1 Introduction

Different ontological standpoints directly impact the obtaining of knowledge from the world, the methods to be employed in the research, the approach of constructing research questions, and techniques to find answers to these questions.

Objectivism is the view that the social entity exists externally from social actors. In other words, social actors are independent of social entities and impact and control social entities by external forces. Conversely, subjectivism is the view that social actors are attached with the social entities and in turn influenced by the complex societal world (Saunders et al. 2009, p.110). For example, customers are members belonging to the social entities whose amassed behavioural change may gradually impact on the entire society. The point view of this research held which is critical realism. Each individual contributes his or her impact subtly, but the accumulative impact on social, political and environmental factors could be huge. Hence each individual is crucial to the ensembled community.

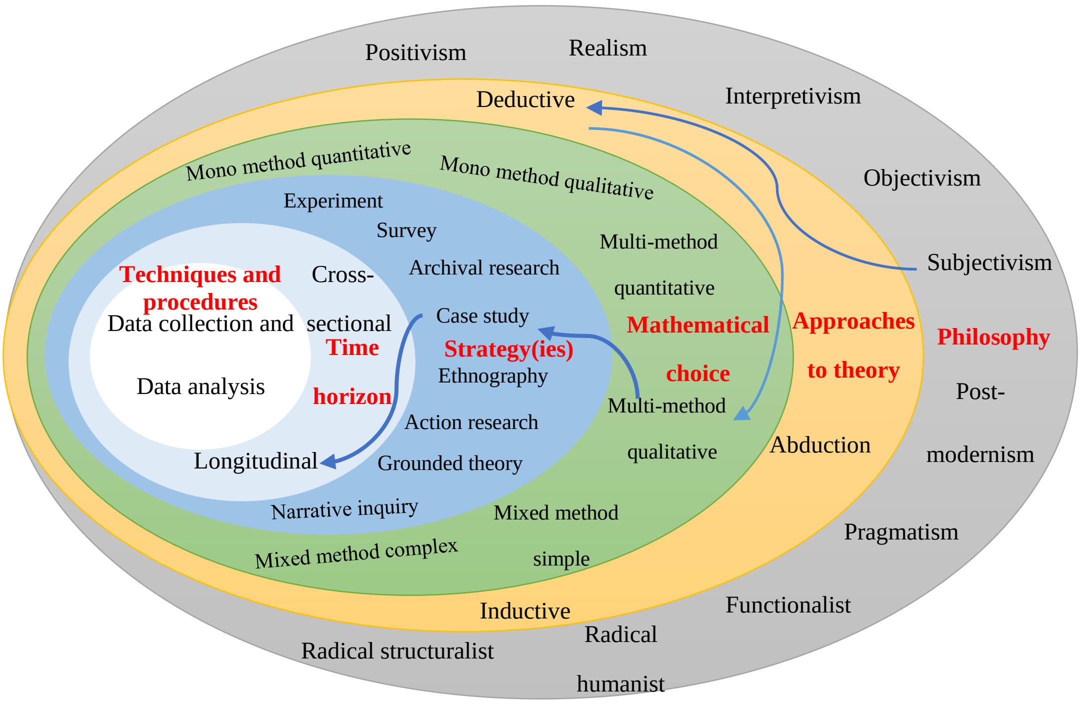
The research literature review in Chapter 2 shows that this research is theory guided and belongs to the area of the deductive approach. But deductive methods are generally used in quantitative data analysis. However, the research in this thesis is qualitative case study dominated and thus the inductive approach should be applied. Thus, the question becomes which mechanism in this thesis should be used?

In 1967, Glaser and Strauss have stated that "…there is no fundamental clash between the purposes and capacities of qualitative and quantitative methods or data" quoted by Wellington (2015:35). Eisenhardt conducted research through an inductive method by case study in which he stated that case-orientated research enabled hypothesis building and theory formation (Eisenhardt 1989). Silverman (2006) suggested alternatively that qualitative research methods can be used in a deductive approach. All the above show possibilities that research could be conducted though the deductive approach but with qualitative method. From the practical perspective, this research was guided by STT theory, that requires a deep understanding of how a regime is structured and how it reproduces itself. This guided the research into the investigation of multiple secondary sources to understand how governance, regulation, markets, competition, and innovation have been shaped by 'landscape' pressures such as the concern over climate change and carbon emissions. Then the focus of network theory required deeper analysis of business-business relationships via further secondary research (to create a database of the networks being formed) and the interview programme. Therefore, this research is *under the deductive approach method with a specific theory guided research.*

This chapter includes discussion on exploring social phenomena under a theory guided qualitative research, what methods are applied, and finally how to establish the research findings through deductive research methods.

## 5.2 Social-Technical Transitions Theory on Ontology and Epistemology

The reason why we need to understand the ontology and epistemology position is '…We only be able to understand – and so change – the social world if we identify the structures at work that generate those events and discourses. … these structures are not spontaneously apparent in the observable pattern of events; they can only be identified through the practical and theoretical work of the social sciences…' (Bhaskar 1989) quoted by (Bryman 2012).




Source: Compiled by author (Saunders et al. 2007, p.102; Saunders et al. 2016, p.124)

***Figure 5.1 The Research 'Onion'***

This research 'onion' is a prevalent visualisation that vividly shows the structure in different positions of philosophies, approaches, mathematical choice, strategies, time horizon, and techniques and procedures to collect data and their relations in a research from the outermost layer to the innermost layer. This research 'onion' (Figure 5.1) was portrayed in Saunders' (2007) book *Research methods for business students* 4th edition and 7th edition to give a better general view of research philosophy. Given the evolution of research methods and ontology over time, ontology in 7th edition is simplified and only five elements are included: positivism, critical realism, interpretivism, post-modernism and pragmatism. This latest version includes objectivism and subjectivism in positivism and interpretivism respectively and simplified other elements in post-modernism. However, the author in this research is trying to display all philosophies rather only 5 elements to identify all the possibilities and therefore, the ontologies in the 4th edition and the 7th are integrated in this onion diagram. The biggest modification between 4th and 7th edition is the discussion of strategy (the way to collect data) which is embedded in mathematical choice (qualitative or quantitative method) in the latest version. It is worth discussing which order could explain the research better. In the latest edition, the research is considered by using qualitative, quantitative or mixed methods first then followed by certain strategies (how to further collect data). Thus the improvement of the newest edition is reasonable (Saunders et al. 2007; Saunders et al. 2009; Saunders et al. 2016).

*Table 12 Comparison of Four Research Philosophies in Management Research*

| | Positivism | Realism | Interpretivism | Pragmatism |
|---|---|---|---|---|
| ***Ontology:*** the researcher's view of the nature of reality or being | External, objective and independent of social actors | Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist) | Socially constructed, subjective, may change, multiple | External, multiple, view chosen to best enable answering of research question |
| ***Epistemology:*** the researcher's view regarding what constitutes acceptable knowledge | Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements | Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts | Subjective means and social phenomena. Focus upon the details of situation, a reality behind these details, subjective means motivating actions | Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data |
| ***Axiology:*** the researcher's view of the role of values in research | Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance | Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research | Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective | Values play a large role in interpreting results, the researcher adopting both objective and subjective points of vies |
| **Data collection techniques most often used** | Highly structured, large samples, measurement, quantitative, but can use qualitative | Methods chosen must fit the subject matter, qualitative or quantitative | Small sample, in-depth investigations, qualitative | Mixed or multiple method designs, quantitative and qualitative |

Resource: (Saunders et al. 2009, p.119)

In the management territory, as Table 12 presents, there are four leading ontology principles (positivism, realism, interpretivism, pragmatism) ranging from quantitative data presented research to qualitative based study. The four ontologies represent very general genres and under which, each ontology is divided into a few detailed branches. For instance, realism includes critical realism which interprets that the independent phenomenon may vary by social circumstances. Similarly, interpretivism as a wide theme that comprises social constructionism and other perspectives. Social constructionism denotes that researchers are a part of reality which cannot be separated and observed, and that users endow values to objects - hence the objects are meaningful such that for example notes, shells and gold can act as money. Technology in ontology is generally defined from the perspective of social constructionism such as the

Social Construction of Technology (SCOT) model of innovation (Yousefikhah 2017), as in a social practice and content (Lynch 2016) or as in an online artefact in a constructed platform (Parmaxi et al. 2013).

In social-technical transitions theory, society and technologies are two mutually overlapped and mutually influenced entities. That is, no matter how and which technology is innovated and upgraded, its impact is mediated by social context. This theory considers social change through technological innovations, and vice versa. Technology therefore, could be illustrated under the position of social constructionism (Bijker 2015; Kynigos 2015; Zuboff 2019).

For example, socio-technical transitions theory has been used to investigate sustainable technology and societal impact in studies such as renewable energy (Kemp et al. 2007b; Johnson and Silveira 2013), green buildings (ONeill and Gibbs 2014), transportation (Kanger et al. 2019), energy policies (Kemp et al. 2007b) and urban water management (Bos and Brown 2012). These technologies can confront social norms and in turn may become socially and politically altered. In these research studies, technology catalyses the adoption of new practices in each area to give the relevant subject a new connotation. Subjectivism requires to survey a subject from inside of the entity, it could also impact the future and other subjects. Technology influences the society from inside, in this case triggering socio-technical transitions.

Guided by theories, deductive approaches are applied to test theory. As Robson (Robson 2016) proposed, the deductive approach explores a theory with steps of proposing hypothesis, expressing how the hypothesis is measured, then testing hypothesis, examining and comparing the outcomes with hypothesis, and lastly revising the theory based on the findings. In this research taking autonomous vehicles as an example, socio-technical transitions theory can be tested, with a hypothesis that ‘the STT theory can be applied in the future context, i.e. CASE in one vehicle’. To evaluate this hypothesis, a few questions that followed from the hypothesis need to be addressed. They are 1) can the theory clearly apply into autonomous, electric, shared and connected vehicles as a future case? If not, is there any supplementary theory suggested? 2) socio-technical transitions theory is a broad symbolic theory with three levels, so which level would be emphasised in this research? 3) in the case study, would any new business model be created for CASE vehicles? 4) theoretically, can the deductive approach be used for future (as yet unknown) cases?

These questions that followed on from the hypothesis are intended help investigate how STT can be applied in the CASE context and what additional issues need to be resolved to complete the investigation. They are from a theoretical perspective intended to enhance the possibilities of applying STT in the CASE context. The questions are addressed in a narrative, detailed and targeted manner to help scrutinize the hypothesis and the research design. For instance, these questions help focus more attention when gathering the secondary resources, to be aware of the relations that can be intertwined as a network. They also helped highlight the STT theory limitations so as to insert an agency to explain the further inspection. Therefore, the research was guided by the desire to frame ongoing and future developments with STT theory. The supplementary questions act as an intermediate step informed by specific circumstances.

In the process of applying socio-technical transitions theory into the automotive case, researchers found that the car manufacturer-based hierarchal supply-demand mode is gradually dissolving, superseded by decentralised networks as groups interweave. Thus, the socio-technical transitions (STT) theory could not simply explain such circumstances, network theory has been added to STT theory to enrich the explanation, and this is the deductive approach to re-organize the theory. Nevertheless, STT has been identified strategically in organizational management (Newton et al. 2011), ontology in the relation of technology and society (Bijker 2001; Bijker 2015), and teaching and learning (Ackermann 2001; Myburgh and Tammaro 2013; Kline 2015).

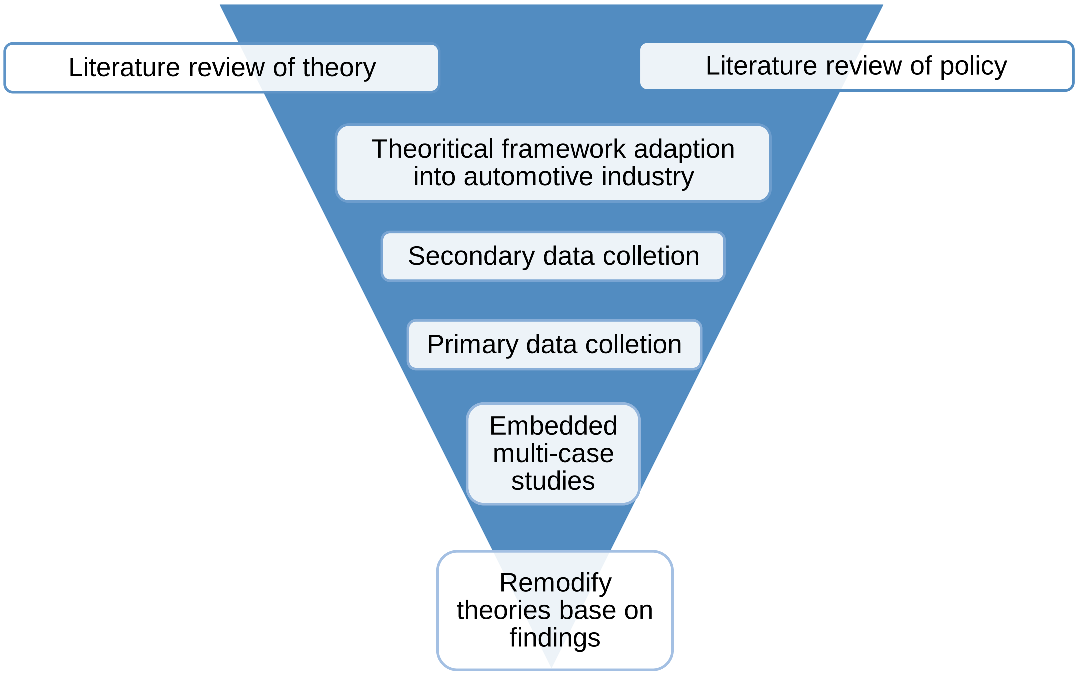
In conclusion, the arrows in the ‘onion’ exemplifies how this thesis is structured. The philosophy of this research has been located under social constructionism and the subjectivism branch with deductive approaches to explore the possibilities of socio-technical transitions theory building the research. Of the mathematical choices as Saunders suggested, the multi-method qualitative approach is deemed the most suitable one. Embedded case studies are practical means to highlight the relations based on autonomous vehicle technology, and interviews are conducted to collect personal opinions for future vehicles. The timelines are chronologically which means the research is using longitudinal way rather cross-sectional method.

## 5.3 Methodology

The literature on autonomous and connected automotive technology is narrow compared with the literature on vehicle electrification and sharing, especially from the business model perspective. Further, the integration of socio-technical theory with CASE vehicles has never been tested. Public or governmental policy plays an essential role in encouraging such vehicle distribution and adoption. The political context and policy support for CASE vehicles is highly variegated owing to geo-political reasons. It is very understandable that a niche of new technologies needs to be supported and protected by local and national rules and regulations (Kemp et al. 1998). All these are resulting in the essentiality of applying CASE in the STT theory.

Therefore, the CASE literature should be established first. The data was collected from 2009 when Google (Alphabet) announced the intention to build fully functional autonomous vehicles by July 2019. This time length and span ensure data abundance and sufficiency to establish a CASE database to analyse data and its trends. The relevant news was collected and classified as automotive manufacturing-centralised relations so that it is easier to compare the case volume and the tendency.

Based on all above research background, the first-round pilot interviews have been conducted around 2017/18 by the combination of formal in-depth interview and informal discussion to collect personal expert insights into the significance of CASE to the automotive industry. Primary data fills the gap of secondary objectivism resources from different angles to triangulate these expert professional opinions.




Source: Author

***Figure 5.2 Methodology on This Thesis***

Then the embedded multi-case studies are designed to illustrate the details of selected companies which aim to build CASE vehicles, whether inside (incumbents) or outside (new entrants) the automotive industry. Figure 5.2 shows the used methodology in this research as explained before.

Figure 5.3 shows a generic strategic research flow that applied in this research. After reviewing the theory literature (Chapter 2) and global policy literature (Chapter 3) respectively, the automotive industry has been redefined and relocated in the STT system (Chapter 4). The methodology and methods with detailed data collection procedure (Chapter 5) presented in Figure 5.4 later. All these followed by two intersecting sections of data representation: horizontally, on one hand, acquired secondary data have drawn a skeleton for entire thesis; on the other hand, through which it finds clues for case studies that explored in Chapter 6; vertically, primary interviewed data obtained from experts have been integrated with experimental collections to verify the validity and reliability of secondary data (Chapter 7). The cases and interviewed opinions have been discussed and concluded in the Chapter 7 and 8, to show the consequence of STT theory integration with CASE vehicles.

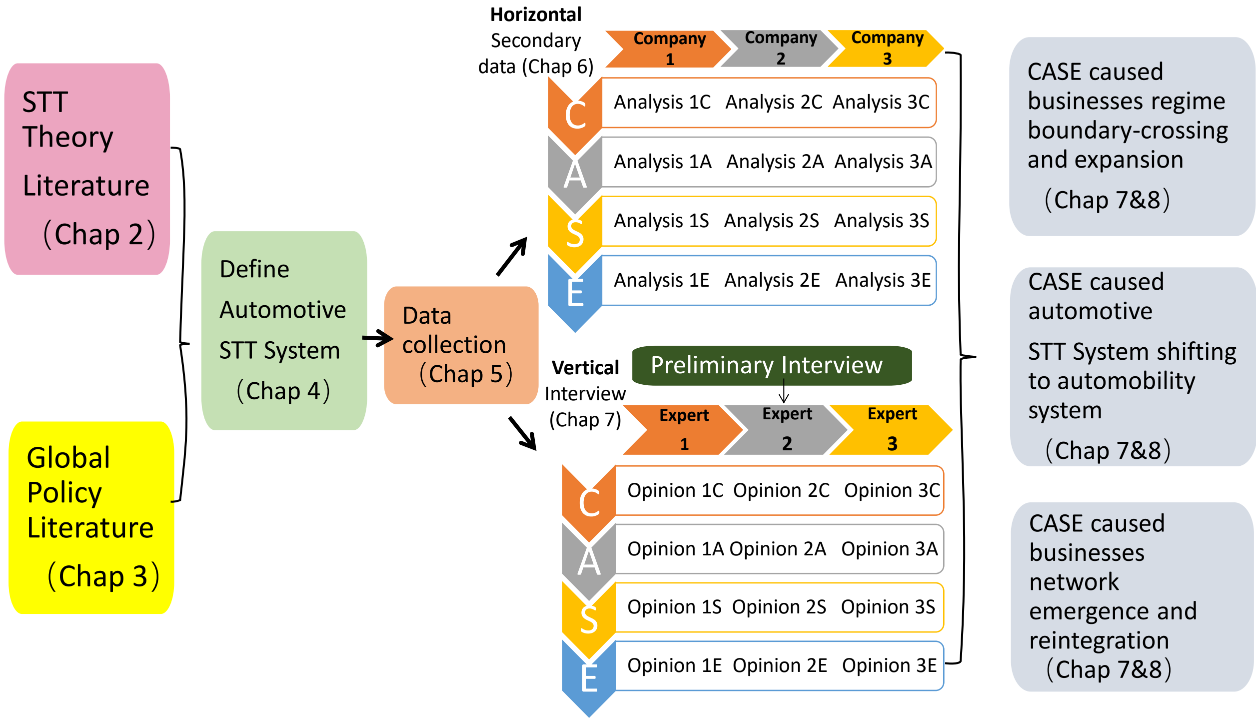



***Figure 5.3 The Strategy Flow for the Research***

Therefore, multi-method qualitative data is mainly used in literature review, embedded case studies and in-depth interviews. Qualitative data is descriptive for the personal opinions and individual outstanding ideas. Even though quantitative data is more precise and accurate, qualitative data is more compliant with the realities that this research explains (Creswell 2009). The purpose of the research is therefore to build on STT by using network theory, and to explore whether this combination might prove useful in explaining the process of socio-technical transitions.

## 5.4 Data Collection

The original motivation of this research is to re-apply STT theory from an ongoing perspective to test whether the theory can provide insights into the future case. The STT theory as explained in the second chapter is mostly rooted in a historical context. The difference of this research with previous studies is the subject of this research --CASE vehicles are an immature concept, fluid and still developing. The initial thought was to collect data focused on the main car companies which are the most able to turn the concept of semi or fully autonomous vehicles to reality. But during the process data collection, it was found that CASE concepts are developed unevenly in regional and national spaces, and that vehicle manufacturers were not always the dominant entity. Rather, ICT companies, and parts suppliers are very ambitious to take a proportion from the mainstream automotive industry. Therefore, the process of secondary data collection had to be expanded to include a much wider range of business organisations and third parties.

### 5.4.1 Multiple secondary sources

The novelty of the research in this thesis is that it is concerned with dynamic, unstable, unpredictable and changing situations with regards to technology development, corporate participation, market acceptance, and transitions outcomes. During the process of data collection, news stories are still constantly occurring. The story line could be changed anytime. An event might be categorised as a ‘shock’ (e.g. 5G issues), or new political ‘pressure’ (e.g. zero emission zone established), or incentives encouraged by government. For example, 5G technology is one of the fundamental infrastructures for enabling the operation of autonomous vehicles. Then, Huawei as a world leader in 5G technologies had questions raised about their relationship with the Chinese government, and various telecommunications services companies became concerned with using Huawei technology. This issue not only hurts Huawei but also becomes a barrier for 5G technology distribution so may delay the process of 5G development and adoption. In turn this means that autonomous vehicle deployment may be delayed or otherwise compromised.

This example strongly shows the speciality of this research: that the relationships may be changed over time, even before the research was concluded. The relationships therefore are also deeply influenced by international/national policy and other ‘external events’ that lie outside the socio-technical system. On the one hand, the dynamic structure yields more relationships being identified during the secondary data collection; on the other hand, this unpredictable affiliation hinders the analysis in terms of being able to draw conclusions and make useful predictions. In some respects, therefore, the broad coverage of the research had to be balanced against the requirement for detailed explanation.

The dynamic, fresh and a wide range of news are necessary in keeping the research theme updated. The reliability of news can be tested through different news websites and official announcements. Furthermore, to portray a clear scenario, hundreds of cases are collected which would be impossible when using primary data collection methods. The reinterpretation of collected secondary data gives a subjective meaning of the case and to finding a fresh research perspective. As such, primary data collection as a supplementary mechanism to further illustrate the results to enhance supportive evidence. Therefore, as Bryman suggested, secondary data has its advantages: condense the time and costs; high-quality if the right resources are found; possibility to conduct longitudinal and cross-country analysis where no extra language skills required; so that secondary data saves time for data analysis and reanalysis (Bryman 2012).

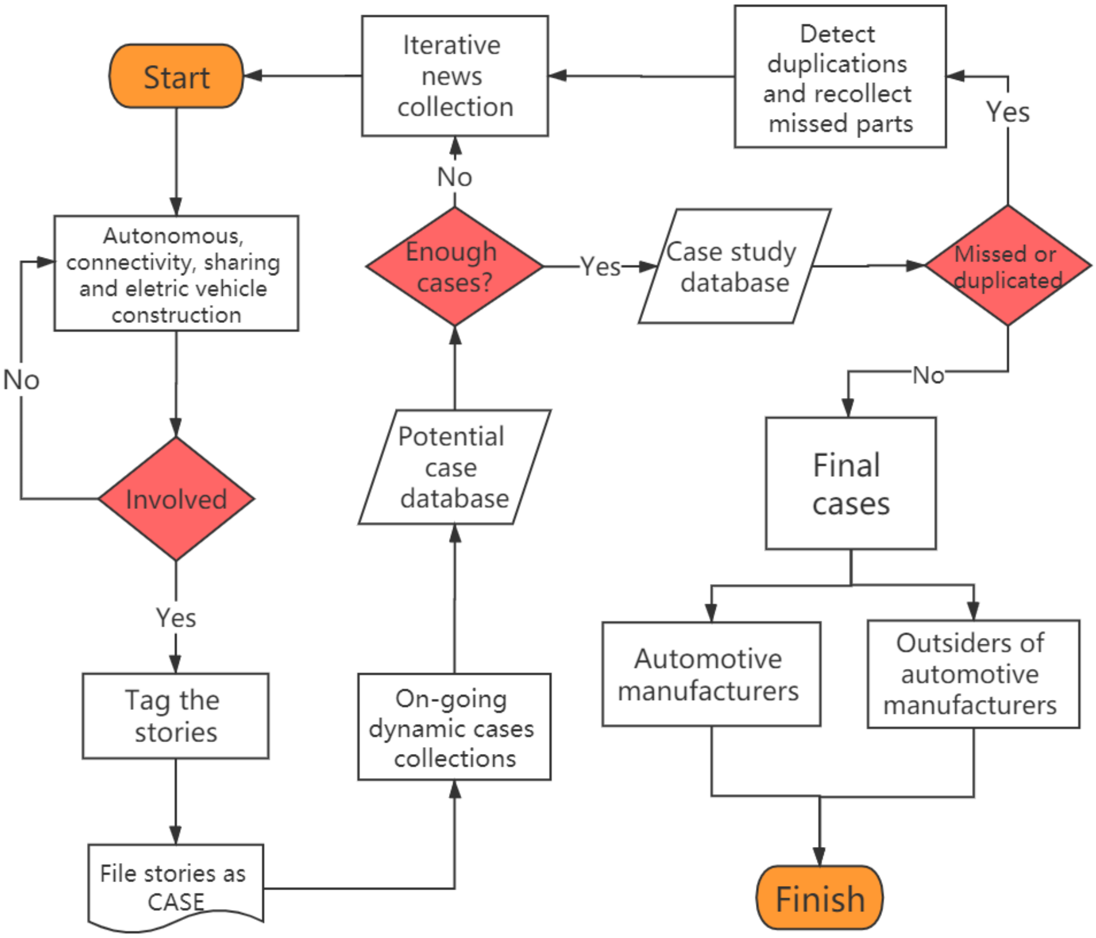



***Figure 5.4 Data Collection Procedure***

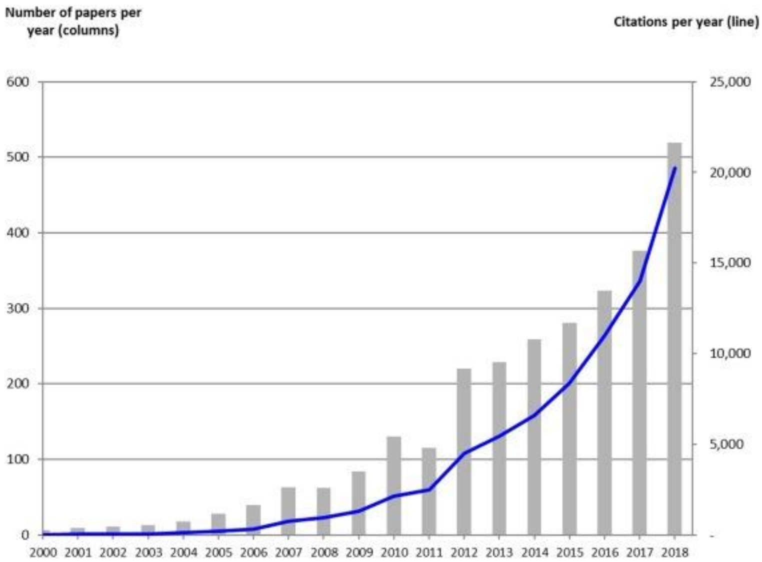
Despite the data instability, the reliability of the data identification is robust. The Figure 5.4 clearly shows each step of the secondary news data collection procedure. Following the rules of flowchart construction, squares are the process, red diamond are decision making step with yes and no choices, this procedure will iterate until the answer turns to be 'Yes'. The flag-shape square is document, which means this step can file the documents. The rhomboid is database, so in this research there are two databases, one is the overall rough database, the other is targeted case-based databank. It worth to remind that there are several backwards arrows that turn the process back to the previous or even first step such as the data duplication or missed. These requirements aim to iterate the data collection to ensure the validity and richness of the database. Then the data is ready to be analysed.

The limitations of using secondary resources are as follows. The validity of secondary data's resources are doubtful. Data obtained from previous resources may not be fully used due to underestimation or mistranslation by authors. Secondary data may not be really 'secondary', it may be transferred from other resources and these resources may be very hard to trace. In this case, it is a bit time-consuming to confirm and familiarise data from varied databases. Also, the benchmark and 'tagging' in each news source is different and lacks of standardisation in data aggregation.

Secondary data has been used in two areas in this research. One is on the literature review to analyse the current position of this research; another is for case study delineation. For the first point, theory development process and relevant policy and regulation background have been reviewed. For the second point, case studies are selected based on news websites where more than a hundred of news were collected.

***Journals***

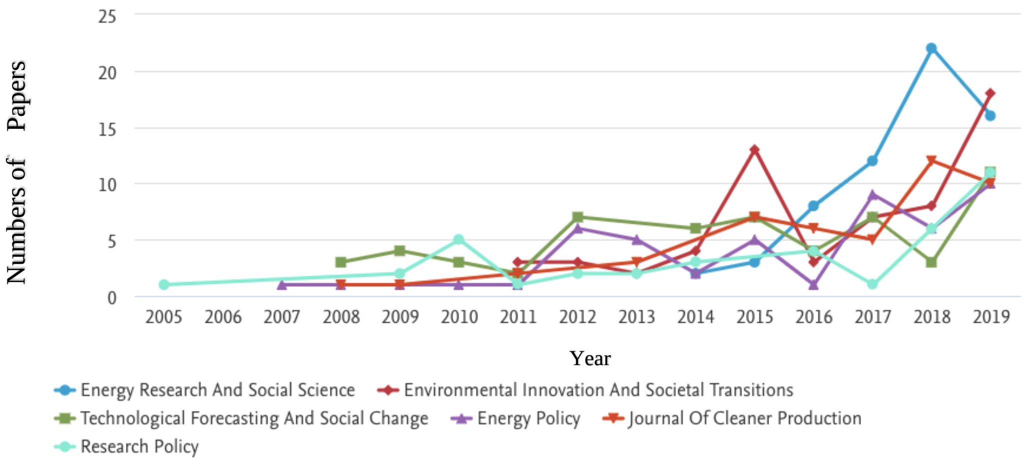
Essential books are used for defining the definition of a term or a context such as the 'case study' or a theory. Mainly, journals are the essential resources to fill the gap of literature and summarise the recent published works. Works on sustainability transitions investigated by Köhler and his colleagues as shown in Figure 5.5 that summarised the published and cited journal papers relevant to sustainability transitions are swiftly increasing since 2012. In 2018 over 500 papers were published (Köhler et al. 2019). It seems that even though transition is a novel topic, the influence is becoming much wider.




Source: (Köhler et al. 2019)

***Figure 5.5 Number of Papers on Sustainability Transitions in Peer Reviewed Journals and Citations***

To minimize the scope, we investigated socio-technical transitions theory credited to Geels (2002) to very recent work in 2019. We searched citations and peer reviewed papers from 1971 to 2019 by keywords 'socio-technical transitions' in Scopus and found 6 highly published journals with words 'socio-technical transitions': Energy Research And Social Science (63 papers), Environmental Innovation And Societal Transitions (61 papers), Technological Forecasting And Social Change (57 papers), Energy Policy (49 papers), Journal Of Cleaner Production (47 papers) and Research Policy (38 papers). Figure 5.6 shows the obtained results by year in that since 2014, especially in 2018 and 2019, topics about 'socio-technical transitions' are dramatically boosted in all journals.




Source: (Scopus 2020)

*Figure 5.6 Socio-Technical Transitions Articles Searched by Publications*

Subjects of articles mostly categorised in social science (21.3%), environmental science (18.6%), energy (16.5%), business, management and accounting (12.4%). However, transportation was not clarified as a specific subject, it could be filtered as the subtitle under the energy, social science, or environmental science. Thus, a group of words have been added for advance search. Firstly, 'autonomous vehicles' is added to further refine the results. The outcomes show that keywords both including 'socio-technical transitions' and 'autonomous vehicles' with only 182 papers are embodied in peer reviewed publications from 1996 to 2020 (February). Typically, the countries that studied such area include UK (42), US (28), Netherlands (24), Germany (17), Canada (13), Italy (11), Finland, Norway and Sweden shared the same number of publications (8), Australia (7), then China, Denmark, Switzerland and France have the same number (6). This result would be important evidence to settle a benchmark to illustrate the CASE vehicles investigation in these countries.

The key word 'automatically' includes automation agents, sustainability, electric vehicles, mobility, automobility, public policy, self-driving cars, multi-level perspectives and social change such high cited words. Interestingly, most of the published articles about autonomous vehicles are based on the computing and modelling, which means autonomous vehicles are not commercialised to have the relevant business model research yet. The autonomous vehicles are in the process of development, transferring from the design and conceptual stage to practice.

Since 2018, a few papers are trying to explore the relations between future transportation and the possibility of autonomous vehicle implementation (Kellerman 2018; Sovacool and Axsen 2018). And more publications explore the detailed relations, for instance, vehicle connectivity and autonomous vehicles along with sustainable transition (Noy and Givoni 2018), business models in mobility under transitions (Sarasini and Linder 2018), transitions of UK government (Hopkins and Schwanen 2018). Later, the tri-relations among autonomous, shared and connected vehicles have been studied in automobility transition in 2019 (Axsen and Sovacool 2019). But still, none of the results show both ‘socio-technical transitions’ and ‘autonomous, connected, shared and electric vehicles’ as a main content in an article.

If there is no one looking from the ‘autonomous, connected, shared and electric vehicle’ perspective to settle socio-technical transitions theory, then network theory within socio-technical transitions theory would be impossible. To illustrate the data stream finely and smoothly, network theory has also been investigated through journals and books. However, network as a very broad theory has more specific and popular sub-theory such as social-network theory, organization network theory and actor network theory. It is useful if giving a refined home for specific category network. In this project however, the network is gradually developed, but not fully formed and hard to be categorized into either of them. It was illustrated foster in Chapter 2 about network theory chosen procedure.

***News***

News features stories that are of short, concise, fresh and dynamic, in which it is easy to capture the events to portraying a general framework for the study. News stories were obtained from various websites, notably expertise websites such as Automotive News, BBC News, uk.reuters.com, automobile.com, electrek.co, economist.com and IEEE spectrum. Topics around autonomous vehicles and relevant characters are subscribed through official websites’ RSS in terms of receiving new cooperation relations and other stories that are updated on time every day. The selected topics can be categorised in very detailed way such as ‘battery electric vehicle’ or individual vehicle manufacturers e.g. Ford. In addition, news also can be received via portable device such as mobile phone. Apple News is a good example which is accessible and can be subscribed with many sub-topics, but it includes too many ‘amateur' websites. These news sources are less reliable, mostly with editors’ opinions and predictions, the sentences with many modifying verbs (e.g. ‘could, may’) to predict the coming collaborations. The reliability of these news was iteratively investigated by comparing with other mainstream sources.

When the actual procedure of collecting data starts, news may be missed. The data is collected from several stages: Firstly, a general group of car manufacturers are selected who make autonomous vehicles and have aggressive actions; then if a story referred to a previous news item which is not yet collected, it is the time to trace back to collect the missed news in order to keep the integrity of the general picture; the ICT companies and parts suppliers are participated in a later stage, so that the range of data collection has been extended which are not limited to the traditional main players in the automotive industry; the last stage is to specify the case studies, in this time news are searched again typically about that company to deepen the depth of the cases.

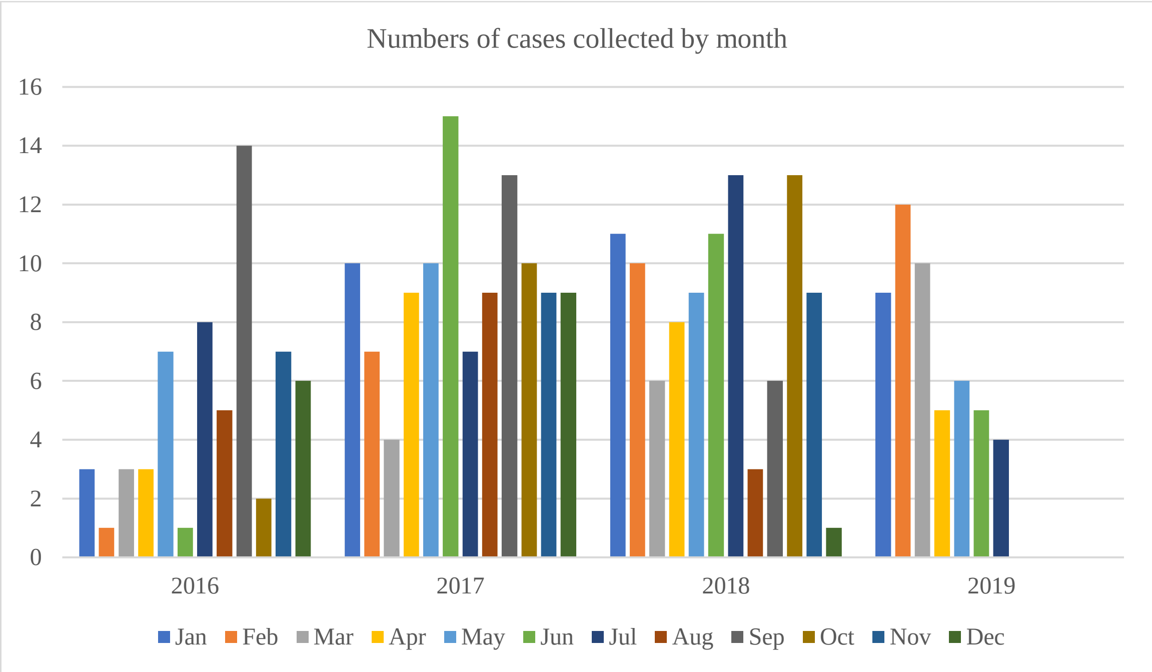
The car manufacturers' relations around autonomous, connected, shared and electric vehicles are gathered from 2009 to July 2019. In which, 340 cases were selected including one-to-one cooperation, one-to-more alliances, joint alliances, and alliances and associations between consortiums. July 2019 is the time node to end the data collection as 1) as a dynamic research, cases could be added over time endlessly but defined stop point is needed for data calculation and evaluation to draw the results; 2) ten years' data is enough to draw a possible outcome; 3) the most important point is that it seems a decelerating trend on those relations in 2019, most alliances and cooperative relations became established in 2017 and 2018. Thus, as the number of cases declined, we select the end of July of 2019 as an ending point. New cases are still going on after July, but they will not be included in the research results. This 'wave' of cases is an interesting first finding from the research, for it suggests that there was a historic moment or period of time when the automotive industry needed to build bridges with other sectors in order to understand and exploit key new technologies, and possibly to defend the market space against potential new entrants or the alliances formed by rival vehicle manufacturers (see (Wells and Wang 2017; Wells and Wang 2019)).

There are some fluctuations during the data assessment procedure, and changes have been made during the process. The established relations only include the collaborations, alliance, acquisitions with two or more companies. However, the original thoughts to define relations around automotive manufacturers are simply 'one + one' which is a car company plus another company. However, it was realized that stakeholders who involved in the autonomous vehicle competitions are not only car manufacturers. There are dozens of more 'outsiders' who also established relations with other 'outsiders' which did not involve the car makers at all. For example, Huawei as a telecommunication company also wants to build autonomous vehicles itself. Automotive manufacturers are not the mandatory in a partnership to make an autonomous vehicles, but could rather to be a 'vehicle supplier' to test and carry the newest functions. Therefore, the research strategy has changed to cover all players who planned to build autonomous vehicles, especially in 2018 and 2019. But still, the aim was to focus the analysis on the vehicle manufacturers.

Another change is that all relations originally are around the same theme: autonomous vehicles within the CASE concept. However, when the data were collected, it was found that autonomous vehicles are designed to connect with the internet and other infrastructures. The concept of autonomous vehicles is extended to be a self-driving taxi, or electricity powered driverless car. Hence the focus range includes autonomous, connected, shared and electric vehicles, of which the relations are also expanded and to be more complex. Furthermore, traditional car manufactures are reluctant to heavily invest an unknown market, while the innovative companies driven by autonomous technologies are reluctant to explore new territories such as automobility. Nonetheless, while these four CASE elements so far looked independent of each other, they were intertwined and already showed some hints of entangling state in later 2018 and 2019.

340 cases are contained in this study in which 2009 to 2015 only with 15 cases. Figures from 2016 to 2019 have dramatically increased by year. 2016 with 60 new relations created, 2017 with 112 collaborations, 2018 has 100 events and 2019 until July with 51 relations. Relationships possibly are not new, they may

endeavour and improve the previous relationship in another area between two same associations. Detailed data shown monthly between 2016 to 2019 (July) in Figure 5.7 except the numbers before 2016 as the numbers are too small to display in the same chart. As we see from Figure 5.6, the cases in these four years are splendid growing. At least every month, a new relation was facilitated by two companies to enhance autonomous technology.




Source: Author

***Figure 5.7 Numbers of Cases Collected Per Month***

***Reports***

Reports are mainly applied in the Policy and Historical chapter (Chapter 3) to present a current overview towards to autonomous, connected, electric and vehicle sharing schemes locally or nationally. After the theoretical framework and methodology had been selected, it was realised that policy was playing a crucial role in the tenor of facilitating autonomous technology to become a mass market.

In terms of the accessibility of resources, there are some differences. Government reports from the UK are easy to obtain from the websites of GOV.UK and Department for Transportation or other relevant departments. All issues, backgrounds, bills and legislation, partnerships, and programmes are presented in the websites. Other than the websites, staff from GOV.UK attend varies activities on autonomous technology promotion exhibitions and conferences to follow technology developments and make network linkages. U.S. official websites about future transportation are also easily accessed such as U.S. Department of Transportation and National Conference of State Legislatures. It is easy to know what rules and regulations are in the proposition stage and which are permitted. Chinese resources, however, do not have a formal official government website to show the upgrade process while expert websites such as China Association of Automotive Manufacturers present relevant trial implementations but not reports as such. After the technology giant Baidu agreed to collaborate with BMW and other car companies to develop autonomous car capacities, some cities have promised to test such technique equipped vehicles.

A drawback of using authorised reports as an important reference is that some local official documents are written in the native language which cannot be recognized by author. The U.S and U.K political relevant official websites are easier to be accessed as they are presented by English. China although lacks such national-based official websites, the test permissions are published in the municipal administration websites because they are regional permissions. Other countries, however, policy support documents cannot be acquired directly from government or official websites, and reports from major automotive news websites. The general policy in EU countries are obtained from multi-language EU websites e.g. European Commission. Other than the EU authorised websites, relevant information are acquired from expertise websites as referred in last section NEWS. Thus, reports from non-English regions are less information obtained and less reliable indirect way due to morphological limitation.

Reports on the other hand, are distributed over the entire thesis for political statements and data analysis. Database are based on a large scale of authorised and expertise financial companies such as Statista, McKinsey & Company, PWC, KPMG international to ensure the data validity.

***Quotations***

Quotations are extracted from a wide range of source materials such as expert websites, news press release on the home page of the car company, and from official reports. All these secondary reliable resources can also be called 'sub-primary data'. Another quotation resource is from interviews conducted by author (see primary data collection, later in this chapter). Quotations are allocated in Chapter 4 contextual framing of automobility, Chapter 6 case studies and Chapter 7 discussion. Quotations represent not only the speakers' opinion, some could interpret author's standing points.

***Others***

In addition, personal opinions are essential to this study, thus these resources also have been included. Before to reach the entirely autonomous and connected vehicle market in the future, public opinions could give a 'would-be' prediction for users and automakers at least drawing the public's awareness. Social consensus could help carmakers to consider the potential users' demand to coincide with users' taste.

Personal blogs such as personal webpages, social media e.g. Facebook and Twitter. Personal website mainly presents personal opinions through full length articles such as journalists' personal webpage, while Facebook, Twitter or WordPress presents by short/middle length articles. News represents a neutral or the official opinion with dynamic and consistent pieces while personal blogs lead to a new eyesight to reflect overall personal ideas and tendency.

### 5.4.2 Primary data collection

Primary data obtained by interview in-person and another is an indirect way as mentioned in last section by quotes in published articles. Here we talk about in-person interview.

***Preliminary interview***

The selection process or interviewees proceeded throughout the research. The overall interviewee targets were informed by the secondary data, with the intention that interviews could provide more detailed information, and so compensate for any gaps in the secondary data. To some extent, interviews were conducted in parallel with secondary data collection.

Preliminary interviews have been conducted with a few experts who are familiar with the topics, and car users in random ages, before 2018. Those people are not listed in the interviewees' table as 1) questions are remodified and refined after the tests 2) they have contributed suggestions during the question design process thus they are interview question design participators 3) most are informal conversations rather than a formal interview, they are less formal and have no recording. After the dialogue with informed individuals, it was realized that purposive sampling interviewees would be important in qualitative research. In addition, the interview conduction methods are important.

The preliminary interviews offer following contributions: 1) To refine the research questions. Research questions have been modified several times before the actual interviews have been conducted entirely. Nonetheless, the preliminary interviewees helped to reconsider questions and give suggestions before, during and after the interview, from question design to methods. Which leads to the second point. 2) To understand the scope for unified research questions, in which each respondent is asked the same set of questions. The research questions should be more flexible to be inclusive, and answers should be allowed to deviate from the topic. This is because the dialogue may contain personal opinions and predictions and reflect the variation of knowledge and expertise of the interviewees. 3) The year 2018 was the peak period for vehicle automation and CASE integration announcements, so that preliminary interviews before this time were too early for respondents to predict outcomes and draw conclusions. 4) It is also time consuming to select the appropriate potential interviewees. Therefore, after a several adjustments, the interviews were commenced.

To meet experts and collect expertise opinions, a variety of conferences, meetings and discussion groups are attended such as NBM (International Conference on New Business Models), STRN (Sustainable Transitions Research Network), and innovation network conferences held by universities with industry participation e.g. EVS 30 in Stuttgart. These platforms offer good opportunities to catch up the latest themes and to inspire the new ideas. Then a list of experts is complied, based on their reputation, expertise, publications and familiarity with the topics. To balance the bias from different interviewees, experts are selected from diverse schools of thought and discipline domains. Additionally, a snowballing method has been used to reach more experts by which one expert will introduce another expert to be interviewed by the end of the conversation. Hence, more and more experts are involved.

Before the interview progressed, ethic forms and consent forms are approved by Cardiff Business School to ensure no ethical issues were involved. Interview questions in this study are purely around personal opinions on future transportation which are anonymous with no sensitive questions. Before each interview started or by the end of the conversation, interviewees are required to sign the consent forms to ensure that questions are valid, and recordings are permitted. Nonetheless, interviewees could ask to cancel any sentences or entire recordings if they so desired.

The interview questions have been amended for several rounds in terms of considering 1) to specify the questions more precisely 2) to structure the logical progression of the questions 3) to compress and shorten the list 4) to ensure the interviews contained both general questions and specific questions. The whole file is in Appendix 1. Thereafter, ethics forms were approved by the School Research Ethics Committee (see Appendix 2).

***Interviewees' selection***

After the preliminary interviews, there is a time gap to refine and redefine the interview questions and interviewees. Several typical groups of people were considered as interviewees. Staff in vehicle manufacturers are the premier consideration because of their pivotal role in the autonomous technology revolution, they serve as the advocates and catalysts of change. In some degree, vehicle manufacturers are the most transparent entities in the research because official reports and mass media provide good coverage of the relevant information. In the contact list, both managerial and sales staff with direct contact with consumers are included. Managers offer a forward-looking perspective on deploying strategic future plans for such new technology, while front-line workers deliver opinions based on consumers' feedback.

Secondly, specialist journalists are considered in the interview list. Generally, journalists represent opinions critically based on their specific area and they have their 'battlefield' to present their opinions. They are a group of people who can be influential as well. Therefore, they can clearly answer the targeted questions so that it is worthy to interview journalists.

Thirdly, a large group of scholars have been included from diverse universities in the UK, EU, and China from a large range of departments such as business schools, engineering schools, geography schools and psychology schools. Their expertise is more neutral, which could offer a different perspective to look at the whole story. These people may inform politicians, policy makers, industry and journalists, they present points with solid evidence and based on rigorous investigations.

Additionally, politicians or relevant policy makers are potentially interview perfect targets if they are able to be contacted. However, rules and regulations can be proposed before they are permitted to speak with researchers. Other than this, they are such a group of people who failed to be contacted. Therefore, there are no interviewees from political arena on the list. This can be regarded as one of the limitations of the research. Nonetheless, policy makers were included and thus politicians by extension. Funding decisions over e.g. R&D for autonomous vehicles can be understood as the real manifestation of political choices.

Last but not least, users must be included in the research. To accept, deploy and generalize the innovative technologies, end-users are their ultimate target. The attitudes and tendentious feedback from users are critical to the entire chain from design to production. In reality, autonomous vehicles are not yet available to users, and even the penetration of electric cars is very inadequate. For these reasons, a large-scale survey or interview programme of users was excluded from the research.

However, theoretical sampling and the generic purposive sampling may differ with reality in terms of the limitations of the interviewees' locations and accessibility. In addition, the quality and validity of useful answers are always uncontrollable.

***<u>Question design</u>***

The main principle of interview questions is around the research questions:

**<u>RQ: How far can STT theory help in explaining the emergence and future prospects of CASE vehicles?</u>**

a) To what extent are connected, autonomous, shared, and electric technologies, integrated into one vehicle, to be commercially released on the mass market from around 2020?

b) What are the potential business challenges pertaining to the integration of CASE technologies in one vehicle?

c) Any supplementary theories needed beyond STT to explain how these CASE technologies have been developed and brought to the market?

To conduct the interviewers, STT theory is complex and had to be fully explained in a limited time, so the basic structure of the discussion was around the strategy of CASE introductions by the vehicle manufacturers. In the first part, some generic questions were be asked. At the beginning, a short question would be introduced about the CASE elements to establish if the respondent believed the elements were mutually supportive or conflicted. This point asks interviewees to consider the relations in between the elements, and to establish the context of their knowledge. Then further detailed questions were introduced such as the impact of the novel technologies on the automotive industry, consumers' reactions and attitudes, etc. These answers assisted in developing an understanding of the STT theory from the interviewees' perspective. Further questions were followed if interviewees were interested in the relations in the automotive industry as a whole, such as the attitude to the new entrants, and whether the business relationships helped or hindered the introduction of CASE technologies.

Followed by the first section, there are four sections corresponding to the CASE elements. Each section has the same context such as the contributions of the element to other elements, and to the entire industry. Also, the typical contributions of this elements to society, to the industry and to future transportation were asked.

The questions are thus inclusive and extensive. It is worth noting that not all questions were answered or raised in all the interviews. Questions acted as a guide in the interview, they were adjusted flexibly in terms of the 1) the situation, 2) the previous answers and 3) interviewees' knowledge.

Therefore, semi-structured interviews have been chosen as the major of the interview method. Owing to the complexity of interviewee groups, broad framework-based questions are listed to catch all possibilities. Among these, a few central questions were asked of all participants to average the opinions about the future transportation. Further, the questions in subsequent interviews may be adjusted according to the answers from the previous interviews, or within one interview new questions may be asked depending upon the direction of the conversation. The semi-structured method is flexible and open-ended, so it is possible to obtain more information in a very time-consuming interview. Therefore, semi-structured interviewing is very suitable for this situation. It indicates the direction during the entire interview but gives flexibility according to the expertise of the respondent. The way of posing questions may lead different answers, which means that the quality and skills of question design and pilot testing are needed. Interview design and relevant skills were trained in the skills developing training provided by the university.

***Interview recordings and interpretations***

The entire interview process ideally should be recorded by a digital device for evidence and later manuscript translation. However, in a few interviews it was the case that owing to the lack of devices they have not been recorded so that note taking was conducted instead. The notes in those note taking interviews have been checked to ensure that the meanings are taken and interpreted correctly by interviewees immediately at the end of interview. Devices such as laptop, mobile phones and a specialised recorder are used in terms of varied circumstances. Recordings are permitted by interviewees and recordings are kept meticulously.

***Interview strategy***

To enrich the primary data, interviews have been conducted by a combination of internet online conversation, mobile phone meeting and face-to-face methods depending on interviewees' preference.

To minimize travelling cost, and contacting and waiting time, telephone interviews were introduced. This method is lower cost and less stressful than face-to-face interview. It is lower quality as a means to obtain information through electric recording devices, and the recording quality highly depends on the surroundings and equipment.

Face-to-face interview are also applied as long as it is possible to meet the interviewees. The typology of face-to-face interviews include mixed personal interviews and group interviews. Group interviews are useful for cost saving and gathering diverse opinions on the same issue at the same time. But a good convenor is needed to control the progress and guide the direction. Additionally, it can be a bit chaotic when data is analysed.

The process to select interviewees was complicated, difficult to achieve, and iterative. Interviewees were intended to be drawn from diverse areas such as entrepreneurs, academia, business consultants, technologists, automakers, journalists, policy makers, and media specialists. Potential interviewees were obtained from relevant professional conferences, meetings, workshops or introduced by friends, who were aware of the general concept of CASE. Users were randomly selected in order to generalise the entire user group. Then interviewees were contacted by email to ask how they preferred to be interviewed and classified the interviewees by i.e. face-to-face or by online/phone call. However, the relevant answers could be obtained from other interviewees. In this process, the interviewees' preferred method was sometimes adjusted in consideration of the travelling conditions, time, costs and other causes. According to the categorization, the relevant interviewees and methods were decided.

The interview phases are February to March 2018 and January to June 2019. Two groups of people had been interviewed, one is from UK and another is from China. It is with a good contrast about managers' attitudes from distinctive perspectives to enrich data resources likewise.

*Table 13 Acronyms on Interviews*

| Acronym | Item | Acronym | Item |
|---|---|---|---|
| **AC** | Academia | **SE** | Software Enterprise |
| **AM** | Automaker | **TC** | Technology Centre |
| **AT** | Autonomous Trucking company | **TP** | Technology Platform |
| **BC** | Business Consulting company | **TS** | Transport Sector |
| **IE** | Investment Enterprise | **U** | Users |
| **J** | Journalist | **UK** | The United Kingdom |
| **LE** | Logistics Enterprise | **CH** | China |
| **NPO** | Non-Profit Organization | **F2F** | Face-to-Face |
| **NGO** | Non-Governmental Organization | **VC** | Voice Chat |

Source: Author

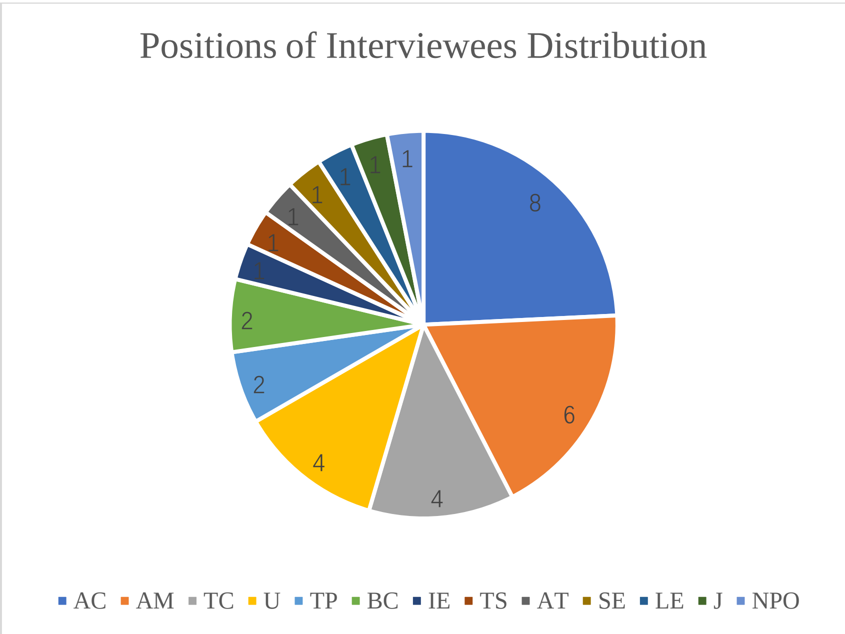
*Table 14 Interview Time and Methods*

| Date | Name | Company | Formal | Position | Methods | Time Minutes | Content CASE | Country |
|---|---|---|---|---|---|---|---|---|
| 2018/2/15 | U 1 | NGO | No | User | F2F | 20 | S/E | UK |
| 2018/2/20 | U 2 | Hospital | No | User | VC | 30 | All | CH |
| 2018/3/15 | AC 1 | University | Yes | Section leader | F2F | 60 | All | UK |
| 2019/1/16 | TP 1 | TP | Yes | Head of Data & Analytics | F2F | 30 | E/S | UK |
| 2019/1/16 | TP 2 | TP | Yes | Programme manager | F2F | 30 | E | UK |
| 2019/1/17 | BC 1 | BC | Yes | Director | F2F | 40 | All | UK |
| 2019/1/17 | BC 2 | BC | Yes | Consultant | F2F | 30 | E/C | UK |
| 2019/1/17 | IE 1 | IE | Yes | Managing Director | F2F | 75 | E/C | UK |
| 2019/1/22 | AC 2 | University | Yes | Former Manager | VC | 50 | All | CH |
| 2019/1/22 | U 3 | N/A | No | User | F2F | 30 | S | UK |
| 2019/1/23 | TS 1 | TS | Yes | Former assistant manager | VC | 30 | All | CH |
| 2019/1/24 | AT 1 | AT | Yes | Senior staff scientist | VC | 50 | All | CH |
| 2019/2/1 | AM 1 | AM | Yes | Project manager | VC | 40 | All | CH |
| 2019/2/1 | AM 2 | AM | Yes | District sales manager | VC | 60 | All | CH |
| 2019/2/2 | U 4 | User | No | User | VC | 20 | All | CH |
| 2019/2/2 | AM 3 | AM | Yes | SQM engineer | VC | 30 | All | CH |
| 2019/2/2 | AM 4 | AM | Yes | Engineer | VC | 40 | E/S/C | CH |
| 2019/2/2 | AM 5 | AM | Yes | Engineer | VC | 40 | E/S/C | CH |
| 2019/2/7 | SE 1 | SE | Yes | Co-founder & CEO | F2F | 55 | Infra @ all | UK |
| 2019/2/11 | AM 6 | AM | Yes | Purchasing specialist | VC | 15 | E | CH |
| 2019/2/18 | AC 3 | University | Yes | Psychologist | F2F | 60 | All | UK |
| 2019/2/21 | AC 4 | University | Yes | Truck specialist | F2F | 40 | E/A | UK |
| 2019/3/15 | LE 1 | LE | Yes | Logistics manager | VC | 30 | E | CH |
| 2019/5/10 | AC 5 | University | Yes | Gerontology researcher | F2F | 60 | All | UK |
| 2019/5/16 | AC 6 | University | Yes | Transport | F2F | 30 | All | UK |
| 2019/5/24 | J 1 | Journalist | Yes | Writer | VC | 30 | All | UK |
| 2019/6/17 | TC 1 | TC | Yes | Business Innovation Director | F2F | 30 | All | UK |
| 2019/6/17 | TC 2 | TC | Yes | Innovation Architect | F2F | 15 | All | UK |
| 2019/6/17 | TC 3 | TC | Yes | Academic Engagement Coordinator | F2F | 15 | All | UK |
| 2019/6/17 | TC 4 | TC | Yes | Manager | F2F | 30 | All | UK |
| 2019/6/18 | AC 7 | University | Yes | Engineer | F2F | 60 | All | UK |
| 2019/6/18 | AC 8 | University | Yes | Economist | F2F | 30 | All | UK |
| 2019/6/27 | NPO 1 | NPO | Yes | Manager | VC | 30 | All | UK |

Source: Author

Table 13 lists all the elements that Table 14 refers by their acronyms. To simplify and anonymise the interviewees' personal details, Table 13 shortens the areas of the interviewees working on as their labelled name given the circumstances of their speech. Acronyms also includes the methods of conducting way (face-to-face or voice chat), and the groups of they belonging to (China or the UK). In which it can identify more background information around the discourse. There are fourteen categories of positions that the interviewees are holding (Table 13) with a very rear overlapping between interviewees (Table 14). The acronyms will refer to all rest of the research especially on this chapter and Chapter 7 Findings and Discussion.

In total, 33 people have been interviewed. The Figure 5.8 shows the interviewees' position distribution. Interviewees from academia and automotive manufacturers take just less than half in total. As presented before, academic scholars hold the wide range of expertise and neutral viewpoints, and car manufacturers are technology providers. They are the most critical and reasonable parts in the interview. For leveraging the opinions, scholars have been selected from 6 different universities, three in Wales, two in England and one in Shenyang, China. All possibilities are taking apart into the interview: engineers, specialists on logistics, transportation, economists, geographer etc.




Source: Author

***Figure 5.8 Positions of Interviewees Distribution***

Notes: the abbreviations see the Table 13.

The same to automakers, interviewees from industry also spread from both China and UK to balance the opinions' differentiation. Interviewees who are working in the automotive industry range from manager level to car sellers which makes the interview more diverse. To specify, interviewees from Technology Centres (TC) form a focus group interview for a) exploring group inspiration opinions b) time and cost saving. Then the last biggest collection is users. Following the same rule, users are also being selected from both China and UK aging from 20's to 70's.

***Advantages and disadvantages***

Primary data has the special advantages: it can obtain the data with a wide range and depth at the same time as required and variables are always under the control. In this research, primary data obtained through interviews, the way of raising questions and the numbers of interviewees are controllable by research conductor. The interviews conducted included group interviews, personal in-depth interviews, and informal interviews. The variation of the interview methods enriched the insights obtained and could allow comparison of the results with the interviewees in the same group (in group interviews) and also by others. This provided another way to iterate the data collection and improve the validity of the insights obtained. The questions are tailored and just aimed to answer where answers are needed. It makes a considerable coherence in secondary data case presenting and personal perspectives assortment.

The disadvantages of interview include: the first, too many digital recordings, notes, and verbal materials to translate and select, it is time intensive on translations and recordings. Digital recordings are easy to save while also easy to lose. To deal with the in-person interview process, two digital devices were prepared at the same time and notes were also made. Questions in some instances may have been asked by a partner and then the author made notes and classified the notes directly. The second is the high travelling cost and time-consuming nature of the interviewers. Travelling to a distance city by any means of transportation is costly. Therefore, the telephone interviews were also introduced to enrich the data and to save travelling costs at the same time.

However, it is a less personal method of communicating, and the discussion is not always as rich. Third, it is difficult to agree a scheduled time to both parties. The email responding rates from interviewees are around 80 percent which is very effective except a few kind rejections. Time arrangements are not always perfect for settled interviews; variations often happen. Additionally, to arrange all interviewees on the same route, around same date is very difficult. It may take a few rounds to meet people who you prefer to meet, and you may miss a few potential interviewees if they are not available. The personal interview programme was addressed with a well organised travelling plan. Over several rounds of discussion and negotiation with interviewees, it was possible to ensure the maximum time saving and efficient use of travel at the same time. Group interviews and personal in-depth interviews were mixed so that interviewees in the same company could discuss the questions and offer supplementary responses. Additionally, opinions only refer to personal opinions, they cannot be considered as professional expertise, even though those opinions may be based on a robust and informed understanding of the issue under discussion. Moreover, the common issues of interview have also happened such as respondents did not provide much useful information, group members did not agree with each other, or issues raised beyond the cover, and had less time than planned. All these incidents have been carefully dealt and sticked to the listed questions.

### 5.4.3 Reliability, validity and flexibility

Reliability, availability or validity, flexibility or replicability, are three standards to judge the quality of research data. This section will firstly define what is data reliability, validity and flexibility, then evaluate the quality of this research.

The criteria vary underneath each mechanism while we only illustrate a few elements which are highly considered during the research progress. Reliability should be examined by consistency through the entire research, which is explored from the data resource, data criteria and personal bias; validity can be illustrated by internal validity (data causation, interpretation), external validity (generalisation of results), predictive validity (as most of questions are based on prediction); flexibility means to what degree the findings generalise from one context to another (Hinds et al. 1990; Leung 2015; Noble and Smith 2015).

And questions under each criterial would be (Hinds et al. 1990; Bryman 2012; Leung 2015):

***Reliability****:* Are all resources clear and reliable? Does interpretation of data have bias and / or misinterpretation? Does all data have the same standardisation?

***Validity***: Does it test what it aims to test? Is all information based on valid and similar variables? Does the research accurately interpret the meaning of the data? Can we generalise internal causations from data? How about the generalization of the result? Or say replication of the result? To what extent? Is it relevant to sampling? Can these findings be applied to everyday life?

***Flexibility*** or generalisability: Can these findings be generalised from context to another?

***<u>Secondary data reliability, validity and flexibility</u>***

***Reliability***

All the sources are clear and reliable. They are distinguishable and published by authorised official websites. News stories are illustrated in the beginning of the chapter, primarily chosen from national wide news press such as BBC News and Reuters. While reporters or authors on specialist websites more or less hold their personal perspectives. With respect to this point, data only includes relations between organisations; personal opinions are not accumulated in the data collection stage. In addition, the iterative method is to test the reliability of data by cross-reference to other interviews and secondary resources.

Additionally, authoritative reports are largely pertinent and accurate. However, to guarantee the accuracy and validity, it is a time-consuming long journey for a report from data gathering to present. The reports therefore are updated to the latest information for the previous year. However, this research requires the latest information as the news are updated rapidly and dynamically, official reports may not show the circumstance in the current year. It encounters the same for peer reviewed journal papers, that have high quality with a bit dated data. To deal with this issue, news press release and stories compensate for such weaknesses. Although documents and journal articles have absolute advantages, many documents just focus on one aspect of the phenomenon and academic journal articles. This shortcoming also can be compensated by data triangulation.

But surely, data may include less reliable sources with vague interpretations and untraceable roots. Similarly, the methods of data collection may be unknown, it could vary from person to another, particularly in the data collection by interview and questionnaire. However, some of those data contain many details, they require comparison and selection from other resources. Reliability also may change over time such as definitions have changed.

***Validity***

Theory validity has been tested. Network theory is integrated with STT theory owing to the complexity relations among variables to illustrate how elements in regime and niche level dynamically change. Networks analysis generated a large amount of data which can be tested by various cases later in Chapter 6. The networks are possibly generalized to other companies even when the company does not belong to car industry. Results are also replicable in many areas because a lot of samples are analysed and time spans widely.

However, data resources cannot ensure the same quality obtained. For example, how to measure or define an ‘autonomous’ vehicle is vague as various definitions to the same term are applied; the vehicle sharing concept has different criteria which include ride sharing, car sharing, rental, ride hailing and car hailing but it does not have a formal standard. Even though primary data compensates for partial flaws from secondary data, a few points are still missed such as politically relevant interviewees.

Although it is declared that the data has been chosen from the most trustworthy websites, the reliability is still doubtful. Deloitte is one of the representatives of quality, it has been identified with many errors from EV's recent growth report (Holland 2019). Therefore, the validity needs to be proven from both research and over time.

Nonetheless the topics in this research are highly correlative to daily life, some concepts can be generalized while others cannot. For instance, the encouragement on buying and using electric vehicles could be under many users' consideration, electric vehicles could be the second choice in accordance with correspondence. This is an applicable result plus the strengthened government policy. However, vehicle sharing is Internet or application based where it is youth's arena such as to take Uber or Blablacar.

***Flexibility***

Data triangulation methods are used in data compilation and exposition. The news events have been collected iteratively to ensure the completeness of entire storylines for each case. The first-time data collection is to track what happened, why it happened and how these organizations deal with these issues. The second round is detail refilling to check what has been missed if there is a big-time gap in between. The third round is for specifying down to the individual company to ensure that the news around the cases are rich in detail and sufficient to be interpreted.

Case results are repetitive. The cases are presenting in different scales of company, country, features which can be repeated in other cases. Case studies have been selected because they have abundant supportive data. It not only can repeat in automotive industry, also can be copied outside of automotive industry who aims to enter the competition of autonomous vehicle constitution.

***Primary data reliability, validity, flexibility***

***Reliability***

The reliability of primary data depends on the sides looking into the question. If reliability indicates the data collection procedures, the answer is that the research followed accepted approaches and is therefore reliable. All interviews have been conducted by the author and consent form signed with no sensitive and ethical issues disclosed. However, if reliability means the answers' quality, it would be disputable. Questions are not always answered the way predicted, or in another words, either the questions could be misunderstood or mis-answered. It links to the quality of data interpretation. How is the data interpreted? The interviews are collected by Chinese and English respectively. The interpretation from Chinese interviews is mostly cognitively through the meaning. English manuscript translation is word-by-word. All manuscripts translation is under the same standardization.

***Validity***

In this research, data has been tested as it should be. To the primary interview data collection, questions are designed directly aiming to answer all questions that are relevant to the research. However, not all questions are answered due to the limitation of the time and expertise from interviewees. Further, this research proposed advanced questions which are beyond all current knowledge, it requires interviewees to use some imagination. Questions are like the possibilities of CASE in one vehicle; particularly the time taken to become fully realised as true of CASE in one vehicle. Questions also covered, the scenarios under which people might to use fully autonomous vehicles. Because of this, this research is full of different perspectives and voices. Different experience does not mean a low standardisation. All interviewees are highly educated, with a reasonable understanding and a commanding point view to see the whole picture.

The bias and the noise need to be avoided to keep each interview acquiring a valid answer from assorted environment and methods. The answers to the interviewed questions can be generalized. In terms of the respondence validity which is firmly guaranteed in the process of interview. The interviewer recapped the mis-understandable answers so that participants are allowed to correct answers during the interview and give comments after the manuscript interpreted.

***Flexibility***

As mentioned before, the data triangulation method has been used in the data collection and presentation. This comes with the research repeatability. If flexibility refers to question repeatability, this research and its data is greatly flexible. Questions are highly overlapped among individual researchers, academia, manufacturers, common users and journalists. Interviewees have read questions before the interview to give sufficient space to understand the interview context.

If flexibility refers to a person who answers questions, it is a bit difficult to repeat and group interviews may be even harder to repeat in terms of particularity of the ‘group’. The reason is that the answer could be changed over time. Most questions are based on assumptions which may ask interviewees to answer the questions based on current knowledge and experience.

To summarise, this research reliability, validity and flexibility meet the standard from data collection, interpretation and result repetition. Additionally, data collection methods from secondary data, primary data and iterative data collection ensured the data consistency, cogency and repeatability.

## 5.5 Software Applied in the Process

This section provides information of software applied in the process of data collection: Gephi, RSS and Zotero. Gephi is used for portraying relations between companies around autonomous vehicles, RSS is used for data acquisition from the news. Zotero is the software to edit bibliography for time saving.

### 5.5.1 Gephi

The Gephi is a tool used to draw, explain and visualise data network constructions. It has a powerful flexibility to filter, spatialize, manipulate, input and output networks in any shape. Pictures could be adjusted according to the requirement of authors by gravity, input/output numbers, velocity, size also adding/cutting notes etc. (Bastian et al. 2009). The network relations are listed in the Excel and saved as .CSV format. The Excel table clearly shows how many relations in total and they can be easily searched by key words. The relations are inserted artificially by alphabet order with the main car manufacturer's name.

To draw a network flower, three elements are needed to ensure the network diagram works: source, target and type. Source is on the first column which is the initiator in the relationship – usually identified as car manufacturers. The second column is target which is the relation acceptor. This column lists all other companies other than carmakers such as IT companies, start-ups or suppliers. If the membership in an alliance are over three, it will be listed as two different relations, as the relations are limited one to one on each line. The last column is type which is used 'undirected' so it only shows a relation in between no matter which point is the initiator (Cherven 2015). By the end of 31 July 2019, Gaphi shows 303 nodes and 525 edges which means 525 relations formed in the network.

'Fruchterman Reingold' has been chosen to show how the relations between nodes. It gives a general layout of the gravity between 5.00 to 30.00. If gravity is over 30, all nodes would be squeezed together and if gravity is less than 5, the structure would be very loose. Gravity is offered a weight if the vector has the most relationships, thus the heaviest elements (with the largest relations) are located in the middle of the graph. We give the minimum to the speed so that the less movement indicates the more stable for the picture. Area defaulted as 10,000, it is displayed in the centre of the screen without any bit out-range. Nodes are coloured based on its weights, nodes with higher weights are coloured darker.

### 5.5.2 RSS

This is a basic function to collect correlate news. When specific websites such as Automotive World have been selected, it can be subscribed through RSS. Further, the sub-titled or a specific page can be added as a feed reader, this makes news more specific and data collection more efficient. Feeders can be manually removed or added by website links to RSS with bottom of '+'. The RSS feed reader has to be installed as an extension on a general browser such as Chrome, Firefox and Safari. Feed notifier will show the feeds subscribed with few short notices. Feed update interval and the numbers of post can be filtered by follower (Fernandez 2019). The advantage of RSS is that it updates quicker and is more convenient to receive information than email or message. But the disadvantages include 1) it needs to be manually checked and 2) the news are updated rapidly so that some important news are missed.

### 5.5.3 Zotero

Zotero is an expert referencing software to help organize references. The researchers prefer not using Endnote editing software because Endnote is more suitable for paperwork e.g. pdf files and word documents. It is a business-friendly software but not convenient on private devices. Zotero has free installation with 300 MB online clouds storage and is available on private laptop. Any typical style can be found through 'document preference' (Ivey and Crum 2018).

Zotero has a few distinctive benefits which matched researcher's requirement. Firstly, news-based research requires the editing software to be website-friendly. Zotero has its extension on Firefox and Chrome web browsers so that it can save webpage directly and capture the information at the same time (Ivey and Crum 2018). It can be edited online or through a standalone application over an account, all data can be synchronized both online and offline. It has the same basic functions as other citation software which could edit citations and a bibliography automatically and manually. It is also integrated in Microsoft Word which can add any citations directly in Word.

Zotero definitely has imperfections. Some websites did not label the year and authors notably on official reports and news press such as on GOV.UK and Automotive News. In this situation, authors have to manually find the earliest publication date to fill in the column of 'date', list the websites name as 'author's name'. For instance, Centre of Connected and Autonomous Vehicles are created without the specific date, while the first publication on this website about such technology was in 2015, so the name and date labelled as (CCAV 2015).

## 5.6 Data Interpretation and Organization

Data has been chosen from documentary database, news press, archival documents, primary interviewed data, quotation, reports, official database etc. Data presentation is detailed in the Chapter 4 and 6; interviewed opinions and discussions are presented in the Chapter 7. This section addresses the data presentation methods, the reason to launch case studies and procedures.

### 5.6.1 Case overview

Secondary data gives a general skeleton of how transitions occur and transform under a context of automobile industry to automobility industry. It offers plots of events, the categories of company that attempts to participate, the numbers of manufactures attended, the major players, and the stories to date. The initial aim focuses on conventional car companies who entered the race of manufacturing high level autonomous cars.

Later on, to build higher level autonomous vehicles, technology suppliers are involved including those providing sensors, navigation items, system upgrades, and those from the energy and infotainment sectors. To establish higher level automated vehicles with sustainable concepts, some manufacturers focus on electric powered engines, while others tend to develop vehicle connectivity with road infrastructures and homes to fit smart city concepts. Since the vehicle automation concept grows rapidly, expertise or leading companies in these specific areas are likely to collaborate with more than one car company. For instance, Nvidia is the expert on visualization, autonomous control and artificial intelligence, and so collaborates with OEMs such as BMW, Audi and many other traditional automakers. Hence, such significant players like Nvidia are also selected in the cases.

Due to the dynamic of the cases collection, the entire story has not been fully collected until middle of 2019. Case chosen route is indeterminate too, along with new stories coming up. Relations between cases also fluctuated which make relations unstable. Overall, the cake of building autonomous vehicle has been shared by various interest holders and more interest holders will be joined so that relations become more complicated in future years.

### 5.6.2 Why case studies?

Case study as a method describes and analyzes typical individuals, groups, communities, or institutions. It is flexible, so the author can unfold an affair from any view. Additionally, case study can be used to explore a case or a phenomenon in depth. In 1998, Merriam showed four basic types of case studies (Table 15). The case study matrix simply composed of single case and multiple cases; during the procedure of analyzing the case, each approach could be subdivided to analyse the whole unit or embedded individual in turn. Basically, a single case study investigates unique and the most representative case which cannot generalise a public situation (less flexibility). While multi-cases could scrutinize several cases at the same time and could be generalised but it lacks in depth investigation (Yin 1994; Merriam 1998; Yin 2002).

***Table 15 Basic Types of Designs for Case Studies***

| | single-case designs | multiple-case designs |
|---|---|---|
| holistic (single unit of analysis) | TYPE 1 | TYPE 3 |
| embedded (multiple units of analysis) | TYPE 2 | TYPE 4 |

Source: (Merriam 1998)

When conducting case study methods, Professor Ning Wang (2016) pointed out that 6 questions should be addressed: 1) information cost and category of evidence; 2) general or individual; 3) representative; 4) extrapolation logic; 5) reason and result logic; 6) validity. He claimed that individual case study is open evidence-based research, to conduct and lead new findings and exploration, and relevant economy of effort. Scheduled projects can be adjusted any time according to practical context which is a multidimensional and in-depth research method. This research is using multi cases from different dimensions to explain the theory, and further details are shown in the next chapter.

Concerning the context of this research, a Type 4 case study is used, in which a multi-case embedded is designed, including two themes. One theme is car manufacturer company dominated which would, or already develop the autonomous and connected technology; another theme is 'outsiders' of automotive industry, parts suppliers, which are ambitious to dominate the autonomous vehicle competition. Under each theme, a few embedded cases are illustrated. The theory that used to clarify the cases is the network theory, which links the entire dynamic relations.

### 5.6.3 What cases?

Horizontally, 7 automotive enterprises have been selected with their essential events since the CASE vehicle concept has been promoted. Actually, there are more than 30 core automakers involved in the automated technology ecosystem R&D, but due to time limitations and material support only the companies with adequate supportive evidence have been chosen. Each car company has distinct character to show the different pathways to achieve CASE strategy. Another 4 'outsiders' have been selected to represent the other competitors which are enthusiastic to deliver the contributions to autonomous vehicle production.

Vertically, apart from car manufacturers, dozens of pertinent industries have been involved in the growth of autonomous and connected vehicle commerce such as the insurance, internet, engineering and, potentially, the advertising industries. They are interactional and stimulated mutually. For instance, to offer more comfortable navigated sphere for passengers, engineers are required to be more creative and human-centric. Correspondingly, connected cars would supply an infotainment environment through the higher internet participation of ICT businesses. Besides, electric cars pay more attention to enlarge electric storage to improve the quality of batteries. Thus, a braided network via diverse industries developed through the concept of CASE vehicles.

CASE vehicle is another latitude to diagnose the various focal points on each company. A filly autonomous vehicle as a comprehensive integrity is difficult to achieve, it is even challenging to achieve concepts of CASE in one vehicle. Additionally, traditional car manufacturers have market strategies and positioning which may not be easily changed by a virtual concept in a short time.

Google “Koala car” is the representative within the Autonomous Vehicle territory because it was the earliest crossover from the IT field to the automotive arena. Autonomous technology to any area seems attractive, it is a sort of technology innovation, rather a small progress based on previous techniques. This is an area not limited to automotive industries where many other companies can show their advantages. Nonetheless, the ‘autonomous’ technology has expanded from cars to trucks, buses and even underground trains. It is a new challenge to the entire transport system.

Tesla Model S, Nissan Leaf, and Toyota are the leaders in Electric Vehicle areas, followed by Audi, Volvo and other car makers. Electric cars have been explored more deeply than autonomous cars, as they possess a more mature technology than autonomous systems. Also, some relevant accessories have emerged and gradually deployed in the electric car industry, such as electric buses and shuttles; also, battery companies have grown because more battery and electricity storage will be needed. Also, alternative energies like solar power, wind and tide energy are going at a fast pace to offer more resources for electric cars. In the meantime, imaginations are not only confined to the car field. Engineers have forward innovative plans such as the smart city and the electric power grid. It offers a wider market to combine electric cars with autonomous and connected cars into city transport systems, to coincide with the requirement of sustainability. Some regions already have projected smart city as future plans. Tianfu district in Chengdu, China, has launched the smart city project in recent years where thousands of citizens would benefit from smart city smart grid very soon. This project will save 48% of electricity consumption and 52% of water usage compared with the same population in other regions (Boyle, 2012).

Snowball sampling methods are not only used in interview process, but also in the cases selection. Not all companies focus on autonomous vehicle development at the beginning. When a small case gradually becomes a sizable and representative one, it is worth collecting more relevant cases around it. Bryman also suggested that research could use more than one sampling approach to dig and think data deeper (Bryman 2012).

At the end, seven car companies have been chosen: BMW, Ford, Daimler, Volkswagen, Volvo, Nissan, Hyundai; and four other companies outside car industry as well including: Waymo, Mobileye, Didichuxing and Nvidia.

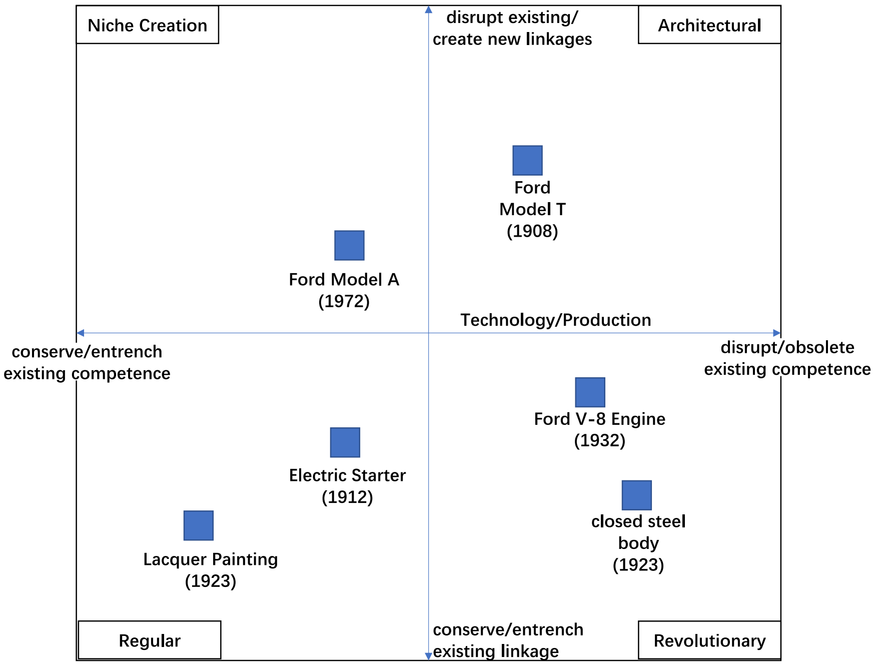
### 5.6.4 Why these cases?

The cases are representative. Automotive is a global industry in which each country has it ‘national’ proud. Automotive system as a socio-technical ecosystem hold diverse cultural, local legislations, users’ preference, brand positioning etc. The selected cases contain typical cultural which can represent European, American and Asian’s individual business and strategy as well as joint venture that clashed with multi cultures. Each brand also has different market positioning to attract distinctive groups of consumers. Self-defining brand can also be categorized as luxury OEMs such as Audi, Porsche, BMW and Mercedes-Benz; middle class OEMs such as Volkswagen, Toyota; low costs like Kia, Hyundai. Correspondingly, partnerships and alliances have different priorities which aims to enlarge the automakers’ brand effect. High-end or luxury marque hunt software specialists who provide software to upgrade next new generation system. Middle class OEMs select telematics adaption, low cost business strategy may invest software seeking alliances to strengthen its weakness (Weiss et al. 2015).

Additionally, cases are repetitive. The cases in this research confirm that both theory and the case results are repetitive. Automotive industry has been defined as an individual socio-technical ecosystem in Chapter 4 in which all activities in three levels are mutually interacted. The theory has been applied in many areas, this research is another application for STT theory in the future transportation. The theory is tested under assorted conditions therefore it is theory repetitive. These cases are under the same system which is automotive system. Selected cases include car manufacturers which are ‘inner’ of the automotive industry, also some ‘outsiders’’ cases. This identifies that the cases results can be repetitive not only within the automotive industry.

The case construction follows the ‘CASE’ strategy. Firstly, it must consist of wholly CASE elements. This step eliminates companies that lack one or more CASE involvement. If a company is not identified in the secondary data analysis with sufficient activity in the CASE elements then it is not selected for further analysis. There will be some bias in this process. For example, the use of English language media sources might result in a bias that neglects news reports in other languages. In addition, not all companies seek to make public their activities in terms of CASE research and development. In other words, it cannot be known how many examples were missed. On the other hand, the use of keywords for regular searches of the specialist automotive media does mean that the research process was very consistent, with a high probability of identifying all the instances of CASE elements being developed in so far as they are reported in the specialist media. Additionally, all cases were constructed in chronological order, or CASE order. This reshuffle followed the CASE to development constantly. This process also excluded those examples who worked on CASE developments more sporadically or with less consistency.

Case selection also consults the following diagram (Figure 5.9) where characteristic of each innovation can be classified as niche creation, architectural, regular or revolution. Niche creation brings a new linkage between existing competences; architectural innovation is more adventurous to create something new to the existing products. As a revolutionary innovation, it crafts new products with latest technology to engrain existing linkages while regular innovation is elevation under the current system statues. Cases with high-end brand, middle class and low-cost OEMs, are classified as varied alliances. Also the innovation of some auto parts suppliers can be regarded as architectural which break a gap to create new productions with new technology for an unprecedented product.




Source: (Abernathy and Clark 1985, p.8)

***Figure 5.9 Technology Revolutionary Diagram in Last Century***

## 5.7 Conclusion

This chapter demonstrates the philosophical location of the research which is social constructionism. The social constructionism refers that physical phenomena (‘things’) emerge as a consequence of human actions. The ‘things’ are meaningful because people endow the value to them. Individuals are the participators of the society, in some degree, they are creators. Therefore, issues have been solved with the ‘things’ which are advanced technology, in turn technologies are further enhanced to fulfil the rapid growing demand.

The primary data has been used to analyse interviewees’ opinions, and secondary data constructs a general storyline for the entire thesis. Case studies intermediate the general framework and the details that act as the ‘dots’ or ‘nodes’ in the network. All cases and interviews were integrated to answer the research questions. The selection and construction of the case study process are based on the idea that the cases could be representative, generatable and reflect regional differences. Through the case studies, it was possible to test the propositions regarding whether the CASE concept is well distributed (across companies and across locations) and whether vehicle manufactures are seeking to integrate the CASE in one vehicle. Additionally, the separate CASE elements are used in each case study to illustrate how far each of the four individual elements have been progressed by the chosen vehicle manufacturers.

Overall, the general research strategy diagram is illustrated in Figure 5.10. This flow chart lists all elements and steps where the research was conducted, it also gives the illustration of where the additional information was attached to the search process.

The search process had a focus on the specialist websites related to the automotive industry, because these sites would by default have a greater coverage of the industry and more depth of analysis in each news item. The specialist sites aggregated third party news feeds (e.g., from Reuters or APF), but also had their own news generating capability. Therefore, these sites were superior to more general news sites or individual news feeds. The sites were searched on a regular (weekly) basis for new stories or feature articles related to the main keywords (connect*, electric*, autonomous, self-driving, shared, mobility-as-a-service, artificial intelligence). News stories were then copied and put into a folder.

Each instance was coded for content according to the vehicle manufacturer(s) involved, the other companies involved, and the primary focus of the instance (for example whether on electrification or connectivity). Coding would include the country or region of application if available. This process allowed the accumulation of instances iteratively to inform the ongoing design of the research and the theoretical framing. Over the period of the research, each instance that was collected would inform the search for other examples (for example, by searching for a newly identified company to see whether that company had instigated other initiatives), while the theoretical framing assisted in the evaluation of how far each instance could be considered significant in the context of the transition to CASE mobility. So, the STT theory has been underpinned by the data collection procedure to guide and integrate CASE vehicles. As Chapter 4 illustrates, this research added network theory to enhance the STT theory especially in the new niche emergence process and mainstream re-coalescence procedure. Both data collection and theoretical underpinning shaped and informed the secondary data analysis while it is still insufficient to analyse CASE from a global perspective. Since the basic outline has been sketched, interviews have been considered to offer additional information from other than automotive manufacturer's perspective. The database of instances allowed identification of themes to be followed up in the interview process. The interviews sought to uncover the wider issues associated with the transition framework, regarding for example the part played by government, universities, or other social agents in the development and deployment of CASE vehicles.

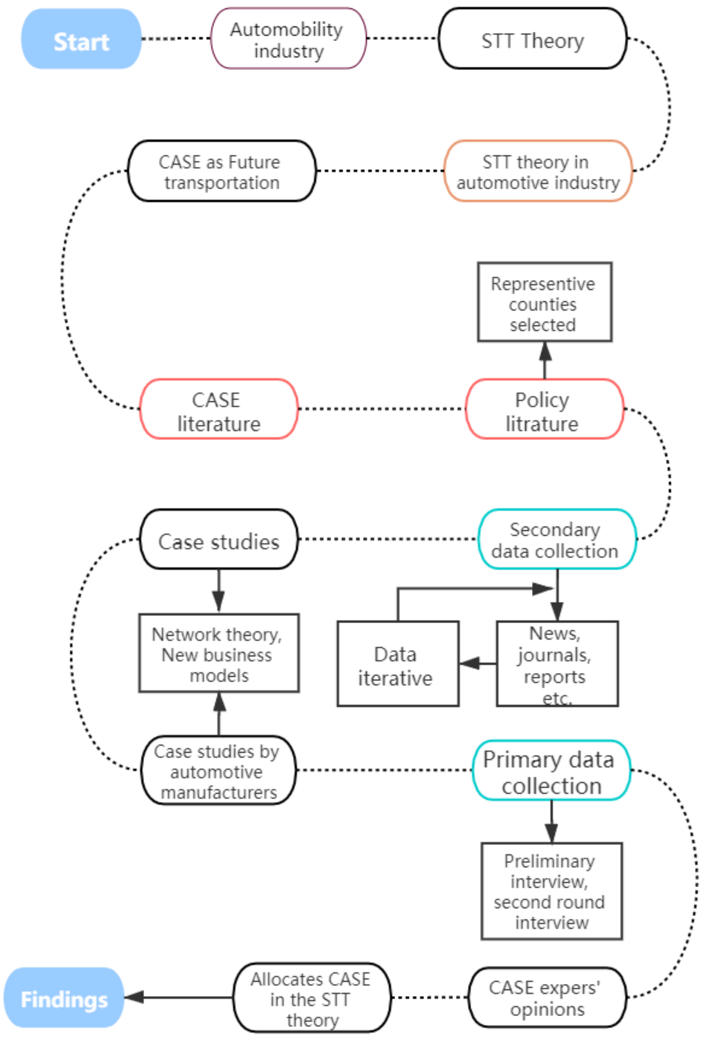



***Figure 5.10 General Research Strategy Flow***

Even though this way may have numbers of errors along with the research, such as lower validity and reliability, it is a good chance to build a complete database to develop and make up this gap for both academia and society. The application and social impact of this technology needs to be understood, by the population as a whole. And this is another reason why this research is worthwhile to do.

# Chapter 6
# Embedded Case Studies and Insights of Expertise

## 6.1 Introduction

Case studies in this chapter consist of selected companies that have participated in the construction of connected, autonomous, shared and electric (CASE) vehicles. Given the variation of geographical, political, cultural and historic corporate capabilities, vehicle manufactures adopt varied strategies to immerse into the new market territory. The automotive industry is global in that it has infiltrated in countries no matter whether highly developed or developing, countryside, or civic centre. Nonetheless, the vehicle models are adjusted to coincide with the local culture, local geography, and local markets. The globalisation is therefore very uneven, for the industry in total and for the individual vehicle manufacturers. Changes in vehicle design and manufacture location are also decided by the market positioning and production portfolio of the manufacturer. All these reasons mean the vehicle manufactures' attention to CASE elements are different to each other. However, it is not possible to investigate the entire global automotive industry in this research. Based on these reasons, this research selected the most typical manufactures around the world, they 1) locate in different areas so that each one is regionally representative, 2) are market leader for the introduction of CASE technologies, 3) have distinct engagement of CASE, and 4) are different in size, reach, and capabilities. Therefore, they are not all examples of mature and successful CASE vehicle deployment, but the examples collectively are broadly representative of the industry as a whole.

Additionally, the selected cases are good examples of the issues that this research is focusing on. Others may not be so interesting, for example they might be struggling to compete in general and not have the resources to get further into CASE boundary crossing. The search process for examples as described in the methodology therefore naturally yields a population of vehicle manufacturers that are more or less engaged with CASE technologies and, by extension, with engagement with third party companies to help bring those technologies to market. The selection process for case study examples therefore was based on an analysis of the database of examples drawn from the secondary research. The case study examples are representative of the industry in that they reflect the inherent diversity of the vehicle manufacturers, and the varying strength of efforts to engage with CASE technologies. Vehicle manufacturers that were not engaged with CASE technologies (so not present in the database) were excluded, though such examples would be few in number.

This chapter include two themes and each theme contains a few cases. The first theme is automotive industry-based theme which covers seven car companies in different regions around the world. The second theme involves peripheral companies such as parts suppliers or those initially external to the automotive industry, as they gradually take a competitive position inside the industry. Network theory is applied in each case where it shows how the CASE concept linked all components in a network. Network theory can be applied in individual examples showing the relations between a central vehicle manufacturer, other vehicle manufacturers, and other suppliers. Network theory can also be applied in a wider sense to the entire automotive industry demonstrating the entwined relations between all parties. Many companies could link with different parties and in this way, therefore a giant network is completed. In terms of the transitions process, the building of these networks across the boundaries of the existing automotive industry is indicative of a reconfiguration of the socio-technical system around these new participants and their technologies. Hence in terms of the propositions it shows that it is possible to use STT theory as a means to analyse future events, because the network analysis shows the construction of the reconfigured system as it unfolds. From the wider perspective, this chapter discusses how the STT theory works in the automotive industry instance. Therefore, this chapter is divided into cases which are inside the automotive industry (Section 6.2) and outside the automotive industry (Section 6.3), discussion (Section 6.4), and the conclusion (Section 6.5).

## 6.2 Cases in Automotive Industry

The conventional automotive industry is under pressure both internally and externally as discussed in Section 4.2, Chapter 4, which including disruptive innovations and systematic changes. The original boundaries of the automotive industry are dissoluble owing to the characteristics of transformation and transition (Section 4.3, Chapter 4). In addition, the boundaries thereby are progressively shaping a space for the ‘new automobility industry’. The emergent automobility industry is not yet a strongly interlinked network or system of parts that positively reinforces the long-term viability of the whole in the manner that has served the automotive industry for so long. The micro-networks of relationships are formed in exclusive clusters initially in transition to a very inclusive format as discussed that is ‘five stages network reintegration’ in Section 4.4 Chapter 4 in a fluid and dynamic manner.

The diagrams in this chapter seek to illustrate the patterns of relationships formed in which this exclusivity emerges. Tables on each section list the relations that are encompassed by others. The flourish diagram shows the relations directly with colours. The redder and larger characters represent stronger relationships within the map and vice versa. It is a partial, incomplete illustration as cases are still going on while the cut-off point of data presentation is 31 July 2019. The data are incomplete in the sense that the relations created in between companies are never complete or finished, with new relationships still being formed. But the research has to set a stop point to commence the data analysis. Another reason is that the numbers of relations are gradually decreased since 2019, most relations have been built and tested before. It is probable that those relationships are deeper over time. In this respect it appears that the peak of new relationship building has passed, but sometimes such events are themselves cyclical. However, the framework used in this research can still be applied to new instances of network formation in this reconfigured automotive industry, so the approach is still valid. Also, it is impossible that all the data could be added due to the drawbacks of data mining methods, but still there is a sense that there are differences in terms of strategy and activity among the various vehicle manufacturers, and indeed those others that would be participants in the new automobility industry.

Notes: Guidance for tables in this chapter

1) Relations are shown between the main (above the table) and other companies. The ‘company’ column lists the picked company where the paralleled others are in the item column with names ***italic and bold***.

2) Dates represent the date of the news reported.

3) Item highlighted the joint technology development, or the covenant agreed between the protagonist above the table and ones listed under the ‘company’.

4) Relations listed around vehicle automation, electrification, vehicle/ride sharing, connectivity.

### 6.2.1 BMW

BMW had not shown a clear statement to create autonomous fleet by 2015, even though a few reports stated that it ‘will’ collaborate with the Chinese tech search engine giant Baidu. In that case, China would be the first place that is outside Germany for BMW driverless cars testing (Affan 2015). At the beginning of 2016, BMW, Mobileye and Intel had join force to build autonomous vehicles. Intel is responsible for chips and inner system operation while Mobileye is for sensors, mapping and navigation (Automotive News Europe 2016a). BMW group claims this action is to ‘develop the necessary solutions and innovative systems for highly and fully automated driving’ (BMW 2016). BMW lacked the knowledge to design computer processing chips needed to analyse dynamic data as generated by autonomous vehicles. As the performance of these processors is key to the performance of the vehicle itself, and hence vital to brand image, BMW needed a close alliance relationship for Intel to develop its technology specifically to BMW requirements. Later, BMW claimed that voice remote control will be equipped in the new generation system with the Alexa wireless service. With this approach, BMW enables its vehicles to connect with a home device and through it, voiceactivated remote control could remotely lock doors, check battery capability and the volume of petrol, which is another step forward for vehicle connectivity. At the end of 2016, BMW and IBM worked together for autonomous vehicles under AI supplementary driving system (Irwin 2016). BMW started its own self-driving business in 2017 with an investment of £100 million in the Czech Republic to build tracks for testing autonomous and electric vehicles (Randall 2019b).

In the domain of electricity powertrain vehicles, BMW is ambitious with a multi-dimensional expansion. BMW negotiated with other German automakers to co-construct an electric car charging system (Ionity) around the EU to boost their electric car business and expand the electric vehicle application range. In October 2017, BMW, Nissan, Renault, Volkswagen, Kia and Mitsubishi built a joint electric vehicle experience centre in Milton Keynes distributing electric vehicle (EV) knowledge with the assistance of UK government (Rory 2016). This showroom is accessible for people considering electric vehicle as their future transportation tools. The similar showrooms have also been displayed in US and China to accelerate the circulation of electric vehicles (Gibbs 2017). BMW also though to magnify capacity and storage on batteries, which can pertain on the next generation of EV models, hence it teamed with Solid Power to upgrade to solid-state batteries with ‘no flammable or volatile components’ that keeps the battery with higher capacity and safety (Manthey 2017; McDonald 2017). In 2018, BMW signed a 5-year contract with Ganfeng Lithium for supplying lithium hydroxide. CATL is another Chinese lithium expert company that invested $430m to join Brilliance led by BMW. Both contracts were signed with the Chinese battery supply company to guarantee a stable future of battery provision. The lithium supplements the R&D investment and investigation in battery storage and usage (Randall 2018a). BMW controls the value chain from pre-sale to after sale to enable a higher possibility and penetration of electric vehicles socially.

BMW also owns its vehicle hailing and sharing platform. In early 2018, BMW acquired DriveNow with £209 million from Sixt and DriveNow became a subsidiary corporation of BMW. Until now, BMW have dabbled in all four territories: autonomous, connected, electric and sharing. BMW later partnered with VeChain with the Startup Garage program using blockchain technology to contribute to the vehicle systems in the near future. In February 2019, a significant step was been taken between BMW and Daimler which is that Car2Go and DriveNow were merged to create five new joint ventures, ReachNow, ChargeNow (charging), FreeNow (ride-hailing), ParkNow (parking), and ShareNow (Hampel 2019a). The hostile relations ended with joint ventures and combined both benefits to compete against rivals' markets such as the fast-growing Uber. After the alliance with all peripheral companies, BMW and Mercedes put aside traditional rivalries, shared information and enhanced their capabilities to compete against the rapidly growing number of rivals. However, this alliance only breaks the boundary of 'share' part, rather the entire CASE concept. Notwithstanding, it is a further leap towards network dissolving and reintegration.

In July 2019, BMW cooperated with the Chinese Tencent conglomerate to implement new businesses around database centre operations and autonomous technology development. Establishing database centres in China is very popular in the automotive industry because data resources come into the centre from all the corners of China. China is probably the best place to collect data since the massive single market has millions of users. Additionally, the overall complexity of the traffic system is higher than many other countries. The difficulty and complexity in the traffic system could help develop and promote the existing automated system, so that a system could be applied in any other cities and circumstances around the world, if it works well in China (Cundy and Shepherd 2019).

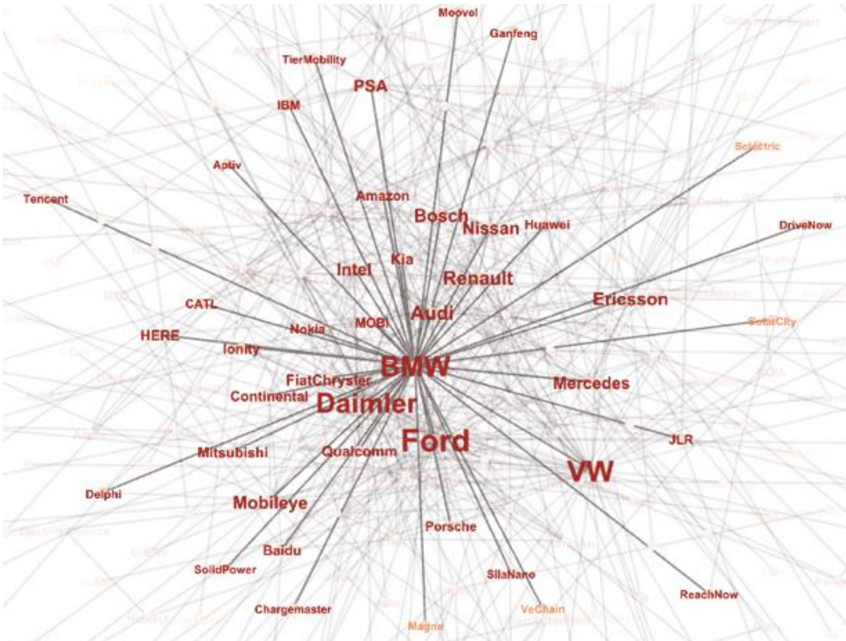
Table 16 below shows the major relationships built for CASE vehicles chronologically between BMW and its partners. The relationships have been assembled between BMW and ICT companies laying a good foundation of autonomous vehicle construction, which was the preliminary aim of the programme BMW focused on electric vehicle R&D and service platform investment mostly in later years.

***Table 16 BMW Network Distribution***

| Company | Date | Item |
|---|---|---|
| HERE | 04/12/15 | With ***Audi*** and ***Daimler*** acquire HERE from Nokia €2.55 billion ($2.8 billion) |
| Intel | 01/07/16 | Highly automated driving system |
| Mobileye | 01/07/16 | Fully autonomous vehicle without human interruption |
| SolarCity | 30/07/16 | Solar power on electric vehicle solution |
| Amazon | 30/09/16 | Home wireless voice connectivity Alexa |
| Daimler | 30/11/16 | And with ***Ford***, ***VW***, ***Audi*** and ***Porsche*** to build a CCS ultra-fast-charging network together alongside the European key highways around 400 locations |
| IBM | 15/12/16 | Driver-assist functions, machine learning, and IBM's Bluemix cloud platform |
| Fiat Chrysler | 16/08/17 | Joined BMW, Intel and Mobileye alliance for autonomous building |
| Magna | 10/10/17 | Joined BMW automated technology collection, also ***Aptiv***, and ***Continental*** |
| Chargemaster | 22/10/17 | With ***Nissan***, ***Renault***, ***Volkswagen***, ***Kia*** and ***Mitsubishi*** fund an Electric Vehicle Experience Centre in Milton Keynes, to spread electric technology which was partly funded by ***UK government*** |
| Solid Power | 18/12/17 | Solid-state battery cultivates with stable elements to keep safe and storage maybe double or triple |
| DriveNow | 29/01/18 | Sixt sold all shares of DriveNow to BMW with €209 million |
| Sila Nano | 20/03/18 | New generation battery with steady chemical segment |
| Ganfeng | 30/09/18 | 5-year lithium hydroxide provision contract signed |
| CATL | 30/09/18 | Invested 430 million dollars in BMW Brilliance joint venture |
| Daimler | 22/02/19 | Mobility services combining with BMW's and becoming 5 new joint ventures |
| Tencent | 26/07/19 | Speeding up for selling level 3 cars |
| Tier Mobility | 14/04/19 | Daimler with ***Moovel*** to create the JV for multi-model transportation service and solution |

Source: (Hillier 2015; Lunden 2015; Cremer and Sheahan 2016; Huetter 2016; Irwin 2016; Johnson 2016; Kurylko 2016; Rory 2016; Automobilwoche 2017; Gibbs 2017; Layson 2017; Manthey 2017; Sage 2017; Manthey 2018a; Randall 2018a; Randall 2018c; Cundy and Shepherd 2019)

In addition, Figure 6.1 clearly shows the BMW relations under the automotive industry surroundings. The redder and larger names in this diagram represent a stronger and more energetic relation in the entire automotive industry. In the case of BMW, it has the relation with a few other automakers e.g. Ford, Daimler and VW.




Source: Author

***Figure 6.1 BMW Relationship***

BMW announced its intention to commercialise autonomous vehicles by 2021. For doing so, the digital mapping business HERE has been acquired by Audi AG, BMW Group and Daimler AG from Nokia by €2.55 billion ($2.8 billion) to assist these automotive manufacturers to create 'high-precession digital road maps' on autonomous vehicles. This enables the vehicle to 'see through the buildings' to refine the interior navigation system. Not only the visualised features on the vehicle have been integrated such as vehicle mapping and navigation, but BMW also invests connectivity structures to enable vehicle become smarter (Hillier 2015; BMW 2019a).

Partnership is another way to acquire additional benefits from partners on the other side of the association. BMW has cooperated with IBM for autonomous vehicle controls by which it also benefits from the IBM Bluemix cloud platform in terms of machine learning and data exchange. BMW may also indirectly benefit from IBM’s investment. In 2016, IBM invested $200 million in the Munich Watson Internet of Things (IoT) headquarters to investigate further on automation, electrification and connectivity (Irwin 2016). However, BMW is not the only one who strategically connected with IBM. In the first half of 2015, Peugeot with IBM agreed to develop connectivity in-car services which link the vehicle to smart grids (Automotive News 2015); GM and IBM have created a new ‘cognitive mobility platform’ OnStar by using IBM’s Watson IoT service (GM 2016).

BMW has its final step forwards autonomous driving. Sokolov, a city near the German border in the Czech Republic, has been chosen to construct autonomous and electric vehicle testing tracks (Cremer 2017). Autonomous vehicle testing spots that can be chosen by automakers generally meet the following criteria: 1) in licence issued places, 2) supported by local government, 3) cheap and easy to run the test.

In 2019, BMW unveiled its future vision on transportation: D+ACES which are Designs for Autonomous Driving, Connectivity, Electrification, and Services. This is another interpretation of CASE with distinctive characteristics. BMW aims to construct future vehicle as a cosy space but leave the right of being a ‘driver’ in that the driver can take over the control anytime. In the new generations of vehicle systems, two modes are optional to switch mode manually to automatically: ‘Boost’ and ‘Ease’. It also has an interaction between vehicles and home, to the electric grid and to the Internet via voice command (Newspress 2019b).

BMW is a conventional automaker and challenging its capabilities constantly in the innovative areas. It realizes the necessity of technicians and engineers for future automobility so that BMW has invested large amounts of capital in battery capacity expansion and electric storage (Harrison 2016). BMW also focused on the customers’ driving experience, keeping the enjoyment of driving for drivers when designing L4-L5 autonomous vehicles. BMW is also a quick strategy responder that participated in the vehicle mobility service market at an early stage. It eventually breaks the cocooning automotive industry boundary to ally with other automotive manufacturers. This forward step perhaps is the primary stepping into the next phase.

### 6.2.2 Ford

Ford is one of the representatives in US automotive industry. It had a significant contribution to automotive history by creating the moving assembly line and parts standardisation with the classic Ford Model T. This time, it aims to challenge the transformation from the automotive industry to the automobility industry. Ford has a very aggressive but positive attitude and movement on innovative technology development and strategic relationship association. The history of Ford to develop its autonomous vehicle is very long and it can be traced back to the Defense Advanced Research Projects Agency (DARPA) autonomous vehicle challenges in 2004. Ford was one of the earliest teams to take the challenge. Since then, over 30 Ford Fusion Hybrid vehicles have been tested up till 2016. Ford Smart Mobility is a later formed project which contains vehicle autonomation mechanisms that push Ford forward to vehicle mobility, connectivity and automation from the consumer experience side. Ford has cooperated with Velodyne, equipping a Solid-State Hybrid Ultra PUCK™ into vehicle which reduced 4 sensors to 2 but maintaining the same amount of useful data (Ford 2015; Newspress 2016a; DARPA 2019). This sensor reduction could reduce the overall cost in building an autonomous vehicle. In 2016, Ford tested its autonomous vehicle in snowy weather, it is a technical challenge for autonomous vehicles to cope with extreme weather. In later 2016, Ford made another claim that autonomous vehicles for sharing and hailing could be available around 2020 to 2021 (Bunkley 2016). Ford has cooperated with new start-ups such as Civilmaps on crafting high-solution maps and LiDAR R&D for higher vehicle automation vision assistance. Toyota has a long-term relationship with Ford that dates back to 2011, and they recently worked on in-car telecommunication systems in the area of vehicle connectivity. Ford also has a long-term partnership with VW Group for electric vehicle platforms. In the autonomous vehicle race, Ford is on the front of the most competitors.

In June 2015, Ford launched an end-to-end project called EasyCar Club which offered a platform for privately owned cars to generate revenues on idle time. This project allowed potential users to access a vehicle whilst providing revenues for owners. This is a sharing prototype that allows vehicle to be shared within a system. However, this EasyCar Club only works for Ford owners who knew the sharing platform, revealing the largest limitation for business growth. Ford also tried a few times to cooperate with varied business entities such as StreetScooter and Domino's to expand into other vehicle types. The StreetScooter is not very popular for vehicle sharing and usage because of the running range limitation, lacking of privacy and location weaknesses. The partnership with Domino's raised another possibility for driverless vehicles for pizza delivery (Newspress 2017c). In August 2016, autonomous taxies were promised for the mass market by 2021 which contributes another new arena for the usage of autonomous vehicles (Bond and McGee 2019). Ford diversifies its strategy often to explore the possibilities of the new technology.

Ford invested a 5-year long-term program in Argo AI, a start-up company in the US specializing in artificial intelligence, with a total capital of $5 billion. At the same time, Ford entered partnerships with Vodafone to equip 4G Internet and WIFI through World Pass. Through World Pass, users can remotely lock doors, check miles, petrol, electricity, tyre pressure and the car location. Another specialised feature is to connect live traffic information and allow a new route when the selected route is busy. World Pass links users to cars and portable electric devices with vehicles and eventually the vehicle is connected with its surroundings so that live information is shared around to all connected IoT entities. These changes transform the function of connectivity from device-centric to cloud-based connection and distribution. In May 2018, Ford had a joint venture with Zotye, trying to combine electric vehicles with ride hailing collectively. This step catches up the Chinese market trend of ride hailing services under the political support of new energy vehicles.

A new competition begun at the January 2019 where Ford and VW have a long-term cooperation. Both companies aimed to construct autonomous vehicles and co-operated with Argo.AI. Like BMW, Solid Power with Ford also co-developed solid battery technology to improve functionality. Then in July 2019, VW invested $2.6 billion to Argo.AI again to strengthen this relationship. Argo.AI later announced that it would construct a self-driving research centre, by investing $15 million to ‘global deployment’ of fully driverless cars. This is an essential announcement from an AI technology company, because it shows their capability to explore autonomous driving technologies independently. Intel even earlier than Argo.AI built a research centre to help develop autonomous driving system and relevant technologies (Salesky 2019). The Ford-VW cooperation illustrates that even major manufacturers looked for partnerships and to dissolve pre-existing competitive boundaries to establish bilateral collaboration within the industry.

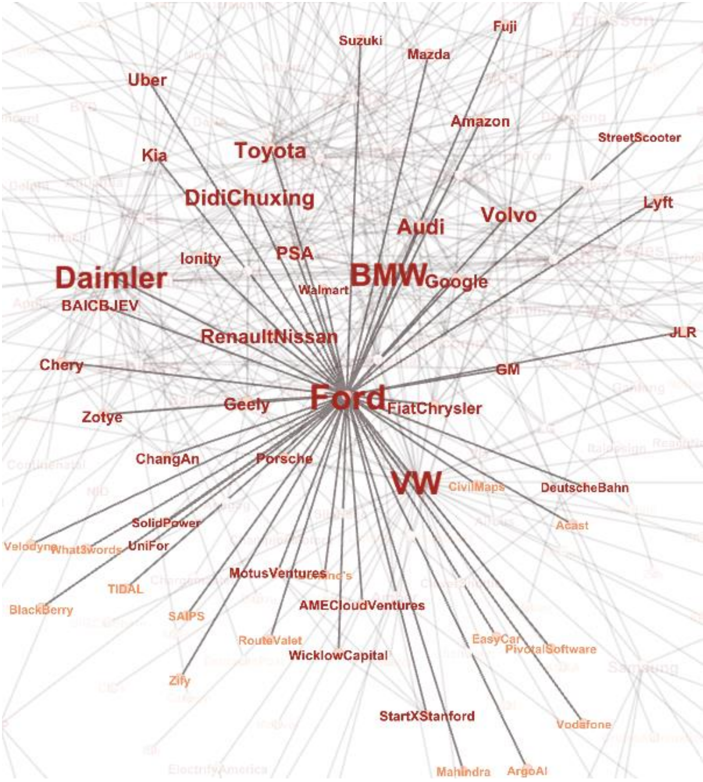
Ford has cooperated with the car sharing platform Lyft to expand an autonomous sharing service. Ford also joined Zotye, Zify and Deutsche Bahn in an alliance for vehicle and ride sharing services. The Table 17 lists the main activities of Ford and its partners, followed the Figure 6.2 of the virtualisation of network by Ford.

***Table 17 Ford Network Distribution***

| Company | Date | Item |
|---|---|---|
| Velodyne | 05/01/16 | Velodyne LiDAR sensor for autonomous system mapping, surrounding 3D model delineation |
| GM | 14/04/16 | Split on autonomous vehicle construction |
| Nirenberg Neuroscience | 17/08/17 | An exclusive licensing agreement with Nirenberg Neuroscience for human-like vision learning |
| Zotye | 29/08/17<br>02/05/18 | Electric vehicle hailing service<br>Set up for a new joint venture for electric vehicle ride-hailing, infotainment service |
| Pivotal Software | --/05/17 | $182.2 million investment for mobile application develop |
| Civil Maps | 15/06/17 | Ford with ***Motus Ventures***, ***Wicklow Capital***, ***StartX Stanford*** and ***AME Cloud Ventures*** invests $6.6 million for autonomous cars 3D mapping |
| SAIPS | 15/06/17 | Machine learning and surrounding adaption |
| Argo.AI | 10/02/17 | 5 years contract with an investment of $1 billion for artificial intelligence software on autonomous vehicles |

| | | |
|---|---|---|
| | 12/07/19 | $2.6 billion investment for acceleration the autonomous construction |
| Vodafone | 27/02/17 | New FordPass Connect and Wi-Fi in car capability |
| StreetScooter | 14/06/17 | Electric delivery van for Deutsche Post |
| Domino's | 29/08/17 | Self-driving pizza delivery |
| Deutsche Bahn | 12/09/17<br>& 2013<br>28/09/17 | With Ford Germany offering FordPass bike sharing service in Cologne and Düsseldorf.<br>2013 joint car sharing scheme<br>Electric van |
| Mahindra Group | 18/09/17 | Mobility, electrification, connectivity and product development, expanding India and other potential markets |
| Lyft | 27/09/17 | Self-driving service providing via Lyft platform |
| Zify | 09/11/17 | Carpooling, SYNC system awarded |
| Acast | 09/11/17 | SYNC system awarded, post cast design for customer |
| RouteValet | 09/11/17 | SYNC system awarded; journey planning integration private with public information |
| Walmart | 14/11/18 | Driverless car grocery deliveries test |
| VW | 15/01/19 | Future transportation, will invest $2.6 billion on Ford Argo AI |
| What3words | 26/02/19 | Redefine navigation accuracy with 3 words |
| TIDAL | 26/02/19 | Music stream with highest quality |
| Solid Power | 11/04/19 | Solid battery development |

Source: (Naughton 2016; Newspress 2016a; Wright 2016; CarAndBike 2017; Ford 2017; Goh 2017; Green Car Congress 2017; Newspress 2017c; Newspress 2017e; Newspress 2017a; Newspress 2017d; Newspress 2017b; White 2017; Manthey 2018c; Waldmeir 2018; Marshall 2019; Newspress 2019d; Newspress 2019c; Randall 2019b)




Source: Author

***Figure 6.2 Ford Network Map***

Ford has developed capabilities on autonomous vehicles and additional mobility-as-a-service offerings, and it has diversified the service to explore the potential possibilities in working with different companies such as Domino’s, Walmart, Deutsche Bahn mail delivery and StreetScooter. According to the listed data, Ford is one of the most diversified companies to deploy the functionality of autonomous vehicles. Indeed, one of the initial aims to have autonomous vehicles is simplifying the current transportation system and diversifying mobility usage. Ford aims to achieve autonomous vehicle adoption, distribution, and deployment. Autonomous vehicles from Ford have also been tested in a few cities in America under extreme weather. Ford has constantly developed vehicle electrification, connection and sharing, and eventually these features may integrate as one. Ford has a unique way to reach the ultimate driverless car with socially-associated vehicles.

### 6.2.3 Daimler

Daimler (Mercedes) provides CASE (Connected; Autonomous; Shared & Service; and Electric) concepts to challenge the new business strategy and models in the automotive industry. It opened a new arena that the possibilities of all concepts could be integrated. Daimler aims to start a 'true revolution' by 'combining them (i.e. CASE) in a comprehensive, seamless package'. This novel pattern is based on vehicle electrification and bundled with new technologies, such as connectivity, autonomous driving and service packages so that it mitigates burdens for drivers, society and the wider environment (Daimler 2016).

Daimler has owned ride sharing companies including Mytaxi, Car2Go (now with BMW) and RideScout, since 2014. Daimler pushed vehicles to the sharing market to switch its role from a vehicle maker and seller to a vehicle service provider. In April 2017, Daimler announced that it would cooperate with Porsche to produce an autonomous taxi at the beginning of 2020, aiming to improve route optimisation, minimise pollution and reduce traffic jams. Daimler also invested $60 million in StreetDot, $250 million in Via and several car sharing companies. In addition, Daimler acquired shares in Chauffeur Privé, a French online car sharing company which is similar to Uber. Daimler has expanded its ride and vehicle sharing service market by different M&A arrangements worldwide. In February 2019, BMW and Daimler integrated their mobility service operations to defend against the emerging rivals such as Uber, as noted above. Daimler has two different strategies to participate in car sharing markets: the first one is to merge and acquire a ride/car sharing company to expand market share such as in Europe, the Middle East and North America; another one is to control self-owned brands (Daimler 2017a). In terms of different markets, different strategies are required. The former strategy is quicker to conquer unfamiliar overseas markets, it is less time-consuming but costly. The latter self-owned brand is more onerous but it could acquaint Daimler with the market conditions when it grows. A key problem for all the vehicle manufacturers has been to assess the true extent of the market opportunity, and then to construct the 'best' way to access that opportunity. So, the Daimler example is illustrative of a general trend of business model experimentation in sharing markets. Many such attempts have been unsuccessful (see Wells et al., 2020).

Daimler tested E Series autonomous cars on the road in Nevada at the beginning of 2016, with a system equipped for deep learning and self-parking. At that time, however, the sensors were not working well under extreme weather i.e. snowing and raining days (Automotive IQ 2016). In April 2016, Moovel was acquired by Daimler, and that brought the opportunity to solve the last mile problem. Moovel was piloted in the Stuttgart area in 2012 and expanded to 11 cities until 2017. The Moovel app could automatically match the local bus and train connections to ‘offer user-oriented solutions’ (Daimler 2017b). In 2017, Daimler announced a long-term goal that ten models of electric vehicles models will be produced before 2025 which will take 15%-25% of the overall sales. Daimler is a world leader in trucks, so it accesses vehicle electrification not only on passenger vehicles, but also on trucks, light commercial vehicles, and buses. With trucks the experimental range has been expanded up to 220 miles in 2017 and electric school bus could have up to 100 miles in running range (Lambert 2017a). Semi-electric trucks such as the eCascadia have been promised for the market with up to 250 miles range and with a fast charging taking 90 minutes to reach 80% capacity (Lambert 2018). Daimler has also heavily invested a research centre to investigate overall electric vehicle functionality. For instance, it spent around €500 million ($589 million) to expand an electric car factory in Hambach, France (Daimler 2018) for the Smart car.

Daimler has a very close relationship with Chinese car manufacturers. It co-runs a joint venture with BYD since 2018 called Denza New Energy with RMB400 million investment from both parent companies. This joint venture was just established at just the right time for Chinese market as the stimulative policy ‘New Energy Vehicles’ was launched in China (Chiu 2018; O’Meara 2020). Another collaboration with a Chinese car manufacture is with Geely that aims to co-develop a car sharing service starting from October 2018. Table 18 shows that the major activities taken by Daimler since very beginning of 2012.

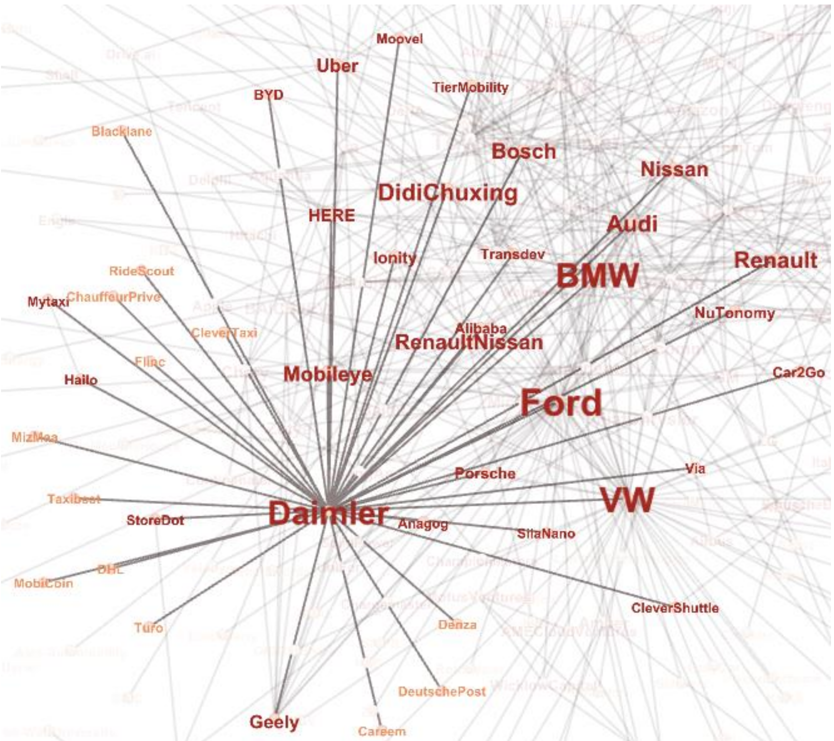
***Table 18 Daimler Network Distribution***

| Company | Date | Item |
|---|---|---|
| Moovel | 11/07/12<br><br>04/10/17 | Mobility service company lunched in U.S<br><br>Full shares acquisition to strengthen its ride sharing competition in the US |
| RideScout | 04/09/14 | Moovel acquired it to expand ride hailing |
| Mytaxi | 04/09/14 | Acquired by Daimler as a subsidiary corporation |
| HERE | 03/08/15 | ***BMW***, ***Daimler*** and ***Audi*** purchase HERE £2 billion preparation for autonomous mapping |
| Deutsche Post | 25/07/16 | Smart will help deliver posts |
| Blacklane | 01/08/16 | An investment more than €10 million ($11 million) a smartphone application based online platform |
| Bosch | 30/08/16<br><br>04/04/17 | With ***Car2go***, joint to design smart car parking system where car could self-parking if driver park in a designed area<br><br>Develop a self-driving taxi system by 2020, also partnership for L4 autonomous vehicles |
| Hailo | 26/07/16 | 60% shares owned by Daimler |
| Car2Go | 30/01/17 | Daimler start to luxury car sharing in US five cities |
| Clever Taxi | 22/06/17 | Romania taxi sharing bought by Daimler |
| Taxibeat | 22/06/17 | Greece vehicle sharing, also with another company ***Pinnington***, acquired by Daimler |
| CleverShuttle | 11/07/17 | Daimler's ***EvoBus*** conducted a minority investment on CleverShuttle mobility service |
| Turo | 06/07/17<br><br>06/09/17 | Turo acquired ***Croov***e, while Daimler invests Turo series D funding<br><br>Co-building a peer-to-peer car sharing platform |
| Careem | 15/06/17 | A large amount investment to this Middle East car-hailing company |
| StoreDot | 14/09/17 | Daimler invests $60 million to StoreDot, also in FlashBattery technology which will apply in the electric vehicle chargings |
| Flinc | 28/09/17 | An acquisition of Flinc peer-to-peer carpooling platform with an outstanding navigation system |
| Via | 28/09/17 | Shuttle-like ride sharing scheme |
| Ionity | 06/11/17 | A joint venture by ***BMW***, ***Daimler***, ***Ford***, and ***Volkswagen*** over an ultra-fast charging network |
| Privé | 22/12/17 | A majority of stake acquired from Privé, a French car/ride sharing online service |

| | | |
|---|---|---|
| Geely | 24/02/18 | Geely bought $9 Billion 9.7% share of Daimler |
| Anagog | 26/02/18 | Daimler with ***MizMaa***, a behaviour analysis software and sensor maker for autonomous vehicles |
| MobiCoin | 06/03/18 | A blockchain-based cryptocurrency to encourage eco-friendly driving |
| Denza | 05/06/18 | Joint venture with ***BYD***, each side invests 400 million yuan ($62.5 million) for electric car new model |
| BMW | 22/02/19 | All services integrated to form being force new joint ventures on parking, charging, sharing, multimodal transportation areas |
| Sila Nano | 16/04/19 | Collaborating with ***Moovel*** expanding its electric scooter business |

Source: (Green Car Congress 2012; Hillier 2015; Automotive IQ 2016; Behrmann and Weiss 2016; Lunden 2016; Nicola 2016; Automotive News Europe 2017a; Bergin 2017; Bosch 2017; Brown 2017; Daimler 2017c; Daimler 2017b; Edelstein 2017; Edelstein 2017; Lunden 2017a; Lunden 2017b; Muoio 2017; Reader 2017; Sawers 2017; Stumpf 2017; Automotive News Europe 2018a; Daimler 2018; Nicholson 2018; Reuters 2018; Hampel 2019a; Hampel 2019c)

Figure 6.3 is the relationship diagram which demonstrates all connections of Daimler with other business corporations. It shows that Daimler has a relatively uniform number of relations with the car manufacturers, service platforms and ICT companies. It distributes the CASE concepts very carefully and well.



Source: Author

***Figure 6.3 Daimler Network Distribution***

There are mutually beneficial synergies between connectivity, autonomous technologies, sharing of vehicles and electric vehicles. However, two fundamental issues for this CASE strategic need to be carefully addressed. First, some elements in CASE are outside the automotive industry which requires traditional automotive manufacturers to embrace new concepts constantly and frequently. The construction and maintenance of such 'constellations' of mutual interest has been more challenging than anticipated. Second, the CASE concept did address the pre-issues in the process of making vehicles more sustainably while it does not directly address the growing pressures to adopt circular business models in the context of a more general circular economy.

### 6.2.4 Volkswagen

VW strategy called 'TOGETHER 2025+', which aims to 'make the automobile cleaner, quieter, more intelligent and safer' (Volkswagen Group 2020). It combined vehicle digitalisation, sustainability, mobility and safety. To some extent this strategy emerges as a result of the 2015 diesel emissions scandal in the US, meaning that VW Group had to undergo a process of reinvention. It is a risky strategy in that if the company is again found to have lied to regulators and consumers, the entire strategy will appear as 'greenwash'.

VW has a long history exploring vehicle autonomous and connectivity features. In July 2016, LG and VW signed the memorandum of understanding to investigate autonomous and infotainment functions. At the beginning of 2017, VW cooperated with NVIDIA to equip AI technology in autonomous vehicles. It also worked together with Mobileye to run data collection and route analysis. In June 2018, to stimulate autonomous technology commercialization in the mass market, a powerful alliance has been established by members of VW, Continental, Nvidia, Bosch and Aquantia which was named NAV Alliance. This alliance is more focused on in-car and Internet connectivity, especially in a highly autonomous environment (Krok 2018; NAV Alliance 2018). The NAV alliance contains all aspects expertise for constructing autonomous vehicles by which VW would build an automotive industry standard. Later, VW cooperated with HERE for building precision and advanced maps, and with Ionity to build fast-charging stations (along with other manufacturers such as Ford and Hyundai). At the beginning of 2019, VW established Elli in Dublin which aims to address electric vehicle transport. VW partnered with Microsoft to expand an automotive cloud to Europe, China and America, also having a vehicle connection project Lighthouse. Working with Microsoft, it announced its transformation from mobility maker and supplier to a service connector. The connectivity, digitization and Cloud based Azure platform will be a part of Internet of Things (Volkswagen Group 2018a) to build a 'Volkswagen ecosystem'. Service can be provided through the cloud and telematics, in a service-user-cloud information exchange. VW sometimes is very aggressive: For example, it bought 75 percent stake in Volvo's Wirelesscar unit with € 110 million (Hetzner 2019) to strengthen the in-car connectivity features.

In terms of vehicle mobility services, VW owns an individual new mobility service, robotic taxi and vehicle sharing company, MOIA. MOIA launched an electric minibus instead of normal cars for electric vehicle hailing and ride pooling services (Rauwald 2017). Gett is an Israel on-demand ride-hailing service company that got one of the biggest investments from VW. VW invested $300 million into Gett in 2016, at that point Gett owned the biggest market share in New York and London. VW also invested in the GIG Car Share service in early 2019. This GIG programme is a new business model with a free-floating package where cars can pick up and park anywhere within 13 square miles of range (Randall 2018b). New Mobility is a joint venture between Mobileye and VW, also with a local partner Champion Motors, to deploy Mobility-as-a-Service in Israel. Israel's local government also contributed to addressing legal issues, local infrastructure and data if necessary. This attempt started in early 2019 and was expected to commercialize in 2022 (Manthey 2018e).

VW has strongly encouraged start-ups to address the emerging technical issues. The Incubator programme is the one that was invested by VW since 2002. In 2018 VW selected 6 companies to support, which covers all essential components of future transportation development including future charging solutions, battery capability and durability, sharing platforms and relevant services, sensors, and software for self-driving systems (Werwitzke 2017).

Table 19 lists the major activities that were taken by Volkswagen. VW invests many excellent start-ups for autonomous vehicle exploration and vehicle electrification investigation which are shown in Figure 6.4.

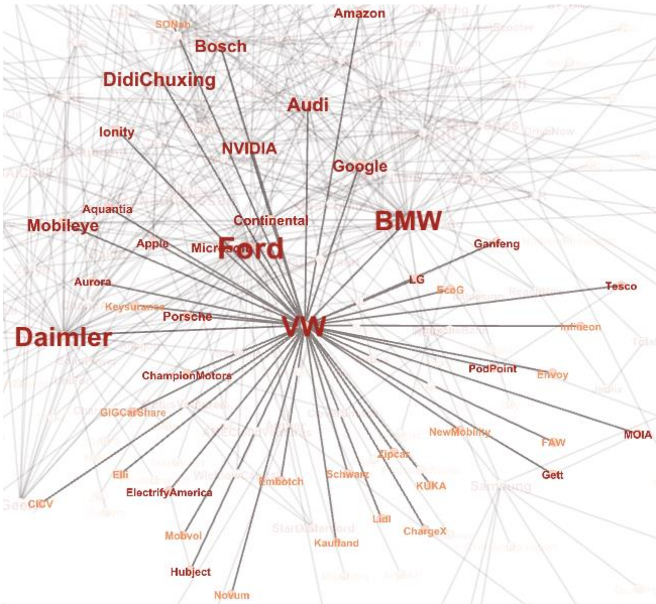
***Table 19 VW Network Distribution***

| Company | Date | Item |
|---|---|---|
| Gett | --/05/16 | $300 million investment strategic partnership for ride hailing scheme |
| LG | 06/07/16 | A joint venture to build an application platform for vehicle connectivity, electronic batteries |
| MOIA | 05/11/16 | Different strategy for business connected commuting pooling scheme |
| Nvidia | 05/01/17 | Cooperate with 12 branches using AI technology |
| Mobileye | 13/02/17 | Create ‘super navigation’ data collection method preparing to launch new autonomous vehicle |
| Mobvoi | 06/04/17 | In-car AI application, VW invested $180m |
| KUKA | 10/07/17 | A research collaboration for innovative automation R&D |
| Ionity | 06/11/17 | A joint venture by ***BMW***, ***Daimler***, ***Ford***, and ***Volkswagen*** over an ultra-fast charging network |
| Google | 07/11/17 | In various areas e.g. machine learning, new battery materials, quantum computing, AI |
| ChargeX | 12/12/17 | And other five start-ups been chosen as VW’s incubator programme. ***Keysurance***, ***EcoG***, ***S O Nah***, ***Embotech*** and ***Novum*** |
| Aurora | 05/01/18<br>11/06/19 | Team for autonomous share solution in cities Mobility-as-a-Service<br>Relation breaks up and turns to ***Ford Argo AI*** |
| Envoy | 14/06/18 | A car sharing scheme around low-income apartment area |

| | | |
|---|---|---|
| Bosch | 26/06/18 | With ***VW*** and other three, ***Aquantia***, ***Continental*** and ***Nvidia*** to establish Networking for Autonomous Vehicles (NAV) Alliance. |
| FAW | 10/07/18 | Working with a Chinese company to co-develop autonomous, connected and electric technology and vehicle |
| Microsoft | 02/10/18 | Azure established a foundation for new connective and autonomous system |
| New Mobility | 30/10/18 | A JV with Mobileye, ***Champion Motors*** also take part in this team. Mobileyes is responsible for autonomy and VW for electric vehicle offering, contributing for MaaS, autonomous electric vehicle sharing |
| Tesco | 30/11/18 | Ally with ***Pod Point*** for charging bays network building near Tesco Extra and other parking space, UK |
| Elli | 08/01/19 | Renewable energy source offer and smart charging solution |
| Ford | 15/01/19 | Future transportation, $1.7 billion planning investment on Ford Argo AI and electric vehicle |
| FAW-Volkswagen | 19/03/19 | ***MOSI*** as a JV operate connective intelligent digital service over VW consumers, form a data-based business model in Chengdu, China |
| Ganfeng | 06/04/19 | Strategic partner on supplying Lithium, also work together for battery recycle |
| Infineon | 10/05/19 | Joining VW supplier network FAST (Future Automotive Supply Tracks) and in the charge of semiconductors |
| Schwarz | 19/06/19 | Charging points installation to expand its WeShare program |

Source: (Newspress 2016b; Volkswagen Group 2016; Campbell and Sender 2017; Stumpf 2017; Volkswagen Group 2017b; Volkswagen Group 2017a; Volkswagen News 2017b; Werwitzke 2017; Davies 2018; Manthey 2018e; Newspress 2018c; Randall 2018b; Sheahan 2018; Volkswagen Group 2018a; Bond and McGee 2019; Infineon 2019; Newspress 2019d; Randall 2019f; Randall 2019e; Volkswagen News 2019)

From the Table 19 and Figure 6.4, VW shows a very strong ability and ambition in exploring autonomous features with various departments, it also intensely supports the start-ups who are capable of dealing with the newest technical issues. The ‘Diesel Gate’ scandal forced VW to transform its business strategy to other options, including vehicle electrification and connectivity utilities. Nonetheless, the scandal can be seen as an opportunity which pushed VW closer to the global sustainability trend.




Source: Author

***Figure 6.4 VW Network Distribution***

### 6.2.5 Volvo

Volvo originates from Sweden, which is not a major automobile production country, but it is imbued with Swedish values on sustainability issues. Volvo as a brand is focused on function of safety and aims to build the safest vehicles in the world. This protocol is also applied when it constructs autonomous vehicles. For autonomous vehicles, safety is the priority compared to all other functionalities as discussed before, the mistake tolerance for machines is much lower than human beings. An important starting point in terms of autonomous car technology for Volvo has been the long-established relationship with Tier 1 supplier Autoliv. This relationship helped form the basis of the joint venture business announced in September 2016 for which the CEO Hakan Samuelsson said: “By combining our know-how and resources, we will create a world leader in AD software development. This means we can introduce this exciting technology to our customers faster.” (Volvo 2016b).

Volvo also claimed to sell fully-autonomous vehicles in five years from 2016. Volvo is keen to develop autonomous technologies and in-car and vehicle-to-vehicle connectivity. As Volvo head of R&D Henrik Green claimed, “There is no single player who can do all aspects of this all by themselves," Green said, "therefore it is the collaborators that will win this race" (Bolduc 2018b).

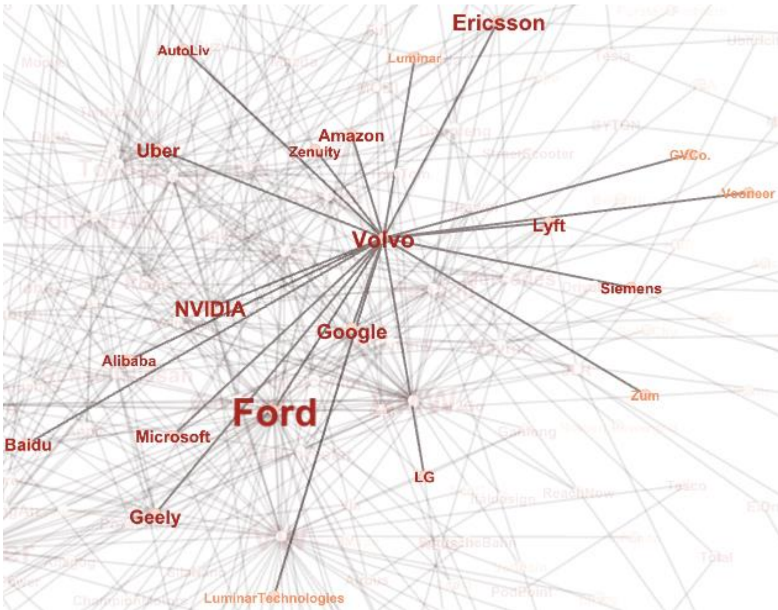
Table 20 provides a summary of these relationships for Volvo and Figure 6.5 shows the independent relationships between Volvo and other partners under a wider context. The listed items in the table show that Volvo invested more on autonomous technology and infotainment.

***Table 20 Volvo Network Distribution***

| Company | Date | Item |
|---|---|---|
| Siemens | 31/08/11 | Joint development of electrical drive technology, power electronics and charging technology as well as the integration of those systems into Volvo C 30 Electric cars. Models shown in 2014. In 2013 the two companies showed a novel superfast charger. The PHEV XC90 in 2016 used Siemens electric motors. |
| Polestar and Lynk & Co. | 14/07/15 | Owned 100 percent by Volvo, later became joint ventures with Geely for development and sale of electric vehicles |
| Microsoft | 05/01/16 | Voice remote control via Microsoft Band 2 |
| Uber | 18/08/16 | Combined US$300m investment in autonomous technologies |
| Autoliv | 06/09/16 | Set up a joint venture company with Autoliv to accelerate the development of advanced driver assistance technologies and autonomous car technologies. |
| LG Electronics | 04/11/16 | Propose (not verified) to enter into wide-ranging agreement for the co-development of components and systems for electric cars and autonomous cars. |
| Zenuity | 27/06/17 | The JV with ***Autoliv***, along with ***Nvidia***, plan to develop software systems for self-driving cars; to develop systems that use artificial intelligence to recognize objects around vehicles, anticipate threats and navigate safely. |
| GV Co. (China) | 04/08/17 | The JV of ***Geely*** Holding and ***Volvo*** cars, can benefit from technology synergy between platforms also with ***LYNK & CO***, a company also owned by Geely born for connectivity and share vehicle technology |
| NVIDIA | 10/10/18 | Deepen the collaboration for L4 automated driving |
| Baidu | 01/11/18 | Mass production and commercialision of self-driving electric vehicles in China by 2025 |
| Luminar | 27/11/18 | Achieved a huge development in Lidar technology on seeing and detecting objects |
| Ericsson | 29/11/18 | Connected vehicle cloud enhance Volvo digital online service |

| | | |
|---|---|---|
| Zūm | 01/03/19 | A ride-sharing service only for school children based on AI, algorithms road mapping |
| Veoneer | 19/06/19 | Develop autonomous vehicle further with Volvo |

Source: (Global Newsroom 2011; Volvo Cars 2015; Newspress 2016c; Seung-hoon and Chang-young 2016; Volvo 2016a; Volvo 2016b; Bolduc 2017; Global Newsroom 2017b; Bolduc 2018a; Browne 2018; Ericsson 2018; Volvo 2018; Newspress 2019e; Vaish 2019)




Source: Author

***Figure 6.5 Volvo Network Distribution***

Volvo Cars became part of the Geely Group (China) in 2010, having been sold by Ford. Volvo since could acquire dual benefits from both its original home market and also the Chinese market. This benefit means Volvo could easily collaborate with local Chinese companies such as Baidu. In addition, Volvo started its journey with connectivity and autonomous vehicle technique exploration, but it joined the vehicle sharing service later than many other participants.

### 6.2.6 Nissan

Nissan Motor Co., Ltd. is a Japanese automaker, is a part alliance of Renault-Nissan since 1999, while Mitsubishi Motors joined the Renault-Nissan transatlantic alliance in 2016. This alliance is a cross-country alliance over France and Japan.

Nissan collaborated with Foster+Partners in 2015 which is a British innovative architectural design and engineering firm, who worked with Nissan to make a ‘smart home’ programme. Nissan aims to link the home with vehicles so as to treat vehicles as an extension of the domestic space and build a seamless transition from home to mobility (Howarth 2016). An advanced concept of self-charging Witricity after self-parking was introduced. In this concept, the ‘smart street’ is part of a ‘smart city’ that links a personal home to the city grid. This connectivity idea could be traced back to 2012 when NissanConnect was introduced onboard. The NissanConnect remote application control conduct services via smartphone such as vehicle lock and open, battery check, and maps & live traffic which could track and navigate personal vehicle anytime anywhere.

Nissan took part in the autonomous vehicle race as well. In 2015, Nissan invited an anthropologist to study the impact of autonomous vehicles on society and possibility of commercialisation in autonomous vehicles. It is the first automobile company, through anthropogenic science, to investigate the impact of autonomous vehicles on society. It is worth noticing that this anthropology plays a central role in the design of autonomous vehicles. Nissan believed that machines should be able to learn like a human being, knowing human mental processes so as to deal with a scene. Nissan launched the ProPilot programme on a semi self-driving pilot system which can follow the car with the same speed ahead. This was the first step that Nissan aimed to build autonomous vehicles. Later, a fully autonomous vehicle with ProPilot technology was tested on Tokyo’s street. Nissan announced 10 highly autonomous models that will be launched on the market by 2020 (Automotive Fleet 2016; Lavars 2017; Financial Times 2019). However, financial crisis and managerial chaos followed the enforced departure of then-CEO Ghosn, and many Nissan plans have been abandoned or postponed.

Transdev is a French based mobility solution company which marked the future of transportation acronym as P.A.C.E. -- Personalised, Autonomous, Connected and Electric. It has collaborated with Nissan to solve future issues around all these technologies. The difference of this slogan with CASE is personalization instead of sharing. The personalization here refers to a flexible content on a standalone platform to address issues of individualisation. The idea serves the first and last mile transition, also with autonomous shuttles in assigned cities (Automotive News Europe 2017b; Mallet 2017). To be sure, it is a good solution that made PACE commercially and commonly available even though within a controlled area. It may work well in Japan as this is a country that focuses highly on privacy. A personalized mobility is not only on a flexible platform, also means a highly private space. Since the vehicle offers a mobile private space, it is relatively difficult to share with others particularly those you are not familiar with. It is worth noticing that even though Nissan enters the CASE competition a bit late, it owns typical cultural characters such as Personalisation in 'PACE', and Nissan Leaf.

On the area of sharing, Nissan has its 'Get & Go' programme which requires potential users to link an account to its mobile application, which is capable of detecting the user's habits. 'Choimobi Yokohama' is another electric car sharing scheme which allows users to pre-order vehicles in advance, and pick up and return vehicles within the Yokohama city. However, this three-year-trial programme has not been extended to another cities in Japan. This is another new advanced trial – autonomous taxi was operated in Tokyo (Campbell 2016; Global Newsroom 2017a; Tajitsu 2018; Nissan News 2019).

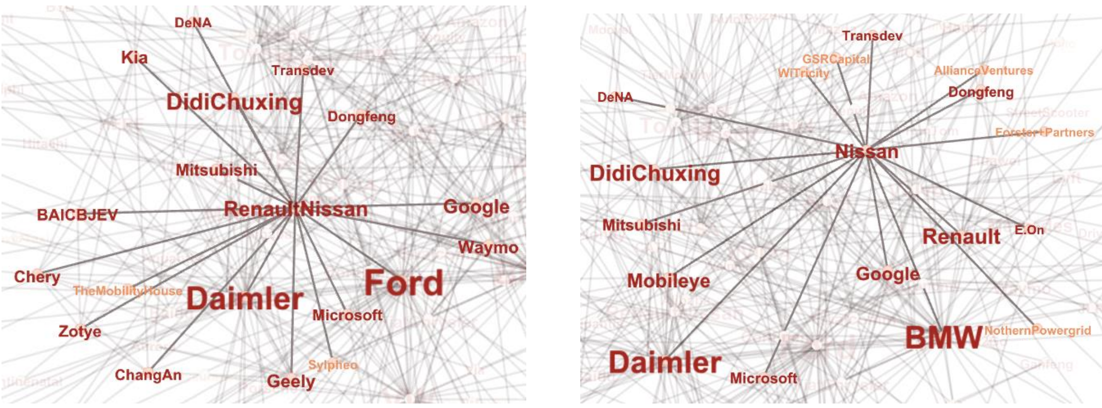
The Table 21 displays the all the relations on Nissan including relations around Renault-Nissan Alliance and Renault–Nissan–Mitsubishi Alliance with other companies aiming to build autonomous vehicles.

***Table 21 Nissan (Renault-Nissan/ Renault-Nissan-Mitsubishi) Network Distribution***

| **Company** | **Date** | **Item** |
|---|---|---|
| Foster + Partners | 11/03/16 | 'Smart street' system and "vehicle-to-grid system" |
| Sylpheo | 20/09/16 | An acquisition from Renault-Nissan, a step forward to vehicle connectivity and mobility service |
| Microsoft | 06/01/17 | Microsoft's Azure cloud helps data collection |
| WiTricity | 09/02/17 | Wireless EV charging |
| Transdev | 27/02/17 | Offering innovative, connected mobility solutions for driverless system |
| Collaborate Partnership Board of the International Transport Forum (ITF) | 05/04/17 | Collaborating with other members to address decarbonising transportation and relevant policy |
| Northern Powergrid | 24/05/17 | A six-year contract signed to explore electric powered innovation project |
| Dongfeng | 29/08/17 | A joint venture established with Renault-Nissan on eGT New Energy Automotive |
| GSR Capital (China) | 29/08/17 | Nissan's energy subsidiary Automotive Energy Supply about $1 billion |
| DeNA | 23/02/18 | Future driverless vehicle connection system to be established in Japan by 2020; Easy Ride service tests (driverless taxi) in Tokyo |
| E.On | 06/03/18 | A strategic partnership for energy decentralisation and system integration |
| Didichuxing | 24/04/18 | Electric sharing program in China with Renault-Nissan-Mitsubishi alliance |
| Google | 18/09/18 | Onboard intelligent infotainment Google assistance system e.g. map, Google Play, Alliance Intelligent Cloud data on cloud exchange on Renault, Nissan, Mitsubishi vehicles; also, for autonomous taxi development |
| Alliance Ventures | 05/11/18 | Renault-Nissan-Mitsubishi alliance's joint venture capital |
| Waymo | 20/06/19 | Self-driving mobility service |
| The Mobility House | 27/06/19 | Investment from Alliance Ventures, for battery, charging and storage solution |

Source: (Garcia 2016; Howarth 2016; Automotive News Europe 2017b; Bass 2017; Krivevski 2017; Newspress 2017g; Newspress 2018b; Newspress 2018a; Tajitsu 2018; Werwitzke 2018; Bigelow 2019; Newspress 2019a)

The Figure 6.6 (a) shows the relations between Renault-Nissan and other business groups, while 6.6 (b) only shows the relations for Nissan. Notwithstanding, relationships between Renault-Nissan and Nissan are partially overlapped, but the business strategy is different. Renault-Nissan has more relations with automobile manufacturers for international manufacturer cooperation and market expansion such as Dongfeng, Geely, ChangAn and Ford. It also cooperated with the sharing platform DidiChuxing and Waymo in the autonomous vehicle area. Nissan itself has more aggressive projects on vehicle R&D connectivity functions and an electric innovation project. For instance, the collaboration with Powergrid is a way to explore new possibilities and future sustainability. "…Building on what we are already doing around innovation projects, this signals the start of a ground-breaking industry partnership to explore new innovations that could support the creation of smarter, greener energy networks and help shape future technologies to support the efficient roll-out of electric vehicles." Jim Cardwell, head of trading and innovation at Northern Powergrid.



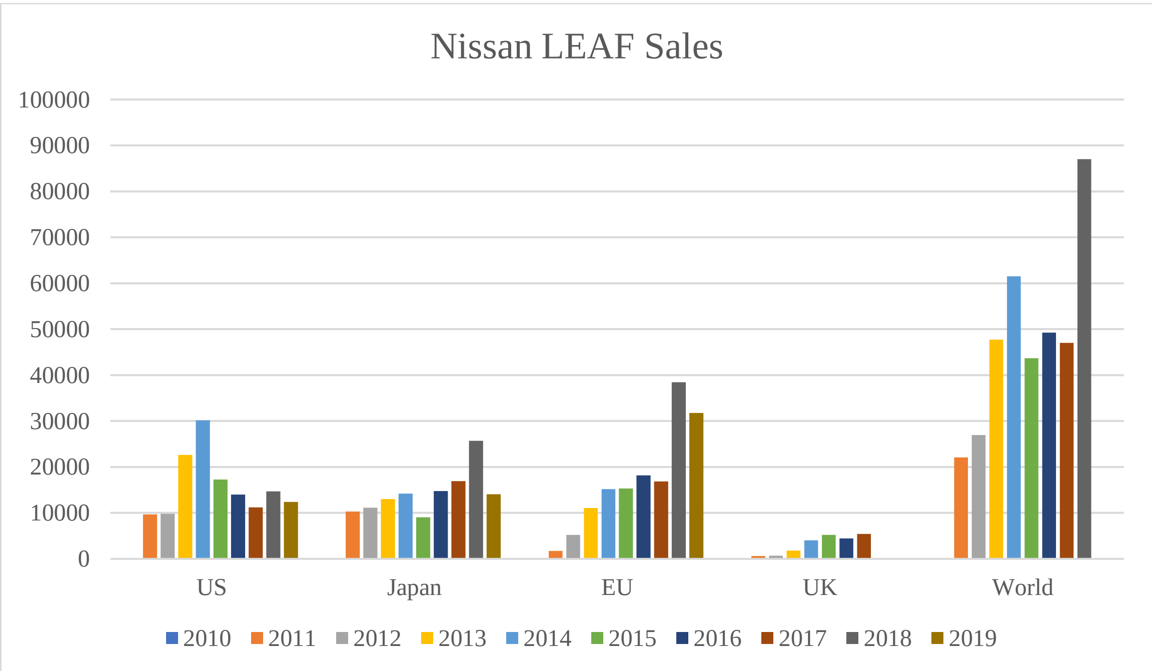

(a) (b)

Source: Author

***Figure 6.6 Nissan and Its Alliances***

Nissan has many successes and forward-looking ideas that combined with local constrained policy. The Leaf model is one of the outstanding examples, it often ranks on the top of electric vehicles sales even compared with Tesla. Nissan entered the market earlier than other companies. The 'Nissan Green Programme' was launched in 2010. In 2017, the second generation of LEAF debuted, meanwhile Leaf e+ with additional 40% range has come to market. In the March 2019, Leaf achieved its milestone of hitting 400,000 sales globally (Nissan News 2019). The Nissan Leaf can charge eighty percent of battery in 30 minutes through fast charging. The popularity of the Nissan Leaf not only relies on the global markets such as Scandinavia and US, the domestic contribution also cannot be neglected (see Figure 6.7). This great achievement benefits a lot from Japan's policy: Japans' government highly values sustainability and energy saving. This forces vehicle manufacturers to develop new energy powered vehicles (Techrunch 2016; Nissan Leaf 2019).

Japan, the US and the EU are the main areas selling Leaf. As Figure 6.7 shows, the US is the largest market for Leaf outside Japan. Therefore, Nissan undertook a 'No Charge for Charge' promotion to improve US market share from July 2014. In 2016 Nissan's Phase II promotion initiated an additional 11 markets with 38 markets in total joining this free of charge promotion for new users, to contend with the local business such as Tesla.




Source: (EU Leaf Sales 2019; Kane 2019b; Kane 2019a)

***Figure 6.7 Nissan LEAF Sales***

To further boost its market, Nissan promotes many activities such as ‘free to charge’ schemes and building infrastructures, targeting to meet different markets. The new semi-autonomous technology ProPilot was released in the Japanese and European markets first, then expanded to the US and China markets later (Techrunch 2016). For the European market, Nissan released its special ‘2.ZERO’ version with four main missions: additional infrastructure investment, battery charging and storage capability, bi-directional charging technology (xStorage) for free power and new electric passenger cars and vans. Additional offers include double charging velocity (now 5.5 hours for full charge), faster home charging, surplus charging station expansion through collaboration with CHAdeMO (the Japanese charge standard, able to support bi-directional charging). For UK consumers Nissan offers discounts for selling ‘back’ of electricity if they buy xStorage home energy units (Newspress 2017f). Nissan Leaf sales were estimated to reach 100,000 by the very end of 2019 (EU Leaf Sales 2019).

Nissan with its specific strategy seized the first mover opportunity in the electric passenger car market, with Japanese high quality and mature technology over the past decade. The contribution of Nissan is not only on the electric powered engine vehicle, it also conducts connectivity via vehicle-to-smart phone, vehicle-to-home, even vehicle-to-street and city linkages. In addition, Nissan launched a self-driving system with electric powered vehicles and floating shared schemes for cities. It also expanded the alliance partnership out of the inner circle of Renault and Mitsubishi, to include Daimler, AvtoVAZ in Russia and China's Dongfeng group to step into autonomous vehicle competition. The drawbacks of this is that all these companies are conventional automakers, which limited Nissan’s ability to develop integrated vehicles. These companies hunt for partners because ‘…there are areas where we don't have visibility, one of the partners will…’(Greimel 2018).

Eventually, Nissan has a vision "…that would bring an edge to connectivity, to electrification, to autonomous driving," and "…partnership has the advantage that you link with someone who has the capability." said by Catherine Perez, a corporate vice president in Nissan (Greimel 2018)

### 6.2.7 Hyundai

Hyundai is one of the rapidly growing automobile manufacturers in the world, it is active in the most important markets in China, the US, India, and Russia and expanding to Europe. This manufacturer is the typical ‘Chaebol’ representative of South Korea which brought the brand of ‘made in South Korea’ out from the country into the world.

To extend its vehicle connection service, Carplay and Android Auto are compatible with internal car systems. Hyundai set up a new data centre in Guizhou, China to lay a foundation for future smart vehicle connection. The collected data in this centre is to analyse travelling patterns and user behaviours, so as to predict and modify routes and avoid congestion. Apart from the data centre in China for vehicle sharing and connectivity purposes, Hyundai also announced its innovative data centre in California which is focussed on five themes: robotics and intelligent systems, mobility services, innovation technologies on new materials and mechanisms, future vehicle transportation and eco-friendly technologies (Hyundai 2017). Hyundai gives a reasonable 10-15 years’ timeline for autonomous technology to achieve the mass production starting from 2016.

In 2017, Hyundai promoted a service of ‘Prime Now. Drive Now’ by Amazon Prime Service platform through which the potential users could book test-drive on-line in limited hours for Hyundai’s all-new Elantra and Elantra Eco (Hyundai 2016). In the middle of 2018, Hyundai, Kia and SK Telecom developed a project named ‘home2car’ which linked homes and vehicles that can switch on lights, AC, and the engine from the home for an advanced experience. In the middle of 2018, Hyundai signed a strategic agreement with Wärtsilä for battery recycling and reuse. It was an imperative step for electric vehicles to embrace the future recycling requirements. The capability of battery and storage extension is very important but how to deal with the battery after-life is also essential. Hyundai in 2020 offered to the market a pure electric version of Ioniq aiming to increase range up to 250 miles.

In terms of connectivity and innovative of future technologies, Hyundai made the biggest attempts after 2019. It endeavors investment on AI and an idea of being “hyper-connected”, later for flying cars. For the higher abstract conception of flying cars, Hyundai teamed with Uber to build a flying taxi which is another good combination of electric with vehicle sharing, but in the air (Morris 2019; Jung-a and McGee 2020). On 20 March 2019, Hyundai Motor UK publicised its hydrogen fuel cell electric vehicle NEXO, with less than 5 minutes refuelling, over 400 miles range. NEXO is equipped with high level driving assistance features, the lane keeping and following, cruise control, smart parking, etc (Hyundai 2019).

In the electric area, Hyundai also strongly invested. Rimac Automobili, a start-up sports car automaker, allied with Hyundai and Kia to deliver two models with high performance, offering efficiency but lower cost electric vehicles by 2020 through the investment injection of €10 million. And Hyundai aims to have 44 electric models by 2025 with €2.5 billion with a total investment of €35 billion on R&D (Randall 2019a).

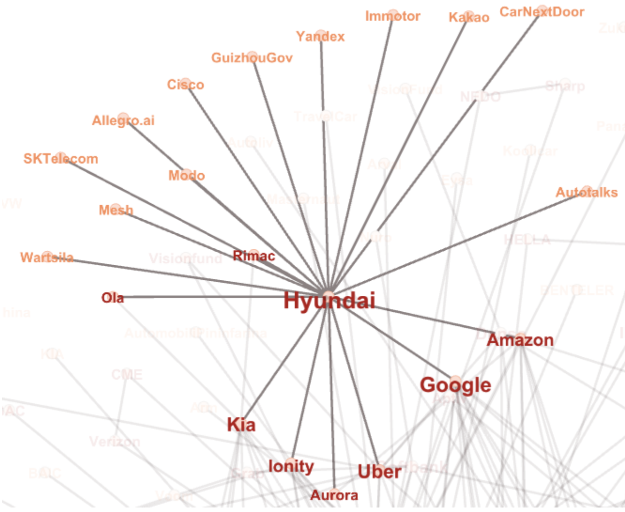
Hyundai tried to combine innovative features practically, it invested in car sharing, electrification and autonomous driving areas aggressively. In March 2019, Hyundai with the Russian company Yandex, a famous car sharing and hailing company, agreed to develop autonomous technology collectively. Russia has the largest car sharing market in the world and it is growing very fast. Also, in the sharing area, Hyundai and Kia invested Ola with $300 million, it also collaborated with Modo to develop a NEXO hydrogen car sharing scheme. Hyundai and Kia invested € 80 million in Rimac Automobili in the area of electric vehicle research and development, battery and petrol vehicles. The Hyundai driverless taxi is estimated to enter the market around 2021. The Table 22 shows the most activities taken by Hyundai in recent years.

***Table 22 Hyundai Network Distribution***

| Company | Date | Item |
|---|---|---|
| Amazon | 30/09/16 | Genesis wireless Alexa voice command |
| Guizhou GOV | 09/11/16 | Agreement with local government building a data centre for service of vehicle connectivity and future transportation |
| SK Telecom | 16/11/17<br>24/07/18 | And ***Hanwha*** Asset Management, and ***Element AI***, $45 million investment on future technology<br>The NUGU AI platform can control Kia and Hyundai's vehicle from home by home-to-car service |
| Cisco | 09/01/18 | Co-develop 'hyperconnected' cars through over-the-air software update service |
| Aurora | 01/04/18<br>13/06/19 | Join the team with ***VW*** and Hyundai for autonomous technology development<br>Expanding the joint area to self-driving technology |
| Wärtsilä | 27/06/18 | To address issues about second life battery, battery storage, production |
| Google | 12/07/18 | Android Auto in-car infotainment system will available in ***Kia*** and Hyundai vehicles |
| Kakao | 12/07/18 | In-car navigation system being available in ***Kia*** and Hyundai vehicles |
| Immotor | 25/07/18 | E-scooter and battery investment to address last-mile delivery service as a part of future business strategy |
| Mesh | 25/07/18 | Another last-mile logistics Korean company to address long-haul shipment and invest $19.9 million |
| Ola | 19/03/19 | Hyundai and ***Kia*** invest $300 million, a transformation from automaker to mobility service |
| Yandex | 19/03/19 | Co-develop fully AI based self-driving, Yandex is responsible for techniques |
| Rimac | 14/05/19 | €10 million investment on Rimac Automobili by Kia and Hyundai for high-performance electric car |

Source: (Cho 2016; Kurylko 2016; Cho 2017; Hyundai 2017; Cho 2018a; Cho 2018b; Davies 2018; Manthey 2018d; Ranger 2018; Bond 2019a; Hampel 2019e; Randall 2019d)

The Figure 6.8 visually shows the relations of Hyundai Motor with other groups. Hyundai is keen to share market in very recent years, and indeed it seized the largest market Russia. In addition, it was interested in innovative technology for extending fleet usage (hyper, flying cars) and inner vehicle connectivity.




Source: Author

***Figure 6.8 Hyundai Network Distribution***

Hyundai’s vision is to build an ecosystem for vehicle manufacturing both for the external operating environment and the internal vehicle architecture. It allied with other groups to address existing issues of battery life, lifecycle performance, production and storage rather than building new factories to consume more resources (Manthey 2018d). It is running a more service-based strategic business model rather aggressively, building fully autonomous vehicles. In addition, the vehicle connectivity to grids, and over air for software service upgrades are well developed (Ranger 2018).

### 6.2.8 Other representative automakers

All the automakers are very active to build autonomous vehicles. Even for Hyundai which is involved in this area quite late, it also announced to take part in the development in autonomous vehicles. Vehicle automation or fully autonomous is an innovative domain which inspires engineers and technicians to conquer tough technical issues, it also created new jobs and industries which did not exist before. Jaguar Land Rover announced the intention to recruit additional employees, and at least 1,000 would be involved in software and electronics domains. However, it subsequently cuts 5,000 employees because of the loss in Chinese diesel market and instability due to Brexit in 2019 (Jack 2019). This result further implied the importance of the global trend which is highly integrated technology and sustainability. This change occurred in other companies as well. By the end of 2017, Ford planned to double work force in Silicon Valley and six times of investment on working space (Bunkley 2016). On the other hand, Ford was also affected by Brexit and the fall in diesel sales in Europe (Allen 2017; Jack 2019).

Many famous and active members such as Tesla have not been chosen in the list of case studies. Tesla initially aimed to build electric vehicles which can beat the performance level of fuel powered vehicles. It upgraded the systems with autonomous function that makes it distinctive compared to conventional automotive manufacturer. Tesla is not a traditional automaker or ‘tech giant’, it created a new territory in which it can directly build an electric vehicle with highly autonomous features. While Tesla is an interesting case, it also shows many unique features compared with the existing automotive industry and therefore does not fit well with the other cases discussed here.

Toyota is another leading manufacturer with several brands. Toyota invested significant capital to escalate its MaaS service. It invested US$600 million to Didi, $500m in Uber and $1bn in Grab to intensify its MaaS market around the world. Toyota also aimed to introduce battery electric vehicles (BEVs) in China and other markets through the MaaS service (Inagaki 2019; Toyota 2019b).

GM is also very active in building autonomous vehicles. Ford joined the service offered by Lyft where General Motors has 9 percent share which it acquired for $500 million in the beginning of 2016. In the same year, GM acquired the San Francisco based autonomous technology start-up Cruise Automation for $1 billion. GM has been testing self-driving Chevrolet Bolt electric cars for a long while, it is the model that combined both autonomous and electric. GM owns the majority stakes from Cruise, Honda also owns 5.7% from Cruise, additional with SoftBank’s Vision investment. The Cruise Origin autonomous shared electric powered vehicle unveiled in January 2020 was conjunct by GM and Honda (White 2016; White 2017; BBC News 2020).

The transmission supplier ZF entered into autonomous market later, working on micromobility and electromobility which are another branches and methods to expand future transportation niche markets. There are also many companies established in recent years as ‘start-ups’ that are not ‘conventional’ car manufacturers. These new companies could apply new businesses models, features, transport solutions into the frontier of the automobility industry.

## 6.3 Cases outside the Automotive Industry

As mentioned before, the automotive industry was the core driving force to start the research, which aimed to illustrate how networks stretched under the dynamic strategy in automotive industry over time. Led by the popularity of the CASE concept and pertinent technologies, companies outside of the automotive industries are gradually involved. Tier 1 suppliers, technology giants, ICT suppliers, even vehicle sharing and ride hailing companies, are involved in any element of CASE. Moreover, many of these new participants are more like dominant incumbents rather than vulnerable new entrants. More than 200 players involved in autonomous, connected, electric and shared vehicle race have been identified as coming from outside the automotive industry in 2017 (Naughton 2017), and now the number has even increased.

This section provides the dynamic relationships of those initially outside automotive industry e.g. mapping companies, search engine companies, public transport authorities, and others that are involved in dissolving the boundaries of the automotive sector.

### 6.3.1 Waymo

Waymo was Google's autonomous vehicle project, and later it has become a standalone division for autonomous vehicle testing and developing under Alphabet. Google investigated self-driving vehicles and announced their intention to build fully autonomous vehicles (level 5) able to be driven without any human interruptions, in 2009. This may be because tech-giants have their speciality on technologies rather vehicle manufacturing. For them, the autonomous vehicles are about the hardware and software technology – needed for autonomous operation, rather than centralised technology identity. For Google, it is easier to commence autonomous vehicles from these application technologies, but not really consider how to build the cars. Waymo is focused on technology development so the testing vehicles were offered by several different automakers with different types of powertrain. Waymo is US based, having at least 6 testing cities, over 25 points spreading around whole country from east to west (Waymo 2019). Among these points, Phoenix is Waymo's sanctuary to lunch the new business. Waymo One was permitted to pick up passengers in Phoenix initially, and another project AutoNation was acquired the first permitted also in Phoenix (Perez 2018; Dawkins and Avary 2019).

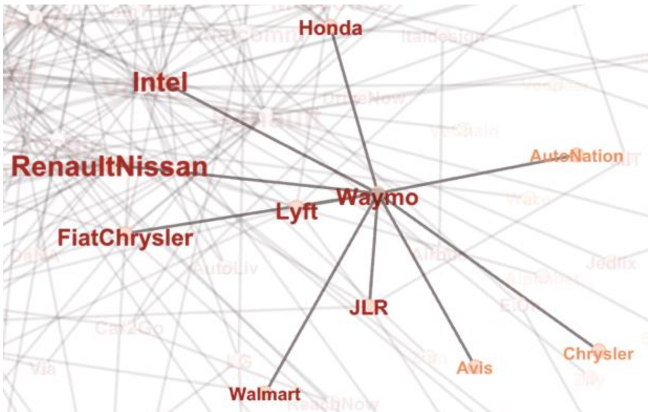
The reason to choose Waymo as one of the typical cases entering into the automotive industry is because its business strategies have varied, and it was one of the first 'outsiders' to make a definitive statement about developing autonomous vehicles. Waymo initially built autonomous vehicles alone, without any official partnership or cooperation. The vehicle acted as a tool to carry its autonomous technology rather a vehicle intended for mass production. However, Waymo realized that the autonomous vehicle is a multi-faceted project rather a single technology which can be cultivated separately, it generally needs partners' support. Another reason is that technological change is faster than ever, Waymo could not sustain the pace alone. The system is over-complex so that a single company cannot cover all points. Nonetheless, Waymo started the autonomous journey earlier than most, but its network of partnerships has been developed comparatively late with varied models such as Toyota Prius, Audi TT, and Lexus RX450h (Sawers 2016).

Table 23 lists the Waymo network distribution for automobility, with most relations with vehicle manufacturers Waymo acts as technology supporter. Figure 6.9 displays a more direct way to analyse the relations.

***Table 23 Waymo Network Distribution***

| Company | Date | Item |
|---|---|---|
| Chrysler | --/05/16 | 100 self-driving minivans carried by Waymo autonomous system |
| Honda | 21/12/16<br>05/10/18 | Co-joint to develop autonomous vehicles<br>It seems failed the partnership owing to the control of autonomous technology |
| Avis | 26/07/17 | Offer fleet support and maintenance services for Waymo's self-driving car program |
| Intel | 18/09/17 | Working with Waymo to improve self-driving technology in all features, already in Chrysler Pacifica minivans |
| JLR | 20/03/18 | Co-build Jaguar I-Pace electric vehicle up to 20,000 in two years |
| AutoNation | 25/07/18 | B2B parts delivery by Waymo’s autonomous vehicle |
| Walmart | 14/11/18 | A pilot project to study user’s preference about autonomous vehicle usage to expand consumer market |
| Renault<br>Nissan | 20/06/19 | Teamed with Waymo for autonomous vehicle system, market and commercialization but without vehicle support |
| Lyft | 27/06/19 | Expanding its self-driving system in mobility service |

Source: (Bergen 2016; Bhuiyan 2016; Avis Press Release 2017; Krzanich 2017; Jaguar News 2018; Perez 2018; Waldmeir 2018; Welch and Barr 2018; Bigelow 2019; Financial Times 2019; LeBeau 2019)




Source: Author

*Figure 6.9 Waymo Network Distribution*

Relations are always iterated. In late 2019, Waymo expanded its partnership with AutoNation B2B delivery that was announced via an official Twitter release in the Phoenix area. The partnership with AutoNation dates back to 2017 when a two-year extension contract was signed. AutoNation is an auto retail giant which delivers auto parts using Waymo's autonomous vehicle technology.

Benefits could also be gained from its relationships indirectly. For instance, Waymo cooperated with Intel, while Intel acquired Mobileye for $15.3 billion which gives Intel capabilities in vision and sensor technology. Thus, Waymo benefits from Mobileye's newest technology as well on sensors and maps. With this collaboration, Waymo aims to achieve fully autonomous vehicles collectively which planned initially to spread among US, Europe and Mobileye's home Israel. As research reported, autonomous market will surge to US$60 billion (2016 base year) to US$202 billion (2019 base year) until 2030 (Techsci Research 2018; Smith 2020).

### 6.3.2 Mobileye

Mobileye was formed in 1999 and it is an Israel expert on visual systems such as cameras, radar, and computer vision chips and route plotting. In March 2007, Intel acquired Mobileye for $15.3 billion. Its famous ADAS (advanced driver assistance systems) system is equipped on more than 90% of top brand vehicles (Sawers 2016). This achievement makes both automotive manufacturers and 'outsiders' collaborate with Mobileye. Most traditional vehicle manufacturers collaborate with Mobileye because of the price advantage (without LiDAR) with higher autopilot functions; companies other than traditional vehicle enterprises also intend to work with Mobileye because it offers higher quality and resolution in innovative technology. Mobileye's collision-warning system is another star product that has been equipped in customer vehicles such as Volvo, Ford and Hyundai (Automotive News 2013; Lambert 2017b).

Mobileye holds a special role in autonomous system development, it therefore has several relations with different stakeholders. In early 2016, GM, VW and Mobileye aimed consonantly to develop the mapping system which is the 'nervous system' for the self-driven vehicles. In July, BMW, Intel and Mobileye reached an agreement to build the BMW smart iNext vision; it was a future plan and an important step for BMW. Delphi later joined into the alliance with members of BMW, Intel and Mobileye and a month later, Continental and Fiat joined as well. This giant alliance comprises all factors to build an autonomous vehicle system. Later, Mobileye strategically agreed with the map giant HERE (linked to Audi, Mercedes and BMW) to enhance the automated system. In this therefore, Mobileye potentially crosses the industry boundaries and established a new arena that sensors and visual associate system are highly required.

Vehicle sharing has also been attempted by a Mobileye and VW joint venture, Champion Motors investigating electric autonomous sharing vehicles in Israel. Table 24 lists the Mobileye network distribution since 2015.

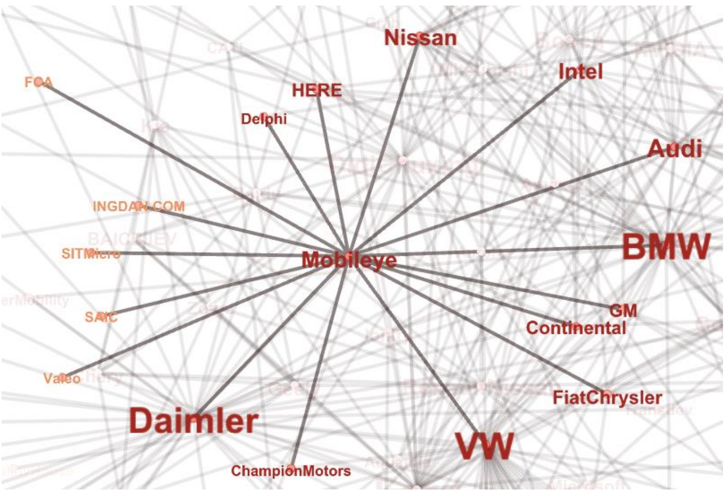
***Table 24 Mobileye Network Distribution***

| Company | Date | Item |
|---|---|---|
| Valeo | 11/03/15 | Signing an agreement to co-develop automated driving productions, including Valeo design and cameras production; Mobileye is responsible for sensors and vision algorithms via its EyeQ system. |
| GM | 11/01/16 | With ***VW*** to refine digital map system more accurately |
| STMicro | --/05/16 | Developing 5th generation Mobileye system to build autonomous system |
| BMW | 01/07/16<br>--/02/17 | With ***Intel*** to form a joint alliance to create fully autonomous vehicle on BMW iNext<br>map data collection for autonomous vehicle |
| Delphi | 23/08/16<br>--/05/17 | Jointly to foster an autonomous and connected driving system and will reach level 4 even 5 after 2019<br>Join the team of ***BMW/Intel/Mobileye*** |

| | | |
|---|---|---|
| HERE | 29/12/16 | HERE Open Location Platform would have a strategic partnership with Mobileye Readlook technology then integrate to become a highly performed digital mapping system |
| Audi | 05/01/17 | Deep learning in image recognition to train vehicle self by machine |
| Intel | 14/03/17 | Acquired by Intel $15.3 billion |
| Nissan | 25/04/17 | Forge an agreement in next generation of driving mapping auxiliary system to safe autonomous vehicles |
| Continental | 20/06/17 | Joining the club of BMW, Intel and Mobileye |
| FCA | 16/08/17 | Join the team of BMW and Intel, inject technical engineers in the team |
| INGDAN.COM | 18/08/17 | Working together for online-to-offline service (O2O) to promote Mobileye ADAS |
| SAIC | 09/01/18 | And ***Navinfo*** to access Chinese market |
| VW | 29/10/18 | With ***Champion Motors*** having MaaS ride hailing service in Israel |

Source: (Wernle 2015; Automotive News Europe 2016a; Beene 2016; Burke 2016; Sedgwick 2016; Ackerman 2017; Audi 2017; Gibbs 2017; Sage 2017; Scheer 2017; Schwartz and Cremer 2017; Trego 2017; Volkswagen News 2017a; Etheringto 2018; Manthey 2018b; Volkswagen Group 2018b; Yvkoff 2018)

The Figure 6.10 clearly shows the relationship of Mobileye with other interest groups. In this graph, Mobileye has a strong relation with vehicle manufacturers which has been elaborated in the last section.




Source: Author

***Figure 6.10 Mobileye Network Distribution***

The relations between Mobileye with automakers are quite simple. Mostly automotive manufacturers collaborated with Mobileye and the other companies to help Mobileye to refine the existing technologies. As a vision and chip company, the most important function is to provide products suitable for different models. It is a positive strategy, because more data can be collected when more vehicles are equipped with the products so that the system could address the bugs.

The VW group has declared: "We are delighted to embark on a joint venture with a world-leading automotive OEM, aimed at delivering a transformational mobility service," said Professor Amnon Shashua, Mobileye CEO and senior vice president at Intel. "Our service aims to intelligently and dynamically adapt to the urban mobility needs of the 21st Century, catering to the mobility-mileage demands within the city while minimizing the direct/indirect incurred societal costs – air/noise pollution, congestion and safety."(Volkswagen Group 2018b)

### 6.3.3 Didichuxing

Didi (short for Didichuxing) is one of the biggest ride hailing service providers in the world and surely the leader in China. The homegrown Didi exchanged all Uber properties and service for stock, and made Uber the basis of the Chinese vehicle sharing and ride hailing market (Shirouzu and Lienert 2018). Didi gained support from Chinese tech giants like Alibaba, Tencent, and Baidu, and also outsiders such as Apple. To coincide with the local policy, it collaborates with automakers to deploy an electric vehicle sharing scheme. Didi planned to offer 1 million electricity powered vehicles shared by 2020 and collaborated with NEVS (National Electric Vehicle Sweden) to deal with Tianjing city traffic congestions and air quality issues through car-sharing and ride-hailing (Lambert 2017b). Didi's strategy is not only confined to the passenger car hailing and sharing, but also for buses, minibuses, and shuttles. In addition, Didi launched an R&D lab focused on Artificial Intelligence technologies to address transportation solutions in California, in 2017. In 2019 it sought to expand vehicle sharing and other on-demand services. In Beijing and Harbin, Didi kicked off the Hitch carpooling service trial, while it is only available for limited time. It is a further development of ride/vehicle hailing or sharing schemes.

Didi has a strategy premised on alliances. In 2017, Didi signed an agreement with National Electric Vehicle Sweden (NEVS), and in the year after, it agreed with 13 other companies including Renault-Nissan-Mitsubishi, Ford, BAIC BJEV, Changan Automobile Group, Zotye Automobile, Chery Automobile, Geely Auto and KIA Motors to deal with new energy vehicle sharing issues in China. NEVS allied with Didi to solve vehicle sharing solutions and develop new energy vehicles for hailing and sharing scheme. In addition to the Chinese market, Didi also cooperated with the Japanese Softbank to serve the Japanese online ride hailing service market. Later, Continental and Didi conducted a deep collaboration on smart connection and personalization for new energy vehicles. At the beginning of 2019, BAIC and Didi created a joint venture, BAIC-Xiaoju New Energy Auto Technology Co. Ltd (JingJu), hoping to address transport issues using AI, transportation sharing and connection. There are 12 automotive manufactures both in China internationally who had joined with Didi, called ‘Didi Auto Alliance’ by Didi. This alliance aims to develop “unified standards for the design and manufacture of new energy vehicles, the development of intelligent driving technologies, and the planning of charging facilities” (details see Table 25) (Shirouzu and Lienert 2018). Didi is another example from vehicle sharing perspective that linked vehicle manufacturers with other CASE suppliers.

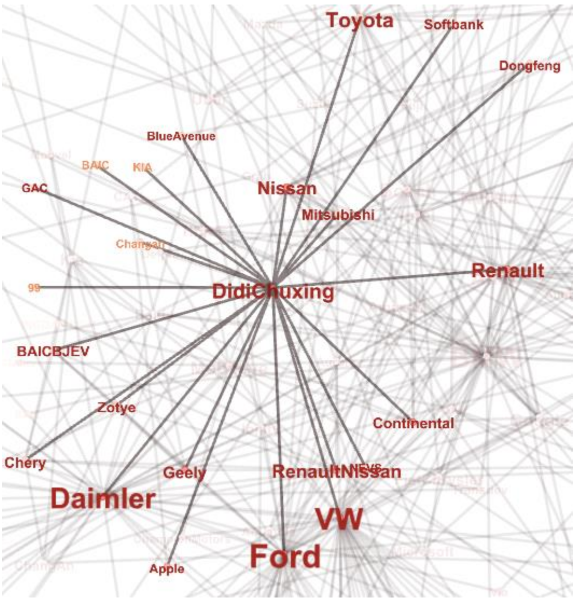
By the end of 2018, about 400, 000 electric vehicles had been registered through Didi’s platform to offer their services. Further, Didi aims to build its “purpose-built” vehicles which will have basic functionality albeit with fewer seats and less aerodynamic styling (Shirouzu and Lienert 2018). This ‘purpose-built’ service also can help companies that intend to develop their own ride hailing and sharing service in turn. As a terminate goal, Didi developed its business for Latin America including Chile, Peru and Colombia three countries (Sun and Goh 2019a).

*Table 25 Didichuxing Network Distribution*

| Company | Date | Item |
|---|---|---|
| NEVS | 26/10/17 | Electric vehicle ridesharing in Chinese market |
| 99 | 03/01/18 | To acquire Brazil's 99, expanding overseas ride sharing and hailing market |
| Ford | 07/02/18 | Didi partner with 12 car manufacturers to build an eco-sharing vehicle system. Including Chinese automakers BAIC BJEV, Changan Automobile Group and Zotye Automobile, Chery Automobile, Geely Auto, KIA Motors and international companies Renault-Nissan and others. |
| Softbank | 09/02/18 | Co-operation on Japan's taxi-hailing service |
| VW | 30/04/18 | Fleet sharing business conjoint, may release 100,000 electric vehicles only in Chinese sharing market |
| Toyota | --/05/18 | Working with ***Uber***, ***Amazon*** and ***Pizza Hut*** to develop self-driving shuttle named ***E-Palette*** for deliverers and users |
| Continental | 11/07/18 | New energy fleets equipped intelligent & connected vehicles (ICV) wish to build |
| BAIC | 28/01/19<br>26/06/19 | A joint venture ***JingJu*** for AI operation, new energy fleet routing solution, vehicle connectivity<br>To set up a JV with BAIC and VW to 'purpose-built' vehicles |
| GAC Group | 26/06/19 | Ride hailing and autonomous driving |

Source: (Lambert 2017b; Edelstein 2018; Manthey 2018b; Newspress 2018b; Shah and Shirouzu 2018; Shirouzu and Jourdan 2018; Shirouzu and Lienert 2018; Spring et al. 2018; Hampel 2019b; Sun and Goh 2019b)

Figure 6.11 shows the relations of Didi with its partners. It can be seen that the majority of the partners are vehicle manufacturers.




Source: Author

***Figure 6.11 Didichuxing Network Distribution***

Even though Didi puts huge effort and contributions into the sharing economy, it incurred $1.6 billion losses in 2018 (Liao 2019). The loss was partially caused by slack supervision and an imperfect driver identification system which led to harassment and murder of passengers, and thereafter a fall in demand (BBC News 2018a; He 2018; Liao 2019). Additionally, the unsustainable business model (cash-burning model) enables profits to go back to drivers, although it aims to encourage more drivers to take part in the ‘Didi driver’ service. Didi also partnered with local bike sharing schemes to expand the business area and develop a new revenue stream. Caocao, a ride sharing self-owned brand by Geely, obtained local online car-hailing licenses and became the major rival to Didi. Compared with Didi, Caocao is an e-taxi sharing platform which provides that all vehicles are new energy powered. Caocao also cooperated with local government to push regulations further. Also, it is a pusher of the Internet Plus model which provided a connection of Internet and conventional industry as an online extension.

### 6.3.4 NVIDIA

Nvidia was founded in 1993 with the provision of computer chips and other hardware in the domains of data, gaming, visualization, AI, and machine learning. Nvidia is similar to many other ICT and original parts suppliers, which played the fundamental role in autonomous technology. The Tegra chip is the core of in-car infotainment systems, which is one of the earliest adopted features from automakers in response to in-vehicle connectivity. One of the central businesses in Nvidia is to supply high-grade, precision and advanced parts for the future vehicles – notable sensors, the ‘eyes’ of a car and to power graphics displays. NVIDA also applies software platforms which can be worked in vehicles to make in-car systems and networks become smarter and smoother. The second generation of software platform Drive PX 2 is named "world's first in-car artificial intelligence supercomputer" (Neiger 2016).

Nvidia has a focus on its unique core electronic chip technology which controls the soul of being an autonomous vehicle(Kenwell 2018). Nvidia has partnerships with most vehicle manufacturers such as Toyota, Audi and Mercedes and equips its products on high-end models. Nvidia has joined a few alliances to investigate autonomous vehicles (see Table 26). Meanwhile, in a parallel competitor group, Mobileye led the relation with BMW and Intel (US) with a similar aim of developing autonomous cars with other members (see BMW section and Mobileye section). Moreover, both traditional automotive suppliers Delphi and Continental, have since joined the BMW cluster.

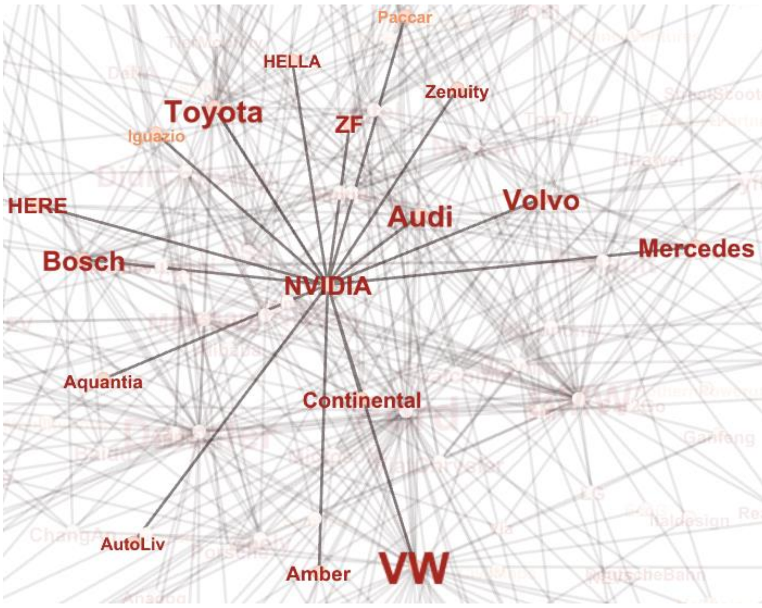
Table 26 shows the Nvidia network distribution since 2016. The majority of the relations taken with Nvidia are vehicle manufacturers, not just restricted in cars, also in trucks. Nvidia took a very active role in an alliance to co-build autonomous vehicles with other members. Nvidia also has its program to keep autonomous vehicle progress, safety and security through visual help and software platform (e.g. the NCAP, New Car Assessment Program).

***Table 26 NVIDIA Network Distribution***

| Company | Date | Item |
| --- | --- | --- |
| Audi | 06/03/16 | Audi self-driving 550 miles from San Francisco to Las Vegas which had Nvidia Drive PX platform |
| HERE | 04/01/17 | Co-develop HERE HD Live Map by feat of mutual AI platform |
| VW | 05/01/17 | Cooperate with all 12 branches using AI technology |
| Bosch | 17/03/17 | With Nvidia enable level 4 autonomous vehicles |
| Paccar | 17/03/17 | Paccar truck company, develop L4 autonomy trucks |
| Zenuity | 27/06/17 | The JV of ***Volvo*** and ***Autoliv***, with Nvidia, enable the autonomous system by Nvidia software systems, via artificial intelligence and computing platform |
| ZF | 06/06/17 | With ***HELLA***, join NVIDIA's New Car Assessment Program (NCAP) to increase AV safety |
| Continental | 26/08/18 | Two with ***VW***, ***Aquantia***, ***Bosch***, ***Continental*** to create the NAV Alliance |
| Volvo | 10/10/18 | Deepen the collaboration for L4 automated driving |
| Toyota | 18/03/19 | To train and validate autonomous vehicles via NVIDIA RIVE Constellation™ platform and AI technique |
| Mercedes-Benz | 08/01/19 | New AI architecture in new generation Mercedes Benz vehicle |

Source: (Neiger 2016; Bolduc 2017; Burke 2017; NVIDIA Newsroom 2017b; NVIDIA Newsroom 2017a; Volkswagen Group 2017b; Krok 2018; Volvo 2018; NVIDIA Newsroom 2019a; Shaporo 2019)

Figure 6.12 is the Nvidia centralised diagram which shows the relations of Nvidia with other partnerships. Nvidia also cooperated with parts suppliers and start-ups to enhance autonomous progress.




Source: Author

***Figure 6.12 Nvidia Network Distribution***

Nvidia's customers are largely premium manufacturers with advanced technologies involved. Therefore, it aims to reach higher levels of autonomy through AI machine learning (Murphy 2016). Being different from Nvidia's production and application, Mobileye focuses on current technology development and deployment with a wide range of users experience.

### 6.3.5 Competitive but collaborative relations

The relations are competitive between OEMs and other tier 1 suppliers, ICT companies, even car sharing and hailing companies. As seen from last four cases notably NVIDIA and Mobileye, their relations are mostly overlapped. For instance, Audi is one of the world-class automakers, its relations with NVIDIA could date back to 2005 on Audi Q4, which enabled Audi to hold the leader in the area with an innovative driver assistance system. Intertwined in cooperation with Mobileye, new generations models such as the Audi Q8 used the Mobileye system to co-develop on-board machine learning.

Uber is a US based ride-sharing platform founded in 2009, but it is beyond the case study list. Because Didi adopted the same business strategy as Uber it has been chosen as a ride sharing representative case. Didi is the one that grows very rapidly even under a very strict regulation inside China. In addition, it is under a typical culture that makes case representative and unique. Actually, Uber owns a 15% stake in Didi, the two giants are in the same community of interest sharing Chinese market while they may become hostile under the worldwide context.

This collaborative but competitive situation is generated in these business models because ‘there is no perpetual friend, nor perpetual enemy, only perpetual interest’. Relations could be extended, deepened, strengthened, or broken. For instance, no matter how the two German auto giants Daimler and BMW are of opposed interests, they can work together to defend against their common rivals if needed. When Uber was immersed into the German market and got rapidly spread around the world, the two automotive giants collaborated to reform platforms including car sharing, charging, smart parking etc. to confront this challenge together.

Alike the competition within the automotive industry and service platforms, the software served on various vehicle systems such as Aurora. Amazon Aurora is a data based service provider which provide huge amount of data via the cloud and platform; it built had relations with VW and Fiat Chrysler Automobiles for example (Bigelow 2019).

### 6.4 Expertise from Interviews

Findings from interviews are collected from CASE aspects to balance the findings from above case studies. 33 experts were interviewed during the primary interview data collection as defined in Chapter 5. Acronyms of the interview names in Table 13, and Table 14 (Chapter 5) listed the position and expertise each interviewee engaged for a general background understanding. The interviewees were asked questions depending upon their knowledge, but generally around the CASE elements. Interview questions have been attached in appendix 1 attachment 1, which has been clarified in the methodology chapter, by the end of section 5.4.2 Primary data collection, preliminary interview. Findings are also surround the CASE one-by-one to answer. Overall, interviewees hold a positive attitude on Connectivity and Electric vehicles; topics around Autonomous vehicles are also very controversial. Vehicle sharing is a very new scheme, the attitudes to the sharing are significantly varied geographically and it is also based on interviewees' knowledge and experience. As for the CASE integration in one vehicle, it was the least considered aspect among almost all interviewees; however, a higher possible credit has been given to the combination of two or three elements communally. Experts tended to focus on their own domain of expertise, and therefore may have under-estimated the significance of CASE integration.

Most interviewees are experts on CASE, but mostly in one area. Still, they hold opinions divergently.

### 6.4.1 Autonomous features

As discussed, the definition for 'autonomous' is vague so that this term is 'defined' differently. This differentiation was inescapable among interviewees and reflects the emergent character of the phenomenon. U 2 as a user considered an autonomous vehicle had flexibility and "*… can go anywhere without hassle*". Functions of autonomous driving could be mixed with connectivity: BC 1 thought "*The autonomous and connected has a big part of overlap*"; and AC 6 believed "*It is almost impossible, to have a fully automated vehicle which is not connected*". The independency of autonomous vehicle is in doubt: AC 1 claimed that it would be "*an additional transportation mode*" (rather than an existing modes), "*they will not replace the private cars*".

Other than the variety of the definition, how to make autonomous vehicle more attractive is also one of the interviewees' considerations. To automotive experts, cost is the priority. Mass commercialisation is only possible if the cost of the autonomous (system) is reduced. Users have a different perspective about price. For them, price reflects safety guarantees. U4 imagined "… *the vehicle over 500,000 RMB has automated functions*", and AM 2 has the same outlook "… *autonomous technology which in high-end vehicles (above 1 million RMB) would be more reliable*". In this case, it gives high-end vehicle manufacturers more confidence on autonomous vehicle construction.

The opinions varied even in the specific type of autonomous trucks. AC 4 (a truck expert) claimed: "*Cars are not varied as much as trucks, e.g. the safety regulations and rules, they are transferable. While truck regulation varies country by country. The road situation is also varied: Germany and UK are much narrower than others, incidents are happened easier*". In addition, for the weather, "*Autonomous trucks in wet weather are even worse than cars, they cannot catch the white lanes*". However, another truck expert suggested: "*Commercial vehicle, logistics, wharf and intra-regional paths should be tested before all others (passenger vehicles)*".

Most issues about autonomous vehicles have yet to happen, thus questions could not be formally answered. This is the area that people are hesitating to give more credit to autonomous vehicles. For instance, U 1 said "*I think I will trust technology, eventually. But crashes, computer failures are major issues now that I am more concerned about*". AM 5 held a very negative opinion about autonomous vehicles: "*The current auto pilot driving system has a high failure rate, it becomes dispensable*", "*(Pure) autonomous driving will never become true. The auto pilot system cannot replace a human, it brings too many hidden dangers*", "*It will have a huge impact on the local economy, the driving schools will shut and so there will be many job losses*". The existing tested autonomous vehicles could not perfectly offer as a reference because "*... most autonomous testing surroundings are too Utopian and highly controlled. If (the same vehicle) were taking passengers, it would not be commercial. All requirements are double or even higher, for accuracy, speed, safety and the solution to the emergency situation".* Thus AM 4 hold the opinion: "*Why do we need autonomous vehicles? It is not necessary*".

But autonomous helps in some way. “*Autonomy increases the rate of utilisation and thus you get the best benefit out of an electric car rather substituting*” said by BC 2; “*The complex traffic system needs the autopilot system to work in an-emergency*” supportive opinion by AM 3.

Some express hope for autonomous vehicles if they are out of the current frame of a ‘car’ and be more creatively applied. For instance, to shorten the time of making a car (break the current rate of development and rules) like Apple. As “*… they (iPads) did it faster and broke more rules, it is as fast as possible from the main business, because they could make decisions fast, a good team*” (IE 1). If autonomous vehicles can work as a product to break the rules and lead to another culture, it would be a success. “*So the key is how do you change the culture broadly*” by IE 1. It may take time to make an alternative change, IE 1 said around 10-15 years and AC 2 supported the change may from many perspectives “*…laws and regulations, political system support, infrastructure, production information, also mind and attitude*”. It will come soon but under a certain condition “*…in a part of the road network, and a well-developed city*” (TS 1). The long time to progress the autonomous vehicles have been agreed also by AT 1, AT 2 (5-10 years).

AT 1 said: “*Three years from now (since January 2019), we will have L3 autonomous driving, while it will take an equally long time to reach L4. However, it will be very soon (to have a L4 or higher autonomous vehicles) in specific areas*”. In this case, all vehicles that have ‘autopilot features’ are categorised as ‘autonomous vehicles’. AT 1 additionally said: “*The robot taxi is far away from now. It lacks abundant tests and data support*”, in this moment, the ‘robot’ refers ‘fully autonomous’.

### 6.4.2 Connectivity features

Most ‘connectivity’ has been considered as involving a smart phone with the car connection via Bluetooth, or navigation which is V2I (vehicle to Internet. It may be an attached feature which could help others better “*The connectivity piece is also in the productivity debate because they are really good at the safety piece*”; it is a condition to make other features accessible: "*When the mobile phone application is becoming an underlying support, autonomous vehicles could be shared*" claimed by AC 2. However, AC 1 is clear that "*I think connected should be a separate issue rather attached with others*". This feature has been described as inevitable by TS 1: "*Vehicle connectivity is an inevitable part of the Internet of Things. Tesla and Mercedes-Benz offer the best answer for connectivity*". Actually, the connectivity features are widely used in the delivery tracking either for people e.g. taxi, or goods e.g. long-haul trucks. AM 2 claimed: "*It can become true that the taxi company shares the users location with local taxis, logistics companies share locations in its distribution centres to manage vehicles*"… "*This function helps regular checks on fuel usage, transportation routes, and the health state of each part, if any maintenance is required*"… The precise tracking technology requires an even higher standard: "*The precision and accuracy of mapping (in China) is high, and it keeps a high and efficient update rate. We have very good navigation and map companies, Gaode, Tencent and Baidu, which connect all information in the vehicle with others*".

To what degree is sufficient for connectivity is very controversial. AT 1 believes that "*If the individual (vehicle) is intelligent, there is no need for connection with other vehicles and infrastructure*". This is largely part overlapped with the conception of being 'autonomous' through which they both have a hidden concept of 'smart'. Additionally, it probably "*takes even longer than semi-automatic driving, as it asks agreement between vehicles and infrastructure*", stated by AM 1, Just because of the complexity of connectivity, it is probably even harder as "*... isolated frameworks are very hard to be integrated together, as one. For example, (the vehicle) lacks the unification of CPU or technical standardisation*".

The common question is how to deal with the cyberattack and Internet failure, this is also the vital weakness for connectivity feature. AC 6 commented: "*Autonomous and connected can work side by side, or government choose one or another, but it is not completely black and white. All vehicles will have to be capable of surviving somewhere if network infrastructures goes down*".

### 6.4.3 Shared features

The ways of sharing varied owing to the diverse definitions of 'share'. Sharing schemes between families and friends are more acceptable for U1, U2, AC 1 "*I am a car enthusiastic, I like cars, cars are mine, but a lot of people do not see at that way, for lot of people, car is only a tool to get to work or something like that. So that less fussy than I am*"; for U3, "*there are not many differences between 'catch a bus' and 'share cars'*". For sure, someone people never think about sharing. Sharing property is a way of sharing privacy. A vehicle for them is a private property. BC 2 said: "*One interviewed person from a famous car company, long time ago, says people they do not share their kitchen and bathrooms, why do they share cars?*" Therefore, the ownership of shared mobility is provocative as it may refer to the vehicle maintenance and vehicle management, and a personal space. "*I think communities will own it rather personally. The private ownership of vehicle will be less or none*" by U1. Autolib was a Paris municipal supported electric sharing programme that was failed due to the rough vehicle maintenance and management awareness.

Sharing schemes are also diverse geographically e.g. AC 1: "*The France or Spain they quite common, while not here (UK)*". TP 1 added: "*UK is more resistant to the car share concept, partly culture thing, and reluctant to trust technology*." With regard to the age of people adopting sharing: "*While young generations prefer to share or lease a car, but later when they have family, they change to own a car according to research. That also slightly changes the car culture, you start sharing cars, but it ends up with owning a car*" by AC 1. AC 5 clarified the elder aged groups according to AC 5's research: "*(older) People used to do it yourself, look after yourself, they are happy to share a vehicle with family, but they decide (with whom)*". Because "*they do not trust technology, they need to do things. themselves and they do not like sharing*". And the time of sharing when you urgently need it: "*When people want cars that is at 0830 at the morning and 1730 at night, they don't want them at days rather of course that is empty during the day or three o'clock at morning*" by J1. But actually they are a workers' friend because: "*(for workers) If you share, you can guarantee the space*", especially in a crowded city with limited parking space. Workers have to leave their homes much earlier in the rush hours because of parking issues.

China is good at sharing, while there are also doubts as some believe the sharing market in China is not healthy. TS 1 commented: "*The future of vehicle sharing is not promising. It only benefits by financing*." AM 1 added the comments: "*Vehicle sharing is a financing project. It is convenient for on-demand travel but traffic jams would not increase (because of sharing), it will get worse*". "*There is an urgent requirement on compromise proposals for vehicle sharing cost and flexibility*" stated by AT 1. They believe that it is a change of a culture and individual's mind. Share would be more accessible in an open-minded culture.

To deal with these issues, businesses owners try to find more ways to share vehicles, free floating and parking in restricted spaces in a city. "*We have the peer to peer part of the business, and now we push forward to manage with land and dealing with hotels, we also arrange a space … nothing like a huge one that can cover 400 spaces in a car park. (Rather)… lots pockets spaces like 20-50 spaces*" TP 1 declared. The sharing scheme is not only confined to space sharing, but also the non-public charging spots as well: "*Airports would be another good start point for sharing of parking, charging*." TP 1 added the opinion.

However, a lot of problems are associated with sharing schemed, and one of them is that a platform needed, the platform mostly carried via automobile devices. This links the 'share' with 'connectivity' obviously, but it makes more disturbances as well. J1 claimed: "*It is suggesting that rather owing a car, you going to have an app, and every time you need your car, you have to use your app*". This asks that users must have a smart phone and relevant applications via that phone. In addition, a personal bank account is required that links to the application account. All these requirements require smart phone users but may disadvantage advanced aged people, those with weak eyesight, those without a bank account, etc. It is also challenging the current business and markets. IE 1 is deeply considered about this point: "*The ownership case is still very valid one, I do not believe everything is shared mobility. As mobility only works if you have a deeply developed market place, which means that the service is immediately available in 5 minutes. So the* *platform investment is important*". Which means sharing is for convenience and it only works if convenience is really provided.

Another intertwined relation between 'share' and 'connectivity' represented on the precise locating requirement. Either to deliver a person or a good, precisely to find a location requires high level technical support. IE 1 believed that it is not an easy process and "*…there are so many technological challenges*". AT 1 added: "*The core of electronic vehicle sharing is to balance the customer demand and the shipping capability on service platform*". A case is imaged by SE 1 who believes sharing is a good idea if it could be combined with more features automatically. "*Rather sharing in the city centre itself, it could be shared in the area of suburb and outskirts to key destination points, and coordinating the whole system from that perspective. And that becomes a case in your app, it says it will take 23 minutes to get from door to door, that is more feasible because everything is timed properly, in that sense. And in the connection, not just from a driving destination to the certain destination without thinking about to the consideration for parking, walking, to get to your destination, all of that time are not being taken into the accounting in the current systems. I think that is something can solve through the future apps. I think the shared vehicle aspect is really good for maybe individual travellers or light packed travellers, I am not sure if it would overtake everything 100 percent, I think peoples till love to own their own vehicle*". Sharing needs to carefully balance the waste e.g. material, energy, time, and the exceedingly technological output, it is as intractable as connectivity and autonomous features.

However, the most important part of 'share', is to understand what is share and why to share. It should be an effective process for current spare asset relocating and reusing. "*From micro or individual level, shared means less vehicles, manufacturer foot print and end of life impact. Basically less capital used to deliver the same effect and that is what shared places mean*" BC 1 stated. Because partial car users possess the second car only for 'share business', this lost the real meaning of 'share'. AC 2 has the same opinion: "*It is a waste of resources of labour manual and material e.g. iron is non-renewable resource. It is not 'sharing'*".

### 6.4.4 Electric features

AM 2 believed that the electric powered vehicle has advantages over many of the others: "*Our electric vehicle has lower cost and lower maintenance fees".* This is on behalf of consumers. Electric vehicle is very efficient expert AC 1: "*The process inner the (electric) car is more efficient than petrol or diesel car, the energy transfer efficiency is higher up to 80% rather 35-40% in petrol and 40-45% in diesel.*" In addition, electric vehicles perfectly match the same electrically powered digital system. As AM 5 pointed: "*A new energy vehicle is an electrical structure based which is superior than a mechanical structure in terms of its agility on data transfer and execution*". Electric vehicles also go well with sharing schemes, as U4 believed "*It is a win-win business on electric vehicle sharing both for vehicle manufacturers and sharing platform*".

However, the uneven progress of pushing electric vehicles onto the market is hindered by so many issues. The popularity of electric vehicles is varied by places: "*It is really rare to have electric vehicles in this city, mostly, our taxies are gas fuelled. I do not see any changes in electric vehicles in the past years and future. But we have electric powered bikes and motorbikes, it is getting more popular.* " stated by U2 who is living in a small city in China. It only works on the places where have less harsh weather. "*It will lack a Northern market if the battery technology has not had a new breakthrough. For instance, the low temperature resistance, duration and natural hazard: flood*", TS1 added an example. "*There is a scarcity of charging points in first-tier cities, they are rare in second and third-tier cities. The same goes for new energy vehicles distribution*" AC 2 explained the reason for less popularity in China. Electric vehicles were generalized by local government, especially in China and it would be easier to push vehicle greening by officials. AC 2 further added: "*Public sector transport (bus) would be easier and acceptable for becoming electric powered vehicles. Manipulation and motivation by officials would have a huge advantage, if they are supportive, sustainable and with a stable management and method*."

From personal perspective, it is expensive: "*I do not have an electric vehicle because it is too expensive.*" Expert AC 1 said, even who clearly knew the advantage of electric vehicle as declared before.

To generalise the electric vehicles some conditions are better to fulfil (AC 1) "*It is possible that electric vehicles fully replace the traditional vehicles, if you have rapid charging, a vehicle suitable for rapid charging and people are happy to wait 20-30 mins.*"

The consequence of mixture of many other elements with electric vehicles should be carefully considered. It is not a simple issue of one plus one equals two, issues increased exponentially. AC 1 pointed: "*Running a system in a car uses a lot of energy, nearly half of the energy in the electric car is to purely run the electronics, if (you) go to connectivity or autonomous, there would be massive energy required. So the energy will be used only for running a car, this is a big problem*". The battery storage for electric vehicles is the weakness, how it is possible to mix with other features? AM 1 added a statement that the electric vehicle should be considered individually like a normal car: "*Electric vehicles are a different powertrain powered vehicle, there is nothing different with a normal vehicle, so it does not have to be automated.*" But several experts believe the electric vehicle helps other functions well (AM 3): "*It is good if shared vehicles are electric powered. It is not in the traffic control, they can stop on the appointed spaces, but locations are limited, less flexible than shared bikes which could return anywhere they want*."

It seems that the electric vehicle does not really tie in well with autonomous. AC 6 thought: "*The electric setup on fully autonomous vehicles would be much easier, but it is not necessary*." LE 1 supported AC 6's opinion: "*Precision on traditional vehicle is lower than electrics. However, on the basis of steer-by-wire (SbW) technology and electronic control technology, the requirement of precision on fuel powered autonomous vehicle does not that matter*". But NPO 1 had the reverse opinion: "*It is inevitable that autonomy and zero emission vehicles will grow together, as restrictions from access in cities due to air quality.*"

There are several other types of vehicles that powered by electricity. But it does not always work right. Electric bike is a helpful substitution while better for some places: "*Electric bikes seem a good increase in the future, but UK market is sports bike oriented.*" TP 2. However, TP 1: "*…battery on bike and on the car are totally different things.*" For electric trucks, it does not always work well either: "*But transfer it to electric truck is a big leap because the power required, the torque, because the trucks are so heavy, the range becomes very limited if they go electric. The power supply for truck is real real real challenging. It also depends on what they carrying. If it is volume-metrically driven, it works, it is something we forgot with*" stated by truck expert AC 4.

## 6.5 Findings

Traditional automotive manufacturers are on the transition stage through which they suffered both the internal and external pressure and challenge. Internally, the pressures come from competitive peers within the industry and externally from other businesses and institutions who aim to step into the automobility industry. It also from governments and regulators pushing change such as electric vehicles. Therefore, the actions taken by those players are very aggressive and positive, which further dissolve the boundaries between industries. The networks are even more complex than before, going beyond traditional alliances, merger and acquisitions, stake purchase and holdings inside the industry as conventionally defined.

### 6.5.1 Business focal points

Vehicle manufacturers like BMW, Ford and Daimler Group, have expanded their businesses range via capital injection such as minor shareholdings, investments or merger and acquisition.

Daimler's transition strategy is very clear in order to align its CASE vehicle concept. Daimler covers the range of autonomous, electric vehicles including trucks and cars but it lacked an innovative sharing platform. Daimler created its self-owned mobility service platform in 2012 and it thereafter expanded business in other countries i.e. Greece, Romania, France, and regions like the Middle East aiming to expand the vehicle sharing and hailing market. Based on the collected data, it may be concluded that Daimler is very keen to expand its mobility-as-a-service against existing rivals.

Ford has a widely divergent pathway with Daimler but they both contributed to building the autonomous vehicles concept. Ford was one of the earliest companies who participated in autonomous vehicle construction, it also keeps a long strong relation with the acquisition of Argo.AI to developing automated systems. It is also assertive in the creation of the SYNC system award competition to cultivate new start-ups which can fill Ford's special requirement on autonomous system. From the previous case on Ford, it is not as active as Daimler in expanding vehicle sharing and hailing services and electric vehicle contribution, but it is more aggressive on autonomous vehicle research and development.

BMW has been very vigorous in its efforts to build autonomous vehicles since 2016, but the electric vehicle element of CASE seems to be more attractive to BMW's business research and investment strategy. BMW invested in the electric vehicle value chain from the start to the end including raw materials such as the supply of Lithium, charging station installation, battery capacity and storage R&D, and security of supply of cobalt. Nonetheless, BMW was late to the vehicle sharing market and mobility-as-a-service, being active since 2018. In order to overcome this drawback, it later co-operated with Daimler.

Other medium business groups such as Volvo and Nissan are not as aggressive as Daimler. Volvo aims to develop a safer vehicle in line with its brand values. Its cloud connection and voice remote control were introduced into their car earlier than many other firms, and this is considered to be Volvo's significant selling point. Volvo Car, the part of Volvo Group, was acquired by Geely Auto in 2010. Geely Auto has a strong position in the Chinese market, thus Volvo could also benefit from this. Their joint venture LYNK & CO was created for new energy vehicles and sharing and hailing schemes. This is an advanced attempt to integrate CASE as one coherent concept. This type of new energy vehicle which is based on a vehicle sharing and hailing company may be more popular in the future. Volvo proposes a moderate strategy to build autonomous vehicles layer by layer rather than jumping to the fully autonomous vehicle straight away.

Volvo is a good example that shows benefits from an acquisition to create a larger corporate entity. Likewise, Nissan is another successful example which gained a lot from an alliance over the long run, notwithstanding events since the departure of Carlos Ghosn in 2018. Nissan benefitted from the French market from its Renault-Nissan-Mitsubishi alliance straightforwardly. It had first-mover advantages with the Leaf and other new generation electric vehicles so that it grabbed the first chance of electric vehicle market. Nissan portrayed their future vision in 2016 that is to construct a ‘smart street—system—community’ to link mobility in the system and service as a service. Nissan came to autonomous vehicle construction is quite late compared to other manufacturers, but again, the alliance with Renault and Mitsubishi is very helpful, for example with economics of scale in electric vehicles.

Hyundai is an interesting example which also turned to the autonomous vehicle concept comparatively late. Hyundai’s strength is on vehicle connectivity e.g. in-car infotainment system, over-the-air connection, home to car service and vehicle-vehicle connectivity. Also, Hyundai focuses on electric vehicles, Hyundai also tried the CASE concept on other areas such as autonomous flying drones.

Volkswagen Group suffered from the ‘Diesel Gate’ scandal, originating in 2015. Nonetheless, the scandal helped VW by turning the business strategy to electric powered vehicles rather than diesel. Electric vehicles have a large potential to explore because they are supported by government globally. VW invested in vehicle connectivity, batteries, carpooling, and charging points since 2016, much of it mandated in the US, and stepped into autonomous design in 2018. VW has the different pathways with BMW even they both focus on vehicle electrification. This point will be illustrated later.

All vehicle manufacturers are seeking proficiency in one or more areas of the CASE concept in this transition stage. By 2019, the above-mentioned vehicle manufacturers were all involved in the future transportation transformation that was led by ‘Autonomous’ vehicle construction, and other aspects of CASE, but to varying degrees. For instance, Daimler is more aggressive on ‘Sharing’ schedule, BMW and VW are on ‘Electric’, while Hyundai, Volvo and Nissan are bias on ‘Connectivity’. Additionally, each element contains several different perspectives that can be explored. Connectivity, for example, could be narrowly identified as vehicle-to-vehicle, or cloud on-air connection, or smart street, smart system and smart home integration. The connectivity features could also be applied in various automotive manufacturers. For instance, Amazon Alexa system is used in several models of Hyundai, BMW, Nissan, and Toyota.

As to non-vehicle manufacturers, four interesting cases were listed in terms of CASE contribution. NVIDIA and Mobileye are overlapped in that both participated in autonomous vehicle sensors and related devices. Mobileye is widely employed because it is more cost effective while NVIDIA aims to the higher-end manufacturers with advanced features that offered LiDAR for autonomous vehicles. Mobileye helps to develop mapping, deep leaning, and machine learning, while NVIDIA develops fully autonomous passenger vehicles/trucks by virtue of an AI platform. Both have a clear marketing positioning and help to shape the latest level automation and highest standard visualisation and algorithms.

Didi is the product of ‘sharing economy’ as a platform business. Didi has aggressively expanded in both China and the oversea markets. It aims to build an eco-sharing vehicle system with alliance with local and international car manufacturers. However, Didi works like another Uber who plays on the border of current rules, as the correspondent regulations of sharing have not been updated in most countries. These businesses could be replaced by others which plays the game under the frame of current regulations. Even though the 'normal' business for Didi runs well and smooth, they are constrained by regulations. Thus, the weakness of political support may be a hinderance for the innovative conceptions and rapid-growing technology.

Waymo was a pioneer for around a decade to developing its autonomous vehicles. However, due to the rapid pace of technological innovation, there is less time for Waymo to explore such technology alone. Waymo therefore is involved in the area of 'autonomous vehicle networking', it is an extreme case to illustrate how the autonomous vehicle contributes the automotive industry boundary dissolution and network.

Therefore, all parties who intend to take a positive position in the automobility industry are involved the CASE concept. The boundaries are dissolving not just in automotive industry, but other industries were also significantly affected by the autonomous vehicle aspirations.

### 6.5.2 Experts illustrations

To the current competitive situation in automobility industry, SE 1 hold a positive attitude. It is a market choice process, "*That could be a potential future where you get one company that becomes as monopoly in that sector in that area. I think competition is good for now just see how different people are approaching with different ideas, and then eventually see who wins, you know*". AC 3 said, this market "*could be full of energies, but I am talking from many aspects like industrial, technological, behaviour aspect and so on, or it could be full of conflicts, I think at least, government policies and regulation these kind of top-down factors, so it could go either way*". "*(The) industry commercial side, need government policy support, especially private, small companies, they do not want to invest something they goanna to lose*".

CASE is the final result naturally, from AC 7 who is very positive to the CASE elements in one conception. "*Autonomous connected shared vehicle is a technology which will naturally fit current transport regulations*". It is sometimes claimed by others who do not agree based on the current situation. "*The most synergy would be autonomous and connected, I think it will fit well with shared mobility*", by NPO 1, "*I am very confident that the future of autonomous vehicle would be electric powertrain pure electric or maybe hydrogen for large vehicles or longer-range vehicles*". AC 3 agreed on the CASE concept as well but it needs relevant supportive structurers or under a certain condition in terms of existing technology and infrastructures: "*There are a lot of synergies on autonomous, shared and electric vehicles, they are not competing, they are complementary to each other, so far. I think all three is very good. Fewer cars, good environment, with less congestions, within 10 years would be getting better*". AT 1 believed that it will become true while "*in a limited range*", which means "*The possibility of CASE is in a small range, low-speed electric vehicle, controlled lanes. Therefore it decreases the journey's endurance and people are less worried about charging*". AT 1 also claimed the weakness of this CASE "*But this kind of high frequency in a limited area travelling pattern, is an abnormal committing way*". Or it may be possible in a typical country AC 3: "*I do not think it (4-in-1 vehicle) will become true in western country, it is clearly not economical, in terms of materials, in terms of energy in a holistic sense*".

Finally, how to develop the innovative technology either building upon the present infrastructure, or rebuilding a set of new infrastructure to make CASE possible, which is very debatable. TC 4 believe that to efficiently use current infrastructure is very helpful for the future development: "*We started informed technology rather than ground zero, so that we could build upon it and save time*", but AC 7 believed that the technology may be innovative which may require a totally different setup especially on autonomous vehicles "*making autonomous to fit into the current technology is more difficult*." Even: "*The share is based on autonomous, electric and connectivity, which will develop later than all three*" stated by LE 1.

Therefore, the combination of four elements is 'limited possible' temporarily that will happen in a long-term future. The CASE is 'a very interesting' thought but still on the theory stage. Because CASE is considered as not ‘essential’, but to combine these elements in the same vehicle spends exponential difficulty. For instance, autonomous vehicle can be powered by any system, it is not necessary to be ‘electricity’ powered, it applies the same theory to other elements.

Two full length interview manuscripts are shown in appendix 3 (by SE1) and appendix 4 (J1). All available interview answers have been categorised in the appendix 5 which gives an overall picture of the interview.

## 6.6 Discussion

From the aforementioned cases, it shows that there are some linkages between constituent elements, and that the relationships were carefully chosen by incumbent firms. Relationships may get strengthen or weaken over time because of more players joining in the alliances or some players’ quit. Either way, multiple players from inside and outside of the automotive industry are joining in the race to bring to market autonomous, connected, shared and electric vehicles, albeit with one or more different focuses. The characters of the relationships formed, are varied from the business strategies due to business effectiveness, cultural, surrounding changes etc. Therefore, there are multiple strategic options available to the automotive industry, but no uniformity of solutions. For instance, for the ultimate autonomous technology, the driver’s role is removed by Waymo and Ford insists that drivers taking back control is a dangerous behaviour (Wright 2016) as it is considered by GM. “We’re going to try to develop the capabilities while still having the driver as a supervisor, so that we can learn and gather data and gain confidence,” Eric Raphael, GM Programme Manager, and Ford insists that driver taking back control is a dangerous behaviour (Wright 2016).

There are also some weaknesses in the cases, in part arising because of the number of cases involved. The relationships shown in the diagrams lack details such as alliance formation dates, alliance types, and frequencies. Relations may indicate that the players have a cooperative agreement, an acquisition of shares, a partnership, a separate joint venture, or an agreement or Memorandum of Understanding. While most relationships are in terms of product development and technology, some involve actions closer to the market creating new and / or shared revenue streams. Some of the relationships were accounted as a part of the development that has been agreed with each other on specific areas e.g. co-developing fast charging, or research together for next generation of electric vehicles. They are all shown in the relationship diagram. The partnerships exhibit specific functions for each partner in an alliance. For example, car makers offered vehicles; visual experts provided sensors, service carriers provided the basic platform for data management and exchange, and another partner may integrate all products as one. Relations may be iterative after the first foray into cooperation, or alternatively cease for one reason or another. These kinds of ‘dynamic’ relations in the diagram are only calculated once. It thus may not clearly indicate that how deep the relationship is and how many times they have cooperated.

Commercialisation is the ultimate goal for developing new vehicles. The ‘autonomous vehicle’ business concept is designed for multiple purposes that can address transportation and environmental issues, it also triggers personal and societal travelling pattern transformation towards to mobility-as-a-service. Autonomous vehicles ultimately aim to achieve the mass market scale. Car manufacturers are therefore claiming to apply the elements of autonomous vehicle technologies to the business market from 2020.

The CASE revolution is changing the traditional business model (e.g. to sell cars to gain the revenue) to a service-added new role e.g. the additional intangible value added service network (Weiss et al. 2015). Practically, traditional car manufacturers attempted many trials to coincide the requirement of automobility. For instance, GM and Cruise have delivered their first autonomous vehicle at the beginning of 2020 which is under the conception of CASE. The ‘Cruise Origin’ was officially advertised: “It is self-driven. It is all electric. It is shared.” (BBC News 2020).

Although the mainstream automotive players were disrupted by new entrants they stayed a relatively stable, the limited incumbents kept their position and market place. The automotive industry is difficult to disrupt or be replaced via technological discontinuities and innovation. Technology response rates in incumbents are higher and quicker than new entrants in terms of its accumulative knowledge and experience (Bergek et al. 2013). However, autonomous vehicles are not in an established market, it is partially overlapped with new entrants which may leave traditional car makers in a less advantageous position.

Apart from the original automotive manufacturers, new innovative technology integrators also immerse into the automotive industry including original automotive parts suppliers. The automobility industry therefore was led by these three parties which were competitive but also mutually supportive. None of the parties are capable of completing an autonomous vehicle individually. It is a massive challenge to all participants because they all have advantages in this area. As AC 8 said: "*You already got media like Apple or Google, but Tesla already knows its cars are connected and collected automatic data (so) they are slowly increasing their degree of automation to make the car mature so even though an true autopilot is long way off, but I can see how the car connectivity and the automation that the drivers feature forced*."

## 6.7 Conclusions

This chapter described the details of restructuring business models in the conventional automotive industry; and the role transformation of existing suppliers and 'outsiders' to hold the important roles in the new areas; with expert comments on each element. The changes from inside and outside industry help to dissolve the boundaries of the automotive industry. CASE concepts have been pushed by various interest groups by different angles. So one of the hardest pushers are the vehicle manufacturers notably on innovative technology area which is illustrated in this chapter and another pusher on electric vehicle adoption mainly from politics which was illustrated in Chapter 3. Business strategies may emphasise points varied by corporate marketing positioning and many other elements. Traditional car manufacturers bear burdens of brand effect and market share, thus the technology development is system upgraded based with customer attractiveness focused. While new tech explorers like Waymo are more focused on the new technology creation, for example, to challenge the Level 5 autonomy without driver supervision. It is a new concept that releases the drivers from the driving system which is replaced by ‘system’.

However, experts may hold diverse opinions as they focus on the general picture of the CASE concept. Business focus for them is one of the elements into the consideration. The more important, is to balance the overall industry sustainability and society requirement.

# Chapter 7
# Discussion

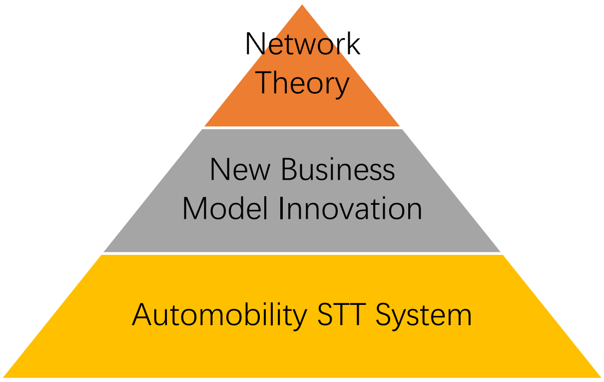
## 7.1 Introduction

Previous chapters displayed the reason why the theories in this study have been chosen, and why the cases and interviews have been selected. The preceding chapters also defined the STT automobility system based on STT theory, identified the CASE pathways from five stages, and noticed that innovative elements and networks emerged from regime confluence and reintegrated in the regime level. This chapter will identify the main findings of how far the STT theory has been integrated with the CASE vehicles concepts one by one, and thus to summarise a general outcome for the research.

## 7.2 Theory exploration

### 7.2.1 The theory relocation

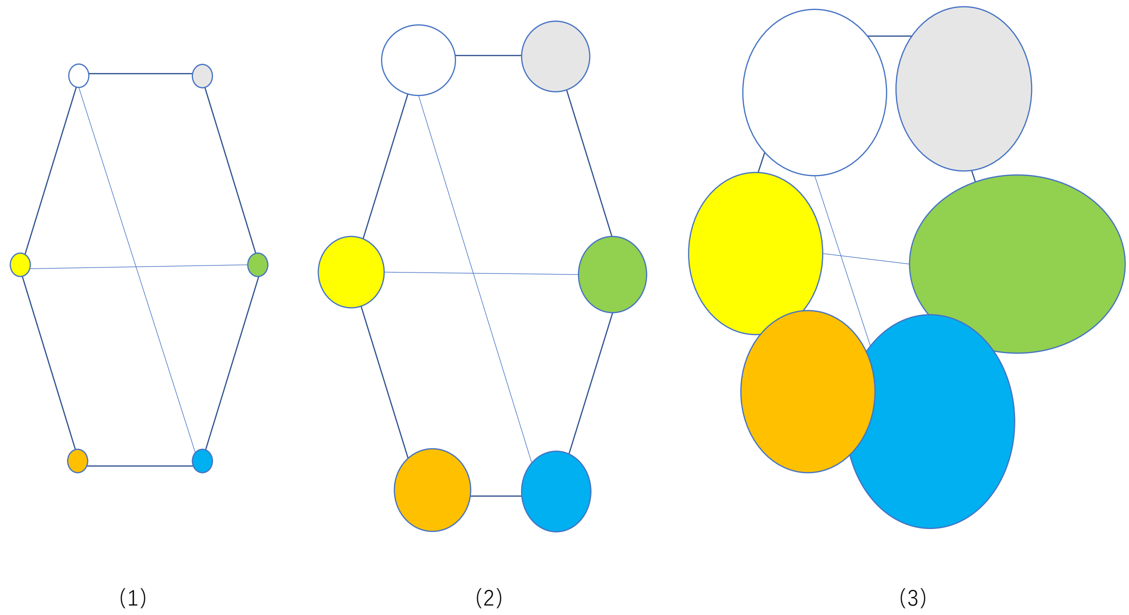
So far, this research has identified the application of network theory in new business models of the CASE concept, then allocated network theory in STT theory at the regime level, and finally defined a new automobility STT system. The relations of the theories shown in Figure 7.1 illustrate this progression. In this relationship figure, the business model innovation arises out of (and partly creates) changes in the automobility socio-technical system. In turn, network theory helps explain and partly creates business models innovation.




Source: Author

***Figure 7.1 Theory Relations***

The networks have emerged due to the collaboration between different enterprises or industries that stimulated the new business model generation just as Figure 7.2 (1) shows. Each colour in this diagram represents an enterprise. It is a dynamically stable structure similar to that described by Geels (2004) in the STT theory regime level. However, as time passes, the boundary of each enterprise is expanding and swollen (Figure 7.2 (2)) to a wider range or invading into other industry. In this stage, the relationship within a community of shared interests is becoming closer but more competitive and comprehensive. In turn, the hierarchy within the network is flattened, and the distance between members are shortened. Eventually, the size of individual enterprise, and methods and directions of growing are less controllable which make the boundary between industries more overlapped (Figure 7.2 (3)).

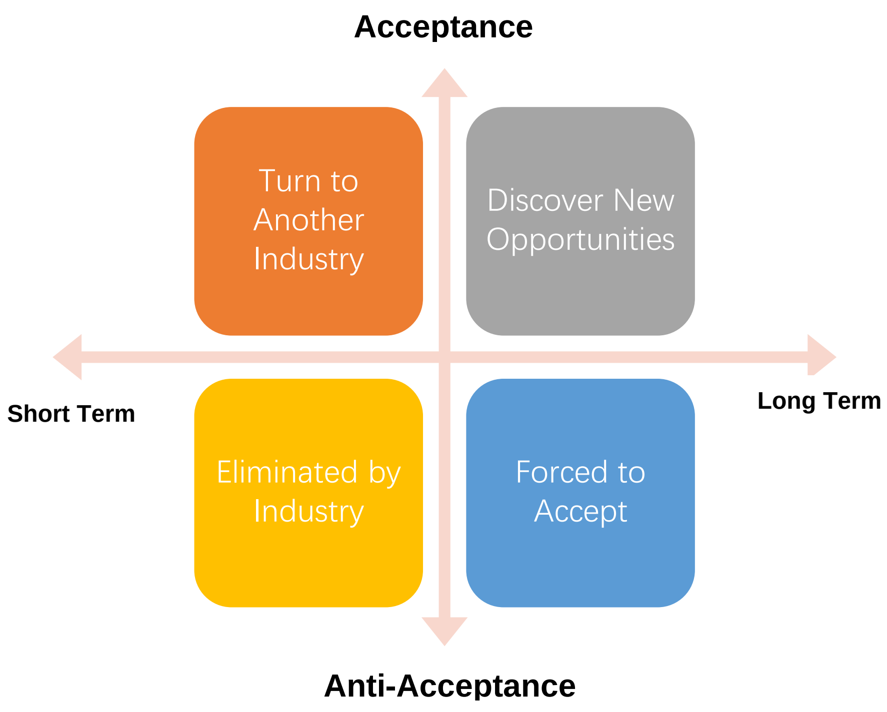



Source: Author

***Figure 7.2 STT Regime Business Boundary Expanding***

Taking the CASE as an example: Vehicle electrification closely links the vehicle industry with the power sector (electricity generation and distribution); while later this concept subverts the attitude of using a vehicle through a new power method so that the vehicle market has to split apart for this novel powertrain. This revolution also influenced the users' attitudes and behaviours, this may involve a culture shock. The vehicle sharing scheme is also a cultural emergence. From taxi seats sharing, to a vehicle sharing and offering on a platform; from a short-range share (one way such as taxi) to a no time-limit sharing; from shared with someone familiar to someone you never know, all these changes are challenging and reforming daily routines. These changes are also driving policy and regulation. Regarding the autonomous and connected vehicles, the revolution of the vehicle industry is to flatten the network, and see the vehicle construction as a mutual activity by all possible suppliers, but still orchestrated by the vehicle manufacturers. Autonomous and connected vehicles may in the future reduce the entry threshold to be a vehicle manufacture, but it is not a business that one company can complete alone. The CASE concept has thus expanded industry boundaries in an ongoing reconfiguration of the socio-technical system. It is therefore the case that business model innovations as the network theory, would accompany technological innovation, and this would facilitate the transition in automobility. This business emergence in this case, appeared in the niche level and regime level coalitions.

It can be seen that the businesses in the original area face the challenge from pressures over time. This is shown in Figure 7.3 with four catagories of outcomes, due to the degree of acceptance in the short-term and long-term. The horizontal axis represents time, from short-term to long-term; the vertical axis is the degree of acceptance. So if a company is unable to accept change and is uable to manage the pressure, it may be elimiated from the industry and gradually fade out of the system. However, a company with weak willingness to change but with some ability to be resilient in the face of change may prevail over the long term, through it must finally accept the change but with reluctance. On the contrary, company with high willingness to accept change and responsed to the pressure benefits both in a short-term and the long-term. In the short-term, to deal with the pressure, the company may turn to help from another industry, to expand another source of income or gain new competences. In a long-term outlook, under the challenge and pressure to the current industry and the elimination of competitors, new opportunities may come out and enterprises may sieze the chance and follow the trend.




Source: Author

*Figure 7.3 New Businesses Growth by Time and Acceptance Rate*

### 7.2.2 The CASE convergent pathway

From a single business perspective, to networks, and to the automobility STT system, much research has been defined within so-called verticals. In the automobility industry, CASE has been introduced as representative for the future of sustainable transportation. Here, the analysis is therefore horizontal: how to analyse the CASE emergence process and combine it with STT theory will be another dimension to illustrate the theory and practice.

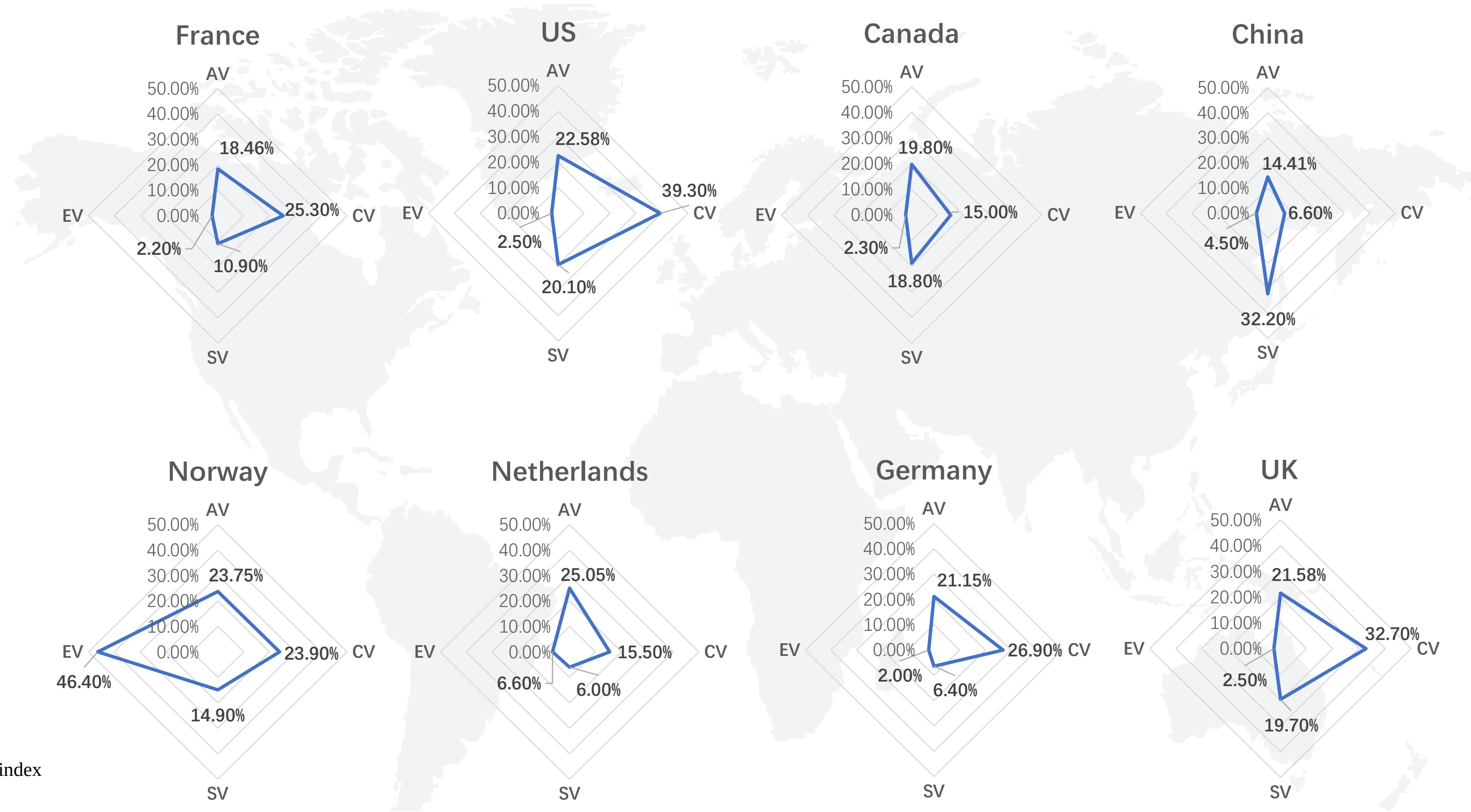
The manufacturers in the automotive industry contribute positively to CASE elements and their convergence from different directions and thus, up to 2020, various forms of the CASE concept have been launched in most business groups. Additionally, automotive companies aim to integrate all the CASE concepts in one vehicle to enable autonomous vehicles with functions of connectivity, electricity powered, and being sharable.

To move to a longer-term solid cooperation around CASE, a few forms of stable alliances have been constructed. For instance, the BMW-Mobileye-Intel alliance offered a foundation for autonomous vehicles construction; and strengthened by Chrysler, Magna, Aptiv, and Continental that joined the alliance later. VW gives another possibility to create CASE vehicle that is via the cultivation of a self-owned (vertically integrated) empire via incubator programmes and investment into start-ups including ChargeX, Keysurance, EcoG, S O Nah, Embotech and Novum. Innovative technology businesses have attracted investments from traditional automotive manufacturers and other parties. The investment into US based technology start-ups surged from $282 million to $4.5 billion in 2018 (Bond 2019b).

To attain economies of scale, vehicle manufacturers are combining for autonomous vehicles: BMW allied with Daimler, Ford partnered with VW. It is a step forward in dissolving the boundaries of ‘independent automotive manufacturers’ from inside of the automotive industry. Relationships, however, are not always solid, many failed collaborations illustrate. For instance, Daimler - Chrysler failed in the merger activity, Ford - GM failed in autonomous vehicle cooperation, Ford - Daimler failed in automotive fuel cell technology collaboration, and VW - Aurora broke up their partnership. The relations on the one hand, represent one agreement or a collaboration from one perspective. The company may have a vast range of business, it may collaborate with other companies from various perspectives. The relations may endure for only a limited period, by the end of contract, or they may continue, or switch to another direction. The above examples show some of the turbulence in the industry, and that experimentation in creating new network relations does not always work.

This situation can be explained from following ways. The relations in this research are counted unidirectional and represent the partial business collaborations of the company rather than entire company to another entire one. They may fail on the vehicle sharing platform integration but may join to develop sensor utility. Another assumption is that to develop and explore the autonomous vehicles is difficult due to the aim uncertainty and imprecision in the concept. The various partners may hold the different intentions to produce an autonomous vehicle, such as whether keeping the steering wheel in the higher-level automation.

So far, many cases indicate CASE could be a reachable goal for automotive manufacturers. There are data abstracted from eight representative countries who are positively contributing to the CASE concept at least in one area (Figure 7.4). The outcomes from the database are drawn as a four-dimensional radar map of market penetration of each element in the selected areas.




AV: autonomous vehicles readiness index

EV: registration as a share of total

SV: share of user penetration

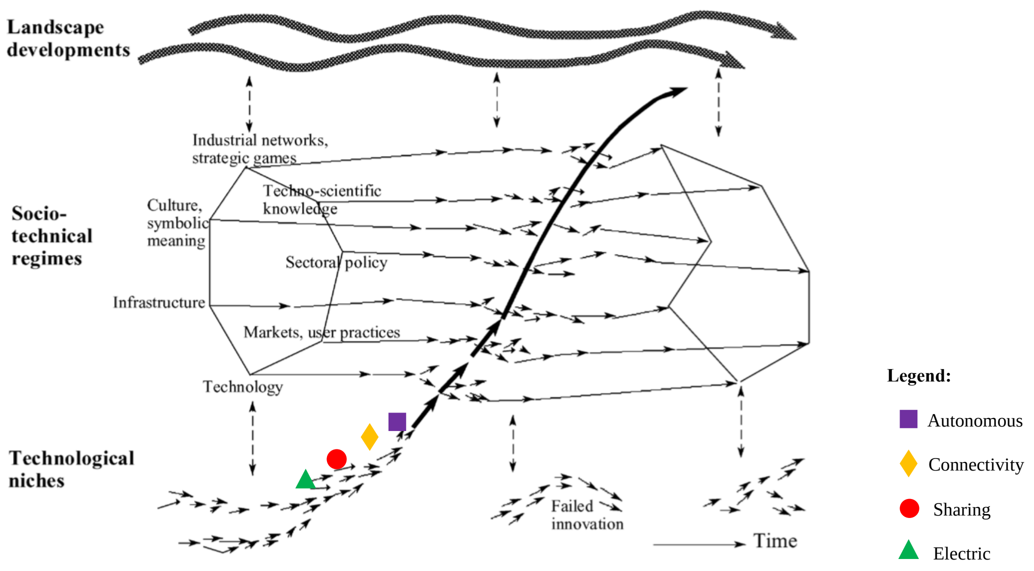
CV: share of user penetration

Source: (Connected Car 2019; KPMG 2019; Ride hailing 2019; Statista 2019a)

***Figure 7.4 CASE Distribution in Selected Countries by 2020***

As autonomous vehicles are not defined in registrations or penetration rates, they were measured through a readiness index. There are some observations for Figure 7.4. 1) Market penetration varied widely, even in geographically close locations e.g. European countries. Strategy, national policy, and market positioning allowed differential result. 2) The general trend from the diagram indicates that vehicle automation took the highest rate, followed by connectivity and sharing, and the last one is vehicle electrification. This is opposite to the media portrayal of electric vehicles and their promotion and stimulation. This is because the next point that is 3) The autonomous features include various types of assistance, autopilot and other features. The definition of ‘autonomous’ is always misunderstood by users and readers, often being interpreted by default as ‘fully autonomous’. It is also because the scale for the ‘autonomous vehicles’ is ‘readiness index’ rather the real ‘market penetration’. Which still represents a high rate readiness on autonomous vehicles ready for the markets. 4) Connectivity is in the second position. On the one hand, it covers a wide range (e.g. vehicle-to-vehicle, vehicle-to-everything, vehicle-to-infrastructure), on the other hand, it covers rapidly growing technologies. 5) Sharing and hailing scheme include the new transport transformation method rather the previous way of sharing – renting. The data thus shows a lower penetration. 6) China has the highest penetration of vehicle sharing and hailing owing to many reasons: terrible traffic congestion, green policy reinforcement, traffic restriction regulations and the high cost to own a car.

Therefore, the outcomes that are shown on the STT theory map in Figure 7.5 are conceptual. Because not all elements have been fully adopted by daily users in the process of accessing the regime level, the elements thus are allocated as niche innovation in the niche level in parallel with being inside the regime. In which, as discussed before, autonomous vehicles mostly approach to the socio-technical regimes, next to connectivity, sharing and the last one is vehicle electrification, but it is dynamically growing very fast now. Each element originally has small sphere and general members to stimulate its growth, while autonomous vehicles have started to break the boundary to integrate all elements.




Source: STT theory (Geels 2002), coloured position by Author

***Figure 7.5 CASE Position Demonstration on Each Element***

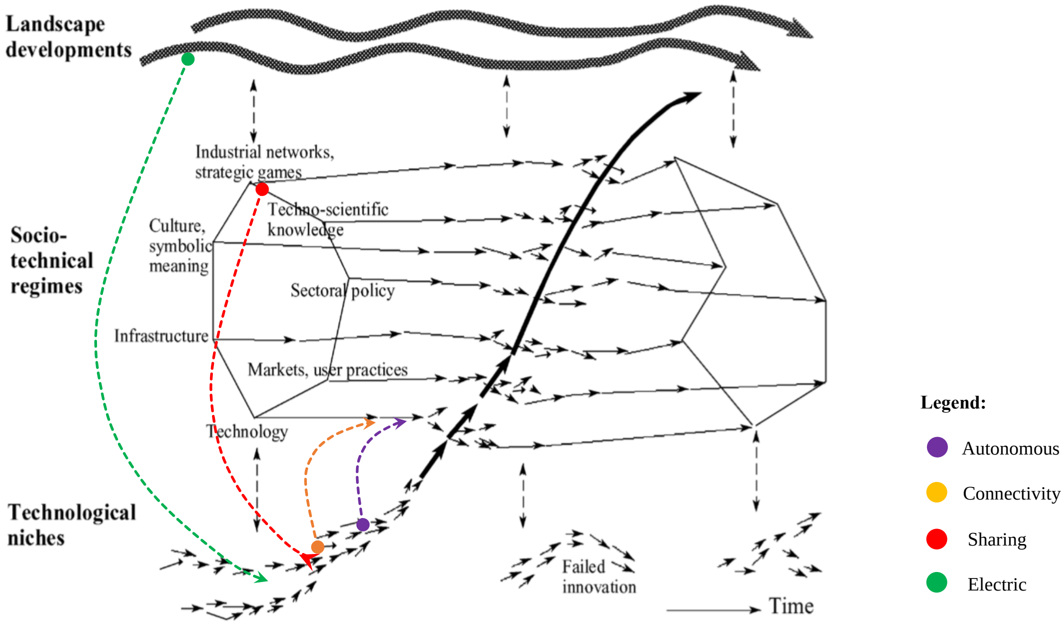
Nonetheless the CASE elements are uneven in application, electric vehicles gained political encouragement and enforcement, aiming to improve air quality, and reduce pollution and $CO_2$ emissions. This type of vehicles is generally officially supported associated with tax exemptions and other stimulus policies. Additionally, electric vehicles have been investigated nationally the National Electric Vehicle Sweden (NEVS) and China National Renewable Energy Centre. However, even in a country like the UK, the market penetration of electric vehicles is still less than 5%, while Norway has the highest penetration rate of new electric vehicle sales at around 50%. Vehicle electrification popularity is less than expected, and the primary reason is that it is significantly restricted by the supportive infrastructure and in-car technology.

In terms of the shared vehicle market, regulations varied country by country or even one city to another. It is mostly affected by consumers' requirements, marketing immergence, advertising, and user experience. Vehicle share schemes comes to the market quite late, lacking standardisation and regulatory support. Combined with other features such as electrification, sharing may protect local air quality and distribute the local traffic streams at the same time.

The leading example of an electric sharing venture was Autolib, supported by the municipal government in Paris, but this programme failed in 2018, losing €300 million. Users complained of high breakdown ratio, and low efficiency to fix technical problems (Matlack 2018).

Autonomous and connectivity features are offered by car manufacturers which can be equipped and upgraded in the new generation of models. In addition, the system is upgraded quite often via software. Vehicle hardware need not be involved in system upgrades delivered as mobile data, so users are not unconvinced.

Therefore, according to the position in Figure 7.5, combined with the political, market, and users' performance, it shows the growing pathway of the CASE in Figure 7.6. The arrow of the line represents the most probable final effect to the corresponding STT level. To keep consistent, the green colour represents electric vehicles, red is for sharing, yellow is for connectivity and purple is for autonomous vehicles. The starting point is identified by a big dot, that is where the force started. Then the arrow on the other end of the line means where the element in question is heading. For instance, political support for electric vehicles started from the landscape level and forced the emergence as a technological niche: which is a top-down impulse line. Both autonomous and connected elements are defined by bottom-up direction of change which are supported by the car manufacturers, developing from innovative niche level to the ordinary regime level. The vehicle sharing pathway is distinctive compared with the others. It was not a policy-driven scheme, rather, it was a market with necessity demand-driven scheme, requiring a quicker technology maturation from technological niche level to meet the rapid development in the vehicle and ride sharing markets. Hence it has the original staring point from the regime level and is applied to the technological niche level.




Source: (Geels 2002), coloured by Author

***Figure 7.6 Pathways by Adoption Method Each Element***

The above illustrated pathway is an average summation. The pathways again vary by country, and by business strategy for each vehicle manufacturer. It is the method and opportunity to achieve the transformation. For instance, electric vehicles are generally promoted by political regulation sustenance, while in VW, it follows the pathway of changing to produce electric vehicles after the diesel ‘shock’ happened.

This pathway is more detailed than the pathways Geels described. In the previous Chapter 2, Table 2 there are L0 to L5, six levels of transition pathways. For instance, if a light shock pressed and resulted in nothing changing, it would be the L0 pressure. In this thesis it is different. The pathways here are more detailed, under the pressure with the specific direction; each CASE element however comes with different directions, origins and destinations. Taking the vehicle sharing as an example, vehicle sharing with fewer regulations and rules to support it, is market-driven (so it generates from the regime level) to satisfy the growing necessity or demand for shared cars, while the relevant technologies are developed (directions from niche level to the regime, with an opposite arrow). From Geels’ Table 2 perspective, the pressures are different as well, mostly in

Level 2 and 3, because Level 4 aims to the replacement pathway which requires a well-developed substitute; and Level 5 pressure was not in the consideration but now is – Covid-19 for instance.

The Figures 7.5 and 7.6, are abstracted from different countries, averaging the global standards. This result could be generalised as the entire CASE in the world. The electric vehicles with the highest encouragement by government could enable higher possibilities for the elements that are less endorsed. Under this circumstance, electric vehicles could gain the benefits from connectivity that supports vehicles to be further controllable by users and also the transport information database. Autonomous and connectivity are highly joined as they need to share the data through connection. This could offer the vacancy to the users who need to rent an empty car. CASE is a good collaboration in this way.

It comes a result that, the CASE elements have different pathways of growth and different strength applied to each element, so that it is very hard to be integrated as one applied into the same vehicles.

### 7.2.3 The STT theory reflection

There were some questions raised in Chapter two:

- What should the environment be defined as?
- What elements could be clarified as ‘landscape’?
- This brings an interesting option, under a societal context: Which element has the most powerful impact on the car industry and which has the least impact?

To answer such questions, the definition under the specific context needs to be clear. In the original STT theory, the environment could be defined as the entire modern society along a time axis. It also could be identified as a specific industry if all elements are covered within a STT system such as in the automobility STT system. In this system, the environment would be the automobility industry relevant system, unitary but with competitive members. In the automobility system, the ‘landscape’ could be the long-term stable context.

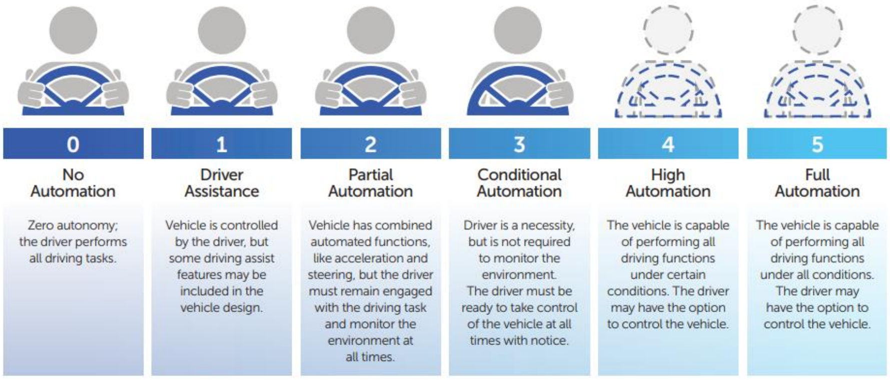
## 7.3 Discussion

The research follows the strategic flow i.e. Figure 5.3, the research flow. This fully explored the positions of CASE from interview and also cases from secondary data. It is a Synthesizing autonomous, connected, electric and shared vehicles is still on the way. The primary challenge is when to achieve full integration. It is a long-term process from perception to building an autonomous vehicle, or build an autonomous vehicle with specific suppliers, partners or providers. Autonomous vehicles cannot be constructed by a single company which therefore has triggered a cooperative-competitive relationship within the automobility industry. Also, it drives an unprecedented chance for new companies and relevant positions to emerge. It is a transformation stage which offers opportunities and challenges. Chip companies, sensor builders, digital technology providers, visual tool creators, route optimization and navigation suppliers, even algorithm integration, AI, topological optimization and so many more specialised companies entered the competition of autonomous vehicle construction.

### 7.3.1 Autonomous vehicles

From 2016 to the beginning of 2017, this period is important for the swift expansion of autonomous technology. The clear declarations of building autonomous vehicles dominated by automotive manufacturers have swept the entire automotive industry. This is a sign of transformation of automobile to automobility that tends to switch the characteristics of an automobile from a fixed asset to a tool of offering additional service and its utility for rent. Since the CASE concept has been built, the corresponding classification and regulations are required. Figure 7.7 is a classification of vehicle automation by Society of

Automotive Engineers in 2017 from Level 0 to Level 5. The boundary between two levels seems distinct such as partial automation or conditional automation in Level 2 and Level 3 respectively, but the context on each level is blurred. This structure gives a general outline of vehicle automation arrangement, but how to match the vehicle to the level is unclear. Each level is slightly advanced on the previous one, but this gap is challenging to cross over. Google has aimed to create a Level 5 autonomous vehicles directly, while BMW and Audi these conventional vehicle manufactures prefer from Level 3 to Level 4.




Source: (NHTSA 2017)

***Figure 7.7 SAE（Society of Automotive Engineers）Automation Levels***

However, the transformation is facing unprecedented challenges. Due to the immature technology and the complicated process of producing autonomous vehicles, the cost is much higher than building a normal vehicle because those vehicles have never been produced before. The willingness to pay the increased cost requires early adopters (Haboucha et al. 2017). For instance, the price for an autonomous taxi is $1.58 to $6.01 per mile, which it is much higher than owning a car for $0.72 per mile (Powell 2019). What is more miserable is that the autonomous vehicles, only ideally under a high level penetration of autonomy, could greenhouse gas emissions be mitigated (Liu et al. 2019). However, higher autonomy may take up to 2030. It needs a giant infrastructure network for support, suitable weather conditions, and high-definition digital maps with updated systems. These weakness were evident both in interviews and case studies (Taylor 2019b).

Official bodies such as the US National Highway Traffic Safety Administration are optimistic about this technology. They declared that “Automated safety technology is going to give us a new path to achieve [our] goals” which is safer road users, fewer injuries and deaths (Wright 2016). Even though the consequences of having fully autonomous vehicles are unclear, it is worth trying to embrace them. Autonomous vehicles are also a stimulus for new regulations to enable and control their use. A prepared regulative framework could address potential issues, and guide a common path in defining future transportation. An open debate on autonomous vehicles is needed to ensure users to understand the benefits and risks, to then embrace novel technologies. City-based autonomous vehicle test permissions are not enough for developing such technology due to lack of complexity of driving conditions (Dawkins and Avary 2019), so user expectations should not be too high.

### 7.3.2 Electric vehicles

Electric vehicles are widely supported by governments with various stimulative policies. However, range anxiety, inadequate charging station networks, price, and battery charging rates are major issues that are considered by consumers (EU electric vehicles 2018; McGee 2018; Rolander et al. 2018; Axsen and Sovacool 2019). Beyond these issues, battery life cycle, electricity generation, and rare metal resources consumption are the hidden issues behind the increased sale of electric vehicles (Stringer and Buckland 2019; UNCTAD 2019; Kamran et al. 2021).

One benefit of growing BEV use is the stimulation to other relevant electric powered vehicles. For example, electric trucks, scooters, and L-category, last mile delivery vehicles, and even electric drone are popular and have great market potential.

For users, electric vehicles are often a pragmatic rather than environmental choice. AM 2, taking of users' behaviour in the Chinese market, claimed *"... they do not care about environmental issues*"…"*they bought electric vehicles especially in 2017 because 1) price subsidies were very high in 2017 for those who purchased electric vehicles. Even though EV has a very high cost, while subsidies help to half the price. 2) The average price of per km could drop down to 0.2 Yuan/km. 3) However, the sales in 2018 are going down because since April 2018, fewer subsidies were available for purchasing electric vehicles." Comparing with the same price range, a petrol-powered vehicle is more cost-effective. "It may take 10 years or more if all the required vehicles are new energy powered. Another reason is that the first-generation battery will be obsolete in 10 years. The cost of battery swap is as expensive as a new electric car*."

### 7.3.3 Shared vehicles

The sharing economy allows people to have extra revenue when they share an asset through platforms, privately and flexibly. In principle sharing solves the land use problem and vehicle usage efficiency issues at the same time. In the centre of London, around 80 million $m^2$ are occupied by cars which is worth around £100 billion in land value (Urban Development Authority 2017). The share also affects the whole number of vehicles on road, "*removing the numbers of vehicles in circulation, or making car space usage more intensive, or taking some cars off the road, are all the positive impacts for sharing*," TP 2 stated.

However, vehicle sharing is more complex. For instance, Autolib availability was defined by the vehicles' range and the distribution of docking stations. The limited number of parking stations significantly affected the users' choice and vehicle mobility. An automobile should be parked where the parking place is easy to park and find, the most important is to meet passengers' requirements. Additionally, for last mile service, the operation strategy is important "*we need to know the entire supply chain and how to make it, then we can solve the first and last mile problem, completing in different ways*" stated by TC 4. The different viewpoints from the users, *"... the most meaningful aspect of sharing is quick response at any time and that is the main issue on sharing*" AC 2 pointed out.

### 7.3.4 Connected vehicles

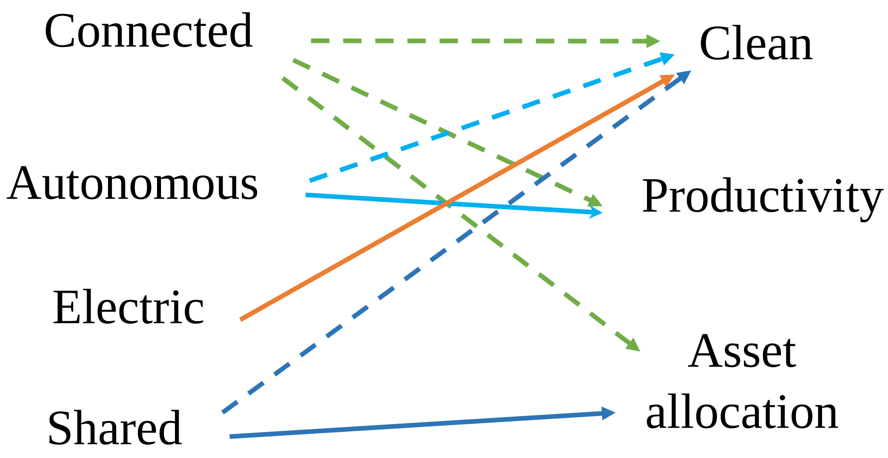
Connected vehicles enable the communication of a car with other nearby vehicles, infrastructures and drivers. However, it is difficult to define a purely connected vehicle because cars are increasingly being equipped with more advanced technologies. Cars have some functions of connectivity at present. Nissan, Volvo, Honda, Volkswagen, and other companies are integrated with the internet and wireless available in the cars, together with more features that are offered to make the car easier to control. Hence, they have cooperated with IT companies, accessory companies and even anthropologists to make their vehicles more intelligent and reliable.

This mechanism plays a fundamental role in the on-demand transformation of mobility as a service. It was estimated to generate by only core service around $560 billion per annum by 2035 (Weiss et al. 2015). Vehicle connectivity is not only a car connecting with the cloud, sharing databases and algorithms, but also an extension from the home to outside via the smart grid (Weiss et al. 2015). However, most of the connection features are rarely used or considered when operating a car. The additional features attract technical enthusiasts who would always follow the connectivity.

Connection in information exchange is the mostly considerable issues among common users (Kim et al. 2020) whereas it is the essential step for autonomous vehicle in judging and making decisions. The huge amounts of data help to customising the 'mobility as a service' offer from IT companies.

### 7.3.5 The CASE vehicle

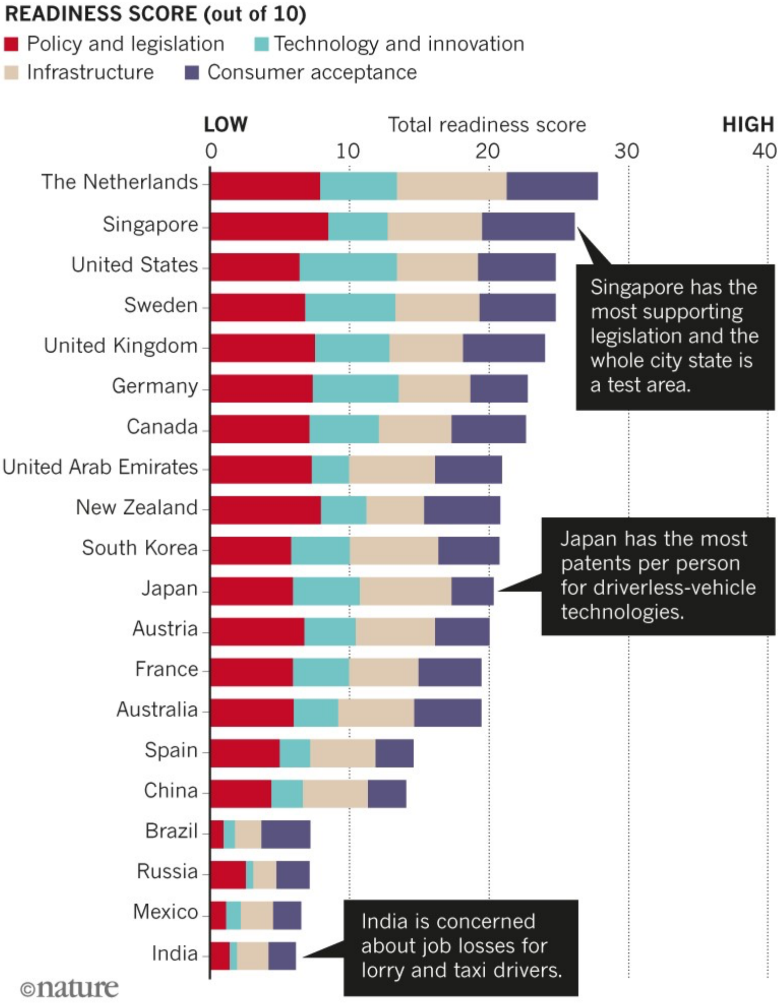
The CASE vehicle has been created to address environmental and personal issues. "*I think the concept of mobility is transferring people from A to B as cheap as* *possible,*" IE 1 stated. By this point, the combination of CASE should have a higher efficiency. BC 2 has matched the functionality with CASE that is shown in Figure 7.8. The dotted line refers to potential benefits or possibilities, whilst the solid line indicates the feature has been locked in the element. Three functions have been addressed by automobilities which are clean, productivity and asset allocation. Environmental issues have been claimed to be tackled by CASE elements especially by electric vehicles, while autonomous vehicle is for productivity and vehicle sharing could help the asset reallocation. The connectivity feature is the one underlying all features, as BC 2 stated, it acts as a base for all functionalities.




Source: interviewee BC 2

***Figure 7.8 Purpose for CASE Allocation***

Currently connectivity has been shown in technological innovation and infrastructure development. Just as BC 2 stated, connectivity has undergone through all features above, it was also shown by Nunes et al. (2018) as Figure 7.8 illustrates. This is a readiness score that demonstrated the locations in the world most able to achieve vehicle autonomy by four categories: policy and legislation, technology and innovation, infrastructure, and consumer acceptance by country. Infrastructure seems to be evenly developed in the top 16 countries (Nunes et al. 2018).




Source: (Nunes et al. 2018)

***Figure 7.9 Road to Autonomy Readiness Score***

CASE elements are intertwined somehow. "*Mechatronics make intelligence possible and accessible*" AT 1 said. The same statement announced by Welch and Barr (2018) is that the autonomous vehicle was better powered by electricity. Waymo, one of the leaders in the fully autonomous vehicle arena, has collaborated with Honda to test electric autonomous vehicles (Welch and Barr 2018). "*It's all about efficiency, if you can maximize the efficiency in resources, revenue, time and people, it is just natural, where it just progresses.*" SE 1 explained how CASE could achieve a higher success.

Therefore, the boundary of the automobile industry is changing because of CASE integration. "*The industry frontier is being reshaped and redefined into an emerging consensus, and there are the certain types of businesses that would likely and will pass* *the future for shared mobility and freely autonomous vehicles. All these things will reshape the industry,*" IE 1 stated. "*CASE seems to be a helpful heading that the industry works for the boundary level, it helps to explain a number of parallel and in some cases overlapping trends that are visible from outside of industry and very tangible from the inside of the industry, in practice they are quite complex,*" BC 1 added.

However, to commercialise the autonomous vehicle requires too many synergies. The automation of vehicles would be "never global" and it needs "latest-generation mobile infrastructure everywhere, as well as high-definition digital maps that are constantly updated. You still need near-perfect road markings," said Volkswagen Head of Commercial Vehicles, Thomas Sedran (Taylor 2019b). Not only for vehicle manufacturers, the entire supply chain has been changed and challenged. It is also stated by TC 4, "*because we are in the transition stage, our supply chain team has been required in the project… largely, our key focus of interest at moment 1) around supply chain market failures and our ability is to diagnose those failures and value them. i.e. what the impacts cost, and communicate that value to the industry financial service sector 2) another project we are considering at and can gain in terms of financial services is that to help smaller organizations obtain investment.*"

However, for consumer markets, users have different thoughts compared to production providers. Users prefer vehicles that could maintain the same functionality, at least *"... close to or the same as existing methods (refuel time)*" to feel there is something not changed too much, AC 2 said. "*When the new energy vehicle (performance) has no difference with traditional vehicle, that is the time of breakthrough,*" AM 5 explained. To expand the consumer market, companies could "*do it in a very innovative way.*" However, technologically from the current vehicle market, to develop an advanced vehicle system is never going to be easy. "*Changing technology is difficult for the mass market. To make two changes in parallel is more difficult. Autonomous and electric is difficult; it makes sense from customer side (like a package) which make their life convenient but from an engineering perspective it does. It does not dramatically shift users' behaviours,*" BC 2 explained.

Therefore, the relations of purchasing vehicles in the short-term from the consumers perspective and the environmental long-term goal from the governmental guidance perspective need to be balanced. "*The decision-making notions are distinctive via consumers and government. The former is myopia while the latter is providence*" AC 2 commented.

The interesting consideration for both Chinese interviewees and UK interviewees is that both are considering that another country is more suitable for CASE application in a mass market. "*The cost of CASE is highly relevant while it can be perfectly achieved such as in Europe first and then US*" TS 1 said, and the interviewees in the UK showed the opposite opinions. This owes to the asymmetric information and realities in each country.

However, the CASE concept neglects an important emergent feature in contemporary economic and policy spheres: the circular economy. Indeed, we put the theoretical view forward that only by seeking to develop a circular business model, will there be a true synergy for all the elements of CASE. The result is a very different vision for future mobility, in which electric vehicles are indeed central – but perhaps not in the form that we currently see. More than 10 models of purely electric passenger vehicles will be developed with investment of around $11 billion by 2025, €500 million for a second battery factory in Kamenz, Saxony for enhanced battery R&D for creating a whole electric vehicle production system (Lambert 2017a).

## 7.4 Conclusion

CASE as stated, is a transformation from the automobile to automobility which requires the multiple incentives and changes to business. Traditional vehicle manufactures are still the main participants compared with other new entrants. "*The advantage in traditional car makers other than many ICT companies is the hundred years of cultivation. The tech companies may not pay much attention to drive mode, comfortable capability, breaking distance, stability, or safety aspects,*" AM1 believed.

However, policy consistency is another issue that is encountered by most long-term projects such as building vehicles. "*The policy in this country (UK) can be changed quickly, so it lacks policy continuity. (The industry people) We want government's stability*" AC3 claimed the same issues.

***Table 27 Impetus to CASE Conception***

| Item | Connectivity | Autonomous | Shared | Electricity |
|---|---|---|---|---|
| Pusher | Car manufacturers | Policy + car manufacturers | Users | Policy + users |

Source: Author

As previously discussed, CASE has been encouraged by different groups of interest holders as Table 27 illustrated. Just because of these uneven incentives, the combination of CASE is difficult. Autonomous vehicles bring more 'legislation issues' while connectivity is 'proper business cases' such as in Renault-Nissan (Automotive News Europe 2016b). Therefore, the uneven growth of CASE, academia may act to a lubricate in the between of vehicle manufacturers and policy makers to help to negotiate information. "*Our job is fundamentally to make sure that we catalyse technologies that develop in academia, in businesses as well but make sure that joining through the academic benefit, at the end we have academia network* "TC 2 describe the functions they acted in the middle of the different groups.

"*The conflicts are more. Acceptance, how you manage these transitions, the social and conflicts with the ways we own vehicles and use vehicles and purchase vehicles, is try to get a mindset change, but then also understand how ideally vehicles would be used to kind of connect with autonomous shared mobility way making that acceptable needy from people, I think there are lots of barriers both from managing and introducing technology and around social barriers.*" NPO 1 stated.

Overall, it could be concluded that system convergence is not a merging of equals necessarily, even though it is a neglected aspect of socio-technical transition. Rather, in this case the automotive industry has remained broadly dominant (at least so far), and the emergence of a 'new automobility' has been relatively limited despite the cross-competence networks created.

# Chapter 8
# Conclusions

This research has applied Socio-Technical Transitions Theory (STT) to the case of connected, autonomous, shared and electric (CASE) vehicles' integration vertically (by country) and horizontally (over time). Theoretically, the CASE vehicle is an achievable goal that stimulates the transition of an established stable routine lifestyle to be more energy efficient and sustainable.

This chapter concludes the whole research by returning to the research questions, highlighting research contributions, and forecasting potential future research that is based on the current research limitations.

## 8.1 Research Questions and Answers

**RQ: How far can STT theory help in explaining the emergence and future prospects of CASE vehicles?**

First of all, it is worth to identify that STT theory has been successfully applied in a lot of arenas, such as energy, water and sewage systems, food production, housing and transportation. Among all studies, the historical archival case studies have taken the highest proportions. This research programme is different compared with those historical archival methods. It is challenging from both methods and methodologies because it applies STT theory in a future (CASE vehicle) and dynamic scenario (on-going data collection procedure). For example, the real-time data collection is more difficult than retrieving the historical archived data, with the lack of corresponding rules and regulations. With historical research it is easier to determine which events are significant, and which data illustrate the transitions processes. In real-time, forward-looking research there is a great deal of data, but it is more difficult to portray a clear narrative.

The STT can be applied in the future context in a general proposition. The major reason is that automobility system is acting in vehicle-centralised society which is similar to the STT theory examples that have been applied in the previous empirical cases in the literature, with three levels of the multi-level perspective. The vehicle-centralised system embedded relevant elements such as culture, policy on the stable layers, daily routines on the regime level, and the new technology updated and required on the niche level. Even though the dynamic future context seems to lack data support, the timeline is relevant. Under the passage of time, the investigation could show the mutual reaction between the three levels, also between each element member. This also shows the business cluster emergence, coalesce, and network. On this point, STT theory fits on the future prospect of CASE development.

There are also some unexpected findings. The first one is the redefined automobility socio-technical system replacing the traditional automotive socio-technical system, which is an additional finding when we expand the theory. Another additional finding is that innovation convergence is not only at the niche level, it also could emerge from the regime level, between different industries, and under the catalyst of new businesses interests such as with the CASE concept.

***a) To what extent are connected, autonomous, shared, and electric technologies, integrated into one vehicle, to be commercially released on the mass market from around 2020?***

In practice it is difficult to define the CASE features and its application range. To some degree, CASE vehicles have already achieved phone-to-vehicle connection, electric battery power, driver assistance systems and ride and/or vehicle sharing. But the integrated CASE as one with highly autonomous vehicle is very difficult to be released in the market around 2020 or even 2025. The release time has also postponed by vehicle manufacturers who have previously acknowledged plans to commercialise autonomous vehicles.

CASE in one vehicle is a remarkable concept that could gain benefits from synergies between the constituent elements, but it is very hard to concurrently achieve. As discussed in the last chapter, the uneven progress of CASE elements has made CASE integration more difficult. In addition, the full integrated achievement of CASE is not entirely within the capability of the traditional automotive industry, it requires a transition process to create a new form of the automobility industry, with multiple external partners and related developments. Additionally, none of the elements of CASE can so far be claimed to be entirely sustainable, which means the integrated CASE would not be 100% sustainability currently.

It may be additionally claimed to help environmental sustainability through the application of CASE elements individually or through two or three combinations by reducing resource waste, improving air quality, enabling a higher proportion of renewable energy generation, requiring less land use, and improving vehicle efficiency to reduce mobility carbon emission. The higher achievement may be reached by CASE elements combined in one vehicle, that could address the above issues in the future. It is assumed that the possibility of the enrichment of STT theory has been shown by the addition of network theory and business models theory; but empirically, CASE vehicle as one commercialized to the mass market is less possible in the next few years.

***b) What are the potential business challenges pertaining to the integration of CASE technologies in one vehicle?***

Nevertheless the above issues, the CASE in one vehicle is a conceptual goal but achievable. The potential benefits of CASE are 1) the mutual benefits within the CASE elements, 2) the origin of each elements of CASE is to improve sustainability so the CASE elements combined in one should be significantly greater than the benefits of each individual element, 3) the CASE concept has been completed by two or three elements in integration, CAVs for instance, which already have been applied in the current circumstance.

The flaws of CASE include lacking the political support. Electric vehicles are widely supported as it claims energy replacement with less waste and consumption, and environmentally friendly performance; CAVs are gradually supported by state government e.g. UK and US, because the technology development needs assistance. Vehicle and ride sharing schemes, however, are fast growing and mostly market-driven but without official support. Therefore, the CASE in one vehicle may be less officially supported because of its imbalance.

The ultimate goal to build an eco-transport system is probably impossible to achieve, including consideration of the infrastructures needed, or the capabilities of the system elements such as software. So the realisation of CASE, is a long-term objective. However, CASE could be a step to building the eco-transport system, to seek which elements are more suitable for such system requirements and which are not.

***c) Any supplementary theories needed beyond STT to explain how these CASE technologies have been developed and brought to the market?***

To explain how CASE technologies have been brought to the market, Network Theory and Business Models theory have been used. The Network Theory scrutinizes the dynamic relations' emergence, collaboration, and fracturing. It intermediates the broad theory of STT and the detailed resources of business model innovation. It also further explained in which level the relations came out and pertained. The businesses models are used as an agency to explain how the businesses have combined and / or conflict with other existing items in the market. The exploration of the new market needed the different strategies, business positionings and target groups.

For the research, there are some generalisable findings as well to other empirical domains. For instance, the energy STT system could be investigated just as automobility STT system, and the food STT system for similar processing and findings.

## 8.2 Contributions of the Thesis

The contributions and implications of this research are summarised below. First, the contribution of each chapter is summarised. Then thematically, a brief summary of the contribution of the whole thesis is given.

Chapter contributions:

- **Chapter 2:** This chapter has three contributions. 1) It re-defines automobility as a special STT system because it contains all elements that a STT system requires. 2) STT macro framework enables detail expansion in each level and the interactions in between. Therefore, it offers space to explain new confluences and emergence between regimes with boundary dissolution. 3) The network theory has been added in the STT theory to bridge the single business and the big picture of STT theory so as to enrich the details of boundary confluence. This chapter helps to identify the new business model in the transition stage, horizontally over time and vertically through technical innovation and political stimulation. A progressive pathway has been summarised for the boundary dissolution that offers critical evidence to both industry and policy makers to know how transition happens.
- **Chapter 3:** This chapter laid a political background for automobility transition by geography. It enhances the evidence to STT theory from policy perspective in three levels (landscape, regime and niche). This chapter gives an updated political background about CASE vehicles in different countries. It gives a reference to other countries and helps to develop the correspondent regulations and rules.

- **Chapter 4:** This chapter gives a general background of current context inside and outside automotive industry that 1) explained the boundary expansion in automotive industry regime and its overlap with multiple industries through critical examples; 2) integrated the network theory with STT theory by illustrating process of transition from automobile to automobility. This chapter enables the automotive industry players to 1) know the change and pressure currently faced; 2) acknowledge the transformation that should be carried within the automotive industry; 3) demonstrate that the CASE vehicles opened the boundary of automotive industry so that it offers opportunities and challenges concurrently.
- **Chapter 5:** The mathematical chapter supports the theory allocation and helps data collection methods so that it was decided that the secondary data formed the frame and the primary data filled the details of different opinions. This chapter helps to allocate the industry in a right position ontologically and epistemologically which refers the correct methods to collect data. The data helps industry build the right business strategy and marketing positioning.
- **Chapter 6:** This chapter explained different case strategies that located in the correspondent theory levels. The represented case studies show different marketing strategies to deal with CASE vehicles, it services the knowledge of the competitiveness within and outside the automotive industry. It provides the cases of business model strategies from various interest groups on different stages. The results show that positioning the corresponding markets and techniques are necessary to benefit more from a clear transition pathway.
- **Chapter 7:** This chapter provides the summary of the entire research to highlight the purpose of CASE build and contribution both in theory and practice. The findings 1) analyse the real users necessities by academia, users, experts, and production providers 2) provide what the industry can offer and the current policies are 3) bridge the gap between established policies and industry requirement, and the gap between users demand and industry's offering 4) also provide the knowledge gap between real and practical e.g. electric offering and buying.

**Thematic summary**

There are three major contributions and implications of this research which summarised as follow:

The first contribution is applying the Socio-Technical Transitions theory in a future context. The most common usage of STT theory is to illustrate the theory by documentary or historical cases, while this research applied STT theory in a future dynamic context, using on-going data to demonstrate how transition achieved. In the process of the transition, it was also identified five stage of transition pathways to complete the transition. In this research the application of STT theory into a dynamic automotive industry enables more possibilities to illustrate the transitions from automotive industry to automobility industry with the competitiveness but collaboration relationships among traditional automotive industry with automobile parts suppliers and ICT companies, which indicates to the second contribution.

The second contribution of this study is applying the Network theory into STT theory as an intermediate to clarify the transition realisation. As competitive but collaborative relations between all members on the transition stage, the boundary of automotive industry was dissolved by the permeation of elements from other industries. The business networks exist in both niche level of the STT theory and also regime level. Participants shared the 'automobility' arena with their merits but intertwined each other. Owing to the competitive and collaborative relations, the hierarchical relations (suppliers and dominator) gradually become flat patterned collaborative relation. The network theory helps illustrate the change and reform of the relations. It is therefore a result from this research that innovation convergence not only is evident in the niche level, it also could be observed in the regime level, between different industries, and under the catalyst of new business relationships around the CASE concept. The innovative CASE concept could be grounded in the established industry regime but also expanded the current industry boundary to create new possibilities. This expansion across the regime boundary may be generated by technology iterations (technology push) or by markets (demand pull). This insight is the consequence of applying the network theory in the STT theory at the regime level. From the theoretical perspective, all elements are intertwined with each other, and network theory is used to explain the relations in between. From an empirical perspective, network theory explicated boundary spanning from the automotive industry to an ‘automobility industry’ that comprises more complex elements that were previously belonging into the other boundaries.

The third contribution of this research is testing the possibilities of connected, autonomous, shared and electric (CASE) vehicles integrated in one vehicle and releasing in the market beyond 2020. The result shows that the uneven development of CASE elements made CASE in one vehicle more difficult specially to circulate in the mass market. This is due to the variety of the local authority concerns, and relevant supportive rules and regulations. To unify the national wide regulations is essential to develop CASE vehicles.

## 8.3 Limitations of the Thesis and the Future Research

The world has been changed rapidly in the past decades. Technological innovation impulses the society into the Industry 4.0. The merit of this research is that it is data intensive and topical, while it is the weakness of the research as well because the changes of the dynamic relations. The data therefore is highly time-sensitive which means the relevant data is validated within a short period time. This change can be seen in interviews particularly, the attitudes of interviewees are varied in terms of their updated knowledge. When the interviews were conducted, interviewees believed that CASE would be a remote goal to achieve. But by the just beginning of 2020, half a year after the interview, GM published its Cruise self-driving shared ‘Origin’ model just for sharing the ‘vehicle experience’ car rather a product or a property to own, which makes a step further to achieve CASE elements integrated in one vehicle (BBC News 2020). The rapid change along with developed technology can be reflected in the potential consumers as well. For example, the willingness to pay for the newest technologies is increasing over the years. The cases are still increasing after the research data collection cut-off date, the development of technological innovation is even faster than ever. To reduce this limitation, this research could be re-tested when changes are more stable.

There is also some improvement space for the interview method. Interviewees were selected because they have experience or knowledge of CASE vehicles, it is a narrow selection. The data therefore may present very representative positive opinions. Thus, interviews could be more diversified and expanded to different interest groups such as policy makers, national infrastructure builders, entrepreneurs, and more environmental protection experts that might have a more critical view. The interviewee groups were only conducted in the U.K, and China, interview CASE vehicle developed countries to provide a more representative sample. Additionally, the sample size can be wider, and cases could be more inclusive such as Tesla. For the data collection, the semi-structured questionnaire is a good method to unify and accumulate all interviewees' opinions. The questionnaire could be conducted as a supplementary method that helps to quantify the measurement of each element.

The development of theory combination and maturation is fast. Before this thesis has been competed, there is limited literature that has combined networks with socio-technical transitions theory. The studies have been completed by Budde and Konrad in 2019 who anticipated future fuel cell innovation under the dynamic network and transitions circumstance, which showed STT theory can be combined with network theory (Budde and Konrad 2019). In this case, the theory could be expanded from different perspectives in the future. The STT theory is successfully applied in the future case, and CASE vehicles integration, it could be piloted on different commuting tools such as electric drones, electric trucks and autonomous delivery cars etc. In addition, STT theory could act as a perfect intermediate to explain the ongoing cases as well, the effect of Covid-19 to society and travelling behaviours. Covid-19 is a sudden shock that highly disrupted the existing routines globally. It is expected that, the post-pandemic routine would be a 'new normal' within a period. The shock gives a pressure from landscape such that transition pathways may be stopped or delayed or even accelerated. Hence, behaviours such as vehicle sharing, may be changed again to coincide with the shock to stop the virous spreading (Wang and Wells 2020).

# Appendix 1

Ethic Form

**ETHICS 2**

Cardiff Business School
Ysgol Busnes Caerdydd

Full ethical approval

**For guidance on how to complete this form, please see Learning Central – CARBS RESEARCH ETHICS**

**Once complete, please send this form and all other relevant documents to the CARBSReserachEthics@cardiff.ac.uk mailbox.**

**If your research will involve patients or patient data in the NHS then you should secure approval from the NHS Health Research Authority. Online applications are available on http://www.hra.nhs.uk/resources/applying-for-reviews/**

**NB: Safety Guidelines for researchers working alone on projects – please go to this University's web link to learn about safety policies - http://www.cf.ac.uk/osheu/index.html**

**Name of Lead Researcher :** **Liqiao Wang**

**School:** Cardiff Business School

**Email:** WangL45@cardiff.ac.uk

**Names of other Researchers:**

**Email addresses of other Researchers :**

**Title of Project:**

Analysis of autonomous and connected vehicles from a socio-technical perspective

**Start and Estimated End Date of Project:** 1st April 2018 – 30th June 2019

**Aims and Objectives of the Research Project:**

This project focuses on how sustainable future mobility (e.g. autonomous connected and electronic vehicles), which is intended to help to reduce environmental burdens such as $CO_2$ emissions and increase human health and quality of living, will be achieved through restructuring of the automotive industry into a new socio-technical system. The primary data will be collected by semi-structured interviews and on-line questionnaires. The aim of this research is to analysis 1) potential customers' attitudes, and 2) manufacturers' current position and future plans.

**Please indicate any sources of funding for this project:**

### 1. Describe the methodology to be applied in the project

The overall thesis will be using qualitative methods involving interviews, questionnaires, case study and secondary documentary analysis. The former two methods will be used in primary data collection and latter will be used throughout the thesis.

The interview will be designed as semi-structured as firstly, having a structure is advantage to track all questions on the right trajectory, secondly, it has abundant space to let interviewees enrich their answer and finally enables the researcher to explore deeply. Typical interviews will last between 45 minutes and 75 minutes, and may be in person or via telephone.

Secondary data will be collected from major mobility expertise websites (e.g. Automotive News, Newspress, Electrive) and professional official websites such as Reuters and BBC News. In addition, reports will be obtained from automotive companies, consultants, NGOs, and others active in creating the socio-technical transition of the industry. The reliability and validity of data resources are reasonably guaranteed, triangulated and traceable by virtue of using diverse sources.

### 2. Describe the participant sample who will be contacted for this Research Project. You need to consider the number of participants, their age, gender, recruitment methods and exclusion/inclusion criteria.

In this research project, sampling methods are based on purposeful selection. The research will target therefore experts in the media, in consultancy and academic practice in the first instance because these individuals are both relatively easy to identify and have a good overview of the changes underway in the industry. Thereafter the research will involve those active in policy-making, and in the industry. Those active in the industry (including vehicle manufacturers, suppliers, and new entrants) have more detailed and specialised knowledge, but are often less forthcoming with information because of concerns over confidentiality. The research will identify those individuals who have spoken in the public domain (e.g. in media interviews) and who might therefore be willing to assist in the research.

Key academics will be asked to give interviews, mostly those concerned in their research with the future of mobility. They will be contacted though email to request face-to-face or telephone interviews. The same approach will apply to media specialists, consultants and NGO representatives.

Business managers and policymakers are crucial as well in entire project. I will contact them also for face-to-face or telephone interviews.

The generic semi-structured questionnaire will be adapted to suit the expertise and insights of the respondent. The overall central theme will be to understand the respondent view on the significance of emergent technologies such as autopilot software and autonomous vehicles, connected vehicles, electric vehicles, and the offer of mobility as a service such as mobility sharing and hailing services. It is expected that in discussion some more detailed matters may arise, for example battery safety may be discussed by some respondents.

There will be no discussion of personal matters, and no personal data will be recorded. All interviewees will be contacted through interviewers' school email which is WangL45@cardiff.ac.uk via an encrypted computer (generally will be my personal laptop and office's desktop), to make sure no one else could access the data resources other than myself.

### *3. Describe the method by which you intend to gain consent from participants.*

Before the interview, a confirmation letter will be supplied to interviewees to ensure they agree the confidentiality protocols. On the interview, before starting, interviewees will be asked if they agree to recording of the discussion. Transcripts of the interviews will be made but only be used in this thesis. All interviewees will be provided with a research ethics statement that makes clear they may withdraw from the interview at any time.

If the required, PhD thesis and findings could be emailed to interviewees. Also, the findings could be obtained by supervisors and other participants.

The invitation letter will be as follows and interview questions will be attached at the end.

Dear Sir or Madam:

First, thank you for your time to help us in this research.

We are conducting research on autonomous, connected, electric and shared vehicles with focus on business and political side point views. Researcher will interview you by phone/face to face data collection. It is an essential part to complete researcher's PhD theses and thus we value your professional insights into the evolution of the automotive industry. You could delate/destroy/cancel any part of the interview if you do not want this part showing in the result. Your responses will be entirely confidential, and you will not be identified personally in any outputs. We will not use the data for any purpose other than academic research. We do not seek any personal information. A consent form (shown in attachment 2) will be sent to you or given to you (if face-by-face) to confirm that all data and confidential information are protected and held by author with your permission, there is no data reuse or leakage permitted.

If you would like to receive our further investigation/research details, please leave us a note. You may withdraw from the survey at any time and refuse to answer any question should you wish.

Thank you for participating this research.

Best wishes,

Ms Liqiao Wang

| ***4. Please make a clear and concise statement of the ethical considerations raised by the project and how you intend to deal with them throughout the duration of the project. (Please use additional sheets where necessary.)*** |
|---|
| All relevant steps will conform to the ethics guidelines from the Association Business Schools (ABS). Anonymity and confidentiality will be guaranteed for the respondents in both processing of data, and in quotations. Respondents have the right to refuse to answer any question during the session.<br><br>Permission will be sought for notes and recordings from interviewees before the session. Respondents will be asked if they would like their family name to appear on the thesis either as evidence or quoting. If not, the name will be made anonymous or translated as Respondent X, to keep respondents' confidence.<br><br>All data will be retained by the researcher, and not made available to any other party, or for any purpose. The data collected in this project just for supporting this thesis. Transcripts will be available for respondents if they required. |

## *5. Please complete the following in relation to your research project:*

| | | Yes | No | n/a |
|---|---|---|---|---|
| (a) | Will you describe the main details of the research process to participants in advance, so that they are informed about what to expect? | ☒ | ☐ | ☐ |
| (b) | Will you tell participants that their participation is voluntary? | ☒ | ☐ | ☐ |
| (c) | Will you obtain written consent for participation? | ☒ | ☐ | ☐ |
| (d) | Will you tell participants that they may withdraw from the research at any time and for any reason? | ☒ | ☐ | ☐ |
| (e) | If you are using a questionnaire, will you give participants the option of omitting questions they do not want to answer? | ☐ | ☐ | ☒ |
| (f) | Will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs? | ☒ | ☐ | ☐ |
| (g) | Will you offer to send participants findings from the research (e.g. copies of publications arising from the research)? | ☒ | ☐ | ☐ |
| (h) | If working with children and young people please confirm that you have visited this website:<br><br>Working with children and young people and vulnerable adults please go to web link - http://www.cardiff.ac.uk/racdv/ethics/guidelines/index.html | ☒ | ☐ | ☐ |

| | | | | |
|---|---|---|---|---|
| (i) | **DATA PROTECTION:**<br><br>(A) Will any non-anonymised and/or personalised data be generated?<br>(B) If "YES" will it be stored beyond the end of the project/archived?<br>http://www.cardiff.ac.uk/socsi/research/researchethics/destructionofdata/index.html | ☐ | ☐ | ☒ |

**PLEASE NOTE:**

If you have ticked **No** to any of 5(a) to 5(g), please give an explanation on a separate sheet.

(Note: N/A = not applicable)

***If there are any other potential ethical issues that you think SREC should consider please explain them on a separate sheet. It is your obligation to bring to the attention of the Committee any ethical issues not covered on this form and checklist.***

Signed:

(Principal Researcher/Student)

| | |
|---|---|
| Print Name: | Liqiao Wang |
| Date: | |

**SUPERVISOR'S DECLARATION (Student researchers only):** As the supervisor for this student project I confirm that I believe that all research ethical issues have been dealt with in accordance with University policy and the research ethics guidelines of the relevant professional organisation.

Signed:

| | |
|---|---|
| Print Name: | Peter Wells |
| Date: | |

Attachment 1

## A/ Synergy questions

1. In your view, are connectivity, autonomous cars, shared cars and electric cars mutually supportive ideas and technologies?

What are the main areas of synergy?

What are the main areas of conflict

2. What are the most important ways in which these ideas and technologies will change the automotive industry?

Revenue streams and profitability

Branding and market positioning

Industry structure and value chain from suppliers to dealers

Vehicle manufacturers' business models

Consumers purchase and use patterns

New entrants as vehicle manufacturers

New entrants as intermediaries between vehicle manufacturers and consumers

3. Fundamentally, do you see these developments as a threat to the industry, or an opportunity?

4. In what ways do new business relationships, alliances, and acquisitions assist or hinder in the development of these technologies and ideas?

Can the automotive industry 'go it alone'?

Is the automotive industry the dominant partner?

How stable or enduring are these micro-networks of relationships?

## B/ Connected vehicles

1. What are the main benefits to the vehicle manufacturers arising from connectivity?

Added value services to consumers

Data analytics

Inform new car design, car maintenance, etc.

Retain the primary link with users

Drive more business to dealerships e.g. sales, services

2. What are the main benefits to consumers arising from connectivity?

Infotainment

Traffic routing and route planning

Enhanced efficiency / utility

3. What is the threat to vehicle manufacturers from Internet companies arising from connectivity?

4. How does connectivity fit with electric vehicles, autonomy or car sharing?

Connected cars benefits from EVs

Connected cars benefits from autonomous cars?

Connected cars benefits from car sharing?

## C/ Autonomous vehicles

1. In your view, how likely or desirable is full autonomy?

What are the main concerns e.g. safety, liability, cost?

What are the benefits of autonomy e.g. reduced crashes?

Will autonomous cars need to be segregated from other road users?

Is full autonomy suited to specific settings e.g. campus areas?

2. How do costs change as the higher levels of autonomy are reached?

Can these costs be recovered?

Can a premium be charged for higher levels of autonomy?

3. To what extent will autonomous cars make cars more of a commodity?

Emphasis on vehicle functionality, A to B travel?

Autonomous cars as luxury cars?

4. How do autonomous cars fit with connectivity, electric vehicles or car sharing?

Autonomous benefits with connectivity?

Autonomous benefits with electric vehicles?

Autonomous benefits with car sharing?

## D/ Shared vehicles

1. Will car sharing, ride sharing and ride hailing result in a significant erosion of private personal car ownership and use?

Where will these services have the strongest impact?

Will overall industry volumes of new car sales decline?

2. What will be the impact of shared vehicles on the business models of vehicle manufacturers?

Is there a real transition from sale of product to sale of service?

Will there be any impact on franchised dealer networks?

Will entities like Uber become the ones that have the relationship with customers?

3. What will be the main factors that could increase the prevalence of car sharing schemes, ride sharing, etc.?

Cost of consumers of private ownership and use becoming too high?

Cars ceasing to represent a ‘status symbol’?

Availability of alternatives in urban areas?

4. How do shared vehicles fit with connectivity, autonomy or electric vehicles?

Shared benefits with connectivity?

Shared benefits with autonomous?

Shared benefits with electric?

**E/ Electric vehicles**

1. Do you consider that the growth in EV market share is inevitable?

Are PHEVs a ‘bridging’ technology?

By what date do you think all new cars sold will be electric?

Which locations will be leading this process, which will be slowest?

2. What are the main drivers of EV market share growth?

Government policy and carbon emissions?

Urban air quality concerns?

Consumer preferences?

3. What are the main barriers to the growth in EV market share?

Product concerns: Safety, cost, range, etc.

Infrastructure concerns

How quickly can these barriers be overcome?

What is the role of government, the automotive industry, others?

4. How do electric vehicles fit with connectivity, autonomy or car sharing?

EVs benefits with connectivity

EVs benefits with autonomous cars

EVs benefits with shared cars

Attachment 2

## Consent Form - Confidential data

I understand that my participation in this project will involve telephone / face-to-face interviews which I may present my personal opinions to autonomous, connected and electric vehicles.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason.

I understand that I am free to ask any questions at any time. I am free to withdraw or discuss my concerns with Professor Peter Wells (email address: Wellspe@cardiff.ac.uk).

I understand that the information provided by me will be held confidentially, such that only the Principal Investigator (Liqiao Wang) and my supervisor panel (Professor Peter Wells, Dr. Yingli Wang and Dr. Phillip Morgan) can trace this information back to me individually. The information will be retained for up to 1 year when it will be deleted/destroyed.

I understand that I can ask for the information I provide to be deleted/destroyed at any time and, in accordance with the Data Protection Act, I can have access to the information at any time.

I, ___________________________________ [PRINT NAME] consent to participate in the study conducted by [Liqiao Wang], consent to participate in the study conducted by Liqiao Wang, Business School, Cardiff University, with the supervision of Professor Peter Wells.

Signed:

Date:

# Appendix 2

Ethical Approval for Data Collection

Cardiff University
Prifysgol Caerdydd

Cardiff Business School
Ysgol Busnes Caerdydd

Liqiao Wang
Cardiff Business School
Cardiff University

19 October 2018

Dear Liqiao,

Ethics Approval Reference: 1617096

Project Title: Analyses autonomous and connected vehicles from a socio-technical perspective

I would like to confirm that your project has been granted ethics approval as it has met the review conditions.

Should there be a material change in the methods or circumstances of your project, you would in the first instance need to get in touch with us for re-consideration and further advice on the validity of the approval.

I wish you the best of luck on the completion of your research project.

Yours sincerely,

Electronic signature via email

Dr. Debbie Foster
Chair of the School Research Ethics Committee
Email: CARBSResearchEthics@cardiff.ac.uk

# Appendix 3

Example 1: full length quotes on interviewee SE1 (7 May 2019)

[background] We are IoT company, trying to develop a network of sensors to go on infrastructure to help in the future, provide vehicle to infrastructure communication between the connected and autonomous vehicles. What we trying to do is to approaching the whole idea but from infrastructure perspective rather than from a vehicle perspective. At the same time, as we want to develop that, again it also comes into the electric vehicle market because with the data we hope to collect, by known the precise location of certain vehicles on the top of the road, we can charge them perhaps wirelessly, as an example. It was done in the Chinese scheme, there is a kilometre road stretch has been done for that, that is something we think about doing in the future as well. [are they in the market?] I think it's being tested not yet in the market. [ how many the test spots are?] it is one test spot, so it's similar to the solar road way, that was tested in the France, that was one kilometre, and another smart road scheme has been tested in the Sweden or Norway with smart lighting. These test spots within the smart road aspect.

[connectivity to infra] I think the connectivity is going to really key for the called green light automatization, if you have all these connected autonomous vehicles on the road, being able to communicate with the network, you can let them know how fast to go, how slow to go in advance of green light or red light, so you can coordinate the such way the maintaining regular speed, without having to have a stop and start until that light, and maybe even coordinate not having lights at all, if those cars could communicate with one and another such they can by-pass those lights the safe to do so, that could be another option. So think about the maximizing, I think the communication aspect are about maximizing the efficiency.

[av, ev or sv which connect with cv more closely]I think it comes in different stages, what's really nice to about electric vehicles is that they are highly efficient as the car system itself, maybe get the energy might be a similar efficiency to combustion engine, but issue with combustion engine is the cars' inefficiency. Whereas the electric vehicle would allow the efficiency of the car are to be maximized. Now, that's going to be good if you want to also maximizing the efficiency of the network, but I don't think that the critical aspect, I think getting the autonomous vehicles with electric vehicle or combustion, you can still develop the communication aspect for connection the autonomous vehicle. Without needing electric vehicle to coming straight away.

[is it possible that a car connect with infrastructures in the current auto industry] I think it is possible, I think Audi is a good example of looking into that because they have done the scheme of I think in the USA with a coordinating or having a system with the traffic lights that let the Audi drivers know when it will turn the signals. I mean even it is a basic communication I see in China when I was in Guiyang, they all alarm the traffic lights had a timer, that just a basic to let the driver know, that is the infrastructure to vehicle in a communication way even if it is the visually. And I think that is the basic, and above of it, but when we have more sophisticated, it is more digital, we can sent transmissions between the infrastructures to the car and affect the control of the car as a result in terms of the recommendations on what actions to do next, I think that is the future step.

[barrier to the systems popular in all car] I think it is the case of just the communicating between all the different parties, because what issues right now is data is either fragmented or cited, there is already the data been collected, about the traffic light infrastructure, but that not being sent to anywhere else. It is a case of people getting together to build these schemes and just say I need these data, and what problems you facing, we can state what we can provide to you, create partnerships through that, and I think can be very cheap, depending on the sophistications of the data be progress, maybe it can be very expensive, especially in controlling autonomous vehicles, just to get the best data and real time data as well, which is the key aspect as well.

[real data transmission] latency is really important, but the bandwidth aspect is really depends on your data source. Because if you talking about video camera, you need to process that kind of video in real time, then yes, 5G will be key for high bandwidth data, whereas if you come up with in genius ways of collecting data, are much less bandwidth, but with the same amount of inside, as a result, it could be a simple of repressure sensor, or LiDAR , you know aspects like that. You only need a small amount of bandwidth, the speed of light are going to be the same, in the either case, in transmitting that data. But you using less data to come up with inside. Camera needs more while LiDAR depends on what kind of LiDAR, the LiDAR for the car, probably need a higher bandwidth, but if you thinking the LiDAR on the infrastructure, kind of how sensors to detect the vehicles approaching the traffic lights, sometimes they use radar, sometimes they use electric magnetic loops, I think sending data from the data sources like that, is very low bandwidth. So you can use lower bandwidth networks, without needing to log up the other systems. [bandwidth car and infra] speed is the same, bandwidth lower down. It only in terms of the volume. It could be even as simple as the other frequencies less than 3G, even less.

[a perfect car with infra] it a case I think we need to speak with manufacturers maybe have a template going for the future on protocols communications between autonomous vehicles, and infrastructure. It is difficult to say.

[what else for infra so far] we are very early start. To enter the market, with the system that could coordinate with the future of autonomous vehicles, right now it going to be very difficult, that is not our focus right now. that is 5/10 years plan. But right now to enter the market, we are trying to find the solutions located to other problems are the key problems right now. For example, managing traffic lights, detecting congestion and pollution all about data monitoring. It is all about passive rather than active with the communication between the vehicles. It is collecting data and creating new inside of that data but a cheaper cost to the current competition. So our plan is once we enter that market prove ourselves, with cheaper systems, we can develop our products as we go towards smart cities and cities keen to take complex technologies.

[if nowhere, how to connect signal to the car] if we going to move to the really smart future, this going to be transitions as we remove cross. In similar to how the road network when it was being developed, when we had horses in the past to cars now, we initially maybe had cobblestones, we had Detroit, really messy for cars and upgraded the roads need to most upgrading first, and in the other areas, the car itself had to manage through either the good suspension of the design, good attributes like that, road safety, or maybe they have to go a lower speed, or they have to have particular tires and so many cases. So the way I see the autonomous vehicles is maybe the busiest areas we have this amazing coordination of the vehicles so we can match the speed of the cars pass through the junction, but in the other areas, the systems had fall back on more promotive approach where as approach the junction, it has to think through itself. So the vehicle think itself through its sensors, and it has to think maybe has to stop or slow down give way, follow the normal rules we currently do as drivers, which might a little bit less efficient, but again, if we have the infrastructure in key areas, hopefully that should minimize these issues occur, but it on the car to be there and in control of that area.

[av could enlarge the population] the sensors still need in risky scenario if they in the middle of nowhere and there is no communication from infrastructure, it has to deal with that environment complete on its own. Usually in the rural areas, villages and key areas coming into and out of villages and towns, I think the car manufacturers are right to focus and worry about that as an initial stage. Once they have set of that stage, they maybe think the communication with the infrastructure as next stage.

[infra connect to apps bike cars] absolutely, that is the key future, I think autonomous cars and vehicles will help solve its the last and first mile problem. The connectivity is not just for the cars with infrastructures but also other infrastructures aspect in terms of public transport, train times, bus times, maybe where the bike stations are. In the case of connecting, user maybe they live in a little bit far away from the train station, so the autonomous car takes them to that location and then goes back home and parks, where they can communicating to that train stations more easily , without having to a worry to finding a parking in that area and such. And again maybe that where is the share aspect comes in. Rather sharing in the city centre itself, it could be shared in the area of suburb and outskirts to key destination points, and coordinating the whole system from that perspective. And that becomes a case in your app, it says it will take 23 minutes to get from door to door, that is more feasible because everything is timed properly, in that sense. And it the connection, not just from a driving destination to the certain destination without thinking about to the consideration for parking, walking, to get to your destination, all of that time are not being taken into the accounting in the current systems. I think that is something can solve through the future apps.

[sv and infra] I think the shared vehicle aspect is really good for maybe individual travellers or light packed travellers, I am not sure if it would overtake everything 100 percent, I think peoples till love to own their own vehicle, sometimes they might want to on holidays, sometimes they need to pack a lot of stuffs, maybe they keep moving areas or houses. So it is hard to say. I think the share aspect probably is going to be really key for the commuting. Maybe the shared vehicle takes part of centre spoke kind of traffic, some of these use away of main roads, and using the other infrastructure facilities like stations on the outskirt and those bus stations. And connecting people laterally rather than centrally towards to the city.

[Chinese has opposite position than you said] I think with the autonomous vehicles shared aspect, maybe that has not really being tested in the suburbs in that way that we would not know what the reaction is, if it came to it. It could be a case of reusing that car to drop another person to another area, or maybe went to the hall. So they made money from that vehicle while its working.

[4 in 1] I think they will combine in the future. It’s all about efficiency, if you can maximize the efficiency in resources, revenue, time and people, it just be the natural, where it just progresses. Electric vehicles because it a better control in the city, less pollution, lots less infusions the road, in terms of system of power plant, within the city, hope the concentration of that kind of pollution will be much less. Autonomous vehicles, because it provides more accessibility to other people, that might not have driven. And connectivity that improve the efficiency in communication and the system for the whole. So you still arrive on the same amount of time, but you just would know how to drive you in a smooth manner. And shared aspect and again, max the efficiency of the space, so rather one person in the car, three or four, it just fine.

[anything other than efficiency] well, efficiency just relate to cost. Because if people don’t see the benefit from in taking part of activities, then it just no point. They wont go for it automatically. When I say the efficiency is in fuel, they would spend less on charging, on equivalent of fuelling, and it costs less money to travel for the same journey. And if you shared that cost for four people, the cost is again, might be four times less. So they save money in the transport cost perhaps, because, that same journey is shared cross the three to four people instead. In terms of efficiency, they managed to save time somehow, or doing the journey in the different way in the same amount of time, then why not? Because they not spend as much of money, on vehicle maintaince and much money on fuel cost for that vehicle. So I think efficiency and costs go hand-in-hand.

[safety] I think the good analogy to that is we need to take the lessons from the aerospace industry and aircrafts how they developed over years of 60s to 70s, perhaps more accidents happening to the aircraft now, they pretty much nearly completely autonomous flying overhead. Usually the pilot is there, in case certain things go wrong, and for landing and taking off, probably even certain aspects, that becomes all autonomous now. I think we need good regulation on the vehicle development, the equivalent problems of in Americans NTSB the national traffic safety board have equivalent for the autonomous vehicles, try to figure out why these accidents, and share these lessons across the broad, rather keeping them secrete, perhaps articulate to the manufacturer, and really learn from these lessons and employ it to the future trust aspect. I think now we trust aircraft because its test alive and they show that probably the most safest means of transport compared the road accidents right now. You know, 94 % of accidents, fatal accidents are occur roads right now, are caused by human error. If we had a different way, if that autonomous method prove to show that accidents rates would decrease, then I think we need to give a chance to develop progress.

[other uncertain elements on road rather sky] I think taking traffic controllers managing these airplanes because they told them to go altitudes and certain height to avoid other planes, coming in and out of the airport terminals. I think that would be the same system applies in the autonomous cars. There are whole systems to, casus it is radio communications between those... It is more dangerous on road, a pedestrian randomly goes across. We learned lesson from aerospace industry and we might put few things differently and we might to go further, on the research aspect and especially the safety, maybe this is where the infrastructure perspectives come in. Maybe smart curbs with pressure on it and let autonomous vehicle knows when they about to leave, come onto the road, and maybe the busiest areas in the city centre we have that sort of system.

[other thoughts] they could be smart trainers communicate with vehicles, like a show or something connect to the infrastructures, to let infrastructure to know who is about to cross the road.

[applications with infra]That could be a potential future where you get one company that becomes as monopoly in that sector in that area. I think competition is good for now just see how different people are approaching with different ideas, and then eventually see who wins, you know. I think it is the same like read a book, eventually in any sector, or in any industry, you eventually hear of get that one winner that becomes to the top company, in that sector in that phase. In the back of 2000 or the early of 2000s, you had Google, Yahoo, whole host of other search engines, but now everyone flocks to Google, that is the known competitors in that space, in terms of the office work space, you know Microsoft Word, Microsoft Excel, Power Point, it is all about Microsoft, they own that office space, and now we know them as that. That probably to hear from them to come to that level. So I think right now what we seeing is the same pattern, being repeated, with these all these companies, for the economy base but eventually will come down to the two, three, will be the key to the dominate ones. To get this point would be 10-15 years.

[drawbacks] electric vehicles I think it would just push the pollution out, so rather being containing it city because it everywhere else, for example, power plans, that is why renewable engine becomes key for that sustainability. But also the mining for the resources to make electric vehicles to begin with. How do we ensure, either the materials source sustainably and humanely as well. I think that would be a key aspect of the future. For shared vehicles, I think as the matter of trust, that always being there, how do you trust the people that you are around, and is the system place, reliable enough, can someone hack it, such way to lie about themselves. Then we have de-connectivity aspect, how can we ensure the system remains robust, do we have backup systems, in place the case of one system goes down, that the vehicles can still making communications one another, or very least, they become these privative, autonomous, like a horse for example, think for yourself and making decisions how to precede without the communications, that is sort of key aspect. When you have a horse for example, without radar, the horse can still think of itself, it can still go and know to jump off the cliff. It is about autonomous vehicle connected system. The Fawkes computing, or edge computing, rather than cloud computing, whereas in the centre. So the process becomes the edge side of things. For the electric vehicles, we all people at the end, so your security only to be as good as that the people follow the security protocols. If you have a person perhaps inside, trying to hack it, that might be difficult. How do you know who to trust, or to get multiple people to get that trust. Maybe a good example is to looking into the nuclear logical, how that system to secure physically before even making a decision to use nuclear. Having multiple people together.

# Appendix 4

Example 2: full length quotes on interviewee J1 (24 May 2019)

The trouble is bigger than it is being.

[support each other or not] that is what made the problem with it, right? I don't think this is the idea that has developed organically because people want these part of vehicle, I think the concept has been developed, because the difficulties of having a personally owned autonomous vehicles. So the idea I don't think something that people necessarily want. I mean it simply what suggesting is that you will place your car within an app, you are put all blame, that is what it is. It is suggesting that rather owing a car, you going to have an app, and every time you need your car, you have to use your app. The only come up with that solution because the support of the autonomous vehicles realize is that is they put forward model of an ownership that we have with the conventional cars then that would be a massive increase of congestion by definition because not only being able to trapped these people into these cars because non drivers would able to use, so in another words, you could send you kids to the school while you go to work, so there would be two vehicles rather one, but also, because along these things will drive them empty, because they will be driving two people who want them, or people drive them to the city centres, they cannot park there so they send their vehicle back home again. And vehicles will come back to them although send them to parking spots somewhere but they will be empty. So they realize that this model would be unpopular. So they came up with this idea, say, oh, you don't need to own your vehicle, you can have a shared use vehicle, I don't see the logic to that, because at the moment, we could have shared vehicle they called taxis and Ubers. So then they say, well, yes, they would be a lot cheaper, because you wouldn't have a driver, but what they don't say that high in cost or have a little cost, because have the equivalent of them, or the driverless equivalent expensive. Secondly, they will need whole operating backup, so they will get stuck whatever the reason, road works or something unexpected happens, they will need a lot of control, you cannot just expect. And they say blind people or people within the dimension to be in these vehicles without some quired anormous support, the idea they are necessarily good be cheaper is very quest. These business model, I think is flawed, because Uber says it has a driverless cars because we won't pay the driver, Then they consider who is going to pay these cars, how they goanna buy these cars or lease cars, they would have to add their cost, rather a driver, but they have to adding the cost to depreciation of these cars that is what don't see why these being any cheaper. So if we want to share use at the moment, we can have it. And that fine to some Millenniums who let them systems to tell, actually I could cooperate help without a car, I only use for driving my grandson down, I don't use it for my own person, I cycle everywhere. But if you live somewhere 5 miles outside, are you really good to have an app? Who is going to provide this service, it is so unreliable, you come out of your house, and that is a car that wouldn't be available to you, personally.

At morning 8 o'clock and you need to work, why these suggesting that these cars empty the 95% of time and 5% of in the cars and that is ridiculous, because when people want cars that is at 0830 at the morning and 1730 at night, they don't want them do at days rather of course that is empty during the day or three o'clock at morning. Again, that is an idea you need cars by its not backed up by the logic of looking at that we use vehicles. Perhaps some people they are not app friendly.

[ev] I think electric vehicle is fine, I think they will increase the numbers, but we know that there are problems about that fail of the range, that is the biggest issues, we need the technology to improve, and either improving that or we need improving further, we need charging points network to be probably set up. But I think that will be an increasing the electric car use, and the government was encouraging the car and people will adopt the technology. The only problem is that it depends how sustainable, depends on how you generate the electricity obviously. And also the issues about battery disposal, battery manufacture whether they are particular metals you need, and a good of soil price for making it. And it will solve in 20 or 30 years' time, and a good percentage of the market will be electric cars but I don't think that is necessarily has anything to do with driverless objective. The predictors to say they are going to be 30 percent of driverless cars by 2030 I think that is completely nonsense. We will have a great difficulties even have 20 or 30 percent of electric cars. I don't know if they see some of the predictions that they make about driverless and how they introduce the autonomous cars rapidly. I am very sceptical of that.

[ev with cv or sv] the connectivity I also find difficult, how connect, who are they connecting to? So connecting to land or to an operator is quite easy, I mean we all can do it by mobile phones, that is no problem. Connectivity between the cars, is incredibly difficult, I mean ideally you can get 30 minutes cars in the uk there are many cars in china, how you get all talking to each other? And identifying individually at speed of light? So they can interact one with another, seems technically difficult. I think to the main autonomous cars drive but told sensibly we goanna to need it, I mean. When you or me put into a junction, or something into the traffic or off the motorway, we kind large to push our way out, we acknowledge each other, you look at another driver, they flash the light. So for driverless cars they drive their way, they need to be connected, but just technique perspective, of having them into the action kind of car, is difficult. You cannot squeeze in to a couple of cars on motorway as autonomous cars, but human driver looking at other cars doing and gradually into the lane, and that is the car connected and technically difficult, and how expensive they going to be.

Acve cars like a heaven a perfect world. Its so difficult to see how we will get where we are now to this world without (driving). It probably in the communist country like China but never possible in New York or Paris. Even in China, I do not think that would be very efficient and a very good way to getting around. I think these cars still drive very badly and you still have to rely on the app to get a car and so on.

[sv] they going a slow market in the UK like Zipcar, and DriveforYou. We got a small market, 5-10 percent of market but that is. Nobody else want babysit their car, they want their car to be available every day, they want small car, they want big car, or the car can take their kids to the school or they want particular type of car. It doesn’t work as a model rather everybody can share their cars. They love their cars, they can use Uber or taxi to do share and that could probably cheaper than that. Actually people want their car, they do not share the car.

# Appendix 5

Categorised Interview Quotes

| | Autonomous | Connected | Shared | Electronic | Notes |
|---|---|---|---|---|---|
| **U 1**<br>15 Feb 2018 | 1. I think I will trust the technology, eventually. But crashes, computer failures are major issues now that I am more concerned about. | 1. the functions I have used in my car are AC and radio. | 1. I think communities will own it rather personally. The private ownership of vehicle will be less or none.<br>2. It is time based share and we refuelled it before return. I have shared cars with other two friends and it was 10 years ago. They used it in weekdays and I used it in weekend with family members.<br>3. My car with 5 seats now. It is very hard to share car with others especially now I have 3 kids. | 1. 70 percent possibility of my future car (maybe 5 years) is electric. | 1. I am a mother with 3 kids, I have shared vehicle in a long period time before I get married.<br>2. The disadvantage of owing a vehicle is that you always worry about being stolen and scratched. |
| **U 2**<br>20 Feb 2018 | 1. I am happy to own a car by which I can go anywhere without hassles.<br>2. I do not drive, my visions are not good enough to focus on driving long time, tired. | 1. I use Bluetooth to connect my phone with car.<br>2. It is dangerous when you are driving and adjusting any features on the dash board at the same time.<br>3. Music is enough for me, if features I have to use, but I can use flash drive. | 1. I shared bus and coach<br>2. I prefer walk, we have a car shared within family members. You know, we are in a small city, there is limited uses for driving a car, everywhere we can reach by foot, almost everywhere.<br>3. Cars are more for cargo, or shopping. | 1. It is really rare to have electric vehicles in this city, mostly, our taxies are gas fuelled.<br>2. Natural gas is more popular, but not in passenger vehicle usage.<br>3. I do not see any changes in electric vehicles in the past years and future. But we have electric powered bikes and motorbikes, it is getting more popular. | 1. I prefer to buy a low speed electric vehicle, the one speed limited under 30 km/h. I will use it for shopping in coming years. I do have a driving licence, but I do not like drive, it is dangerous, I will use the low speed vehicle only in town. It is enough for me. |
| **AC 1**<br>15 Mar 2018 | 1. Automated vehicle would be an additional transportation mode (rather instead one or more existed modes), they will not replace the private cars<br>2. The mainstreams one day could be niches such as sailing ship and horses and that will happen on private cars as well I think.<br>3. It will be unsafe eventually… these kinds of cars will not | 1. Running a system in a car use a lot of energy, nearly half of the energy in the electric car is to purely run the electronic, if go to connectivity or autonomous, there would be massive energy required. So the energy will be used only for running a car, this is a big problem.<br>2. The platforms | 1. I am a car enthusiastic, I like cars, cars are mine, but a lot of people do not see at that way, for lot of people, car is only a tool to get to work or something like that. So that less fussy than I am.<br>2. The France or Spain they quite common, while not here (UK).<br>3. Another car sharing like city car club or Zipcars, they are another car sharing scheme.<br>4. The ownership with | 1. I do not have an electric vehicle because it is too expensive.<br>2. I usually walk to work or cycle to work, so when I use a car, it is over long distance, and that is the most electric vehicles not above the rest.<br>3. It is heavier than traditional cars<br>4. For some people, it is perfect. If I am commuting by car, probably charging only | 1. The early adaptors (enthusiasts) are easy to compromise so for them it is good enough. But the next generation may less compromise in that (wait) area and that is the behaviour change that people will get into.<br>2. It is important that zero emissions 'AT POINT OF |

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| | test as the same degree of the traditional cars, it is a different standard they work for.<br>4. The only way to make money on the Uber of Lyft business models, is to let them be autonomous.<br>5. There are always somethings we have not thought of, (and it will cause fail) because they do not think like a human.<br>6. The safety and zero hazard slogan are for government, but I do not buy it. They need government's support. | conjunction should be managed useful or unified as one.<br>3. I think connected should be a separate issue rather attached with others so it should be four issues rather than three. | private will be much less than today while it would not completely disappear.<br>5. While young generations prefer to share or lease a car, but later when they have family, they change to own a car according to research. That also slightly changes the car culture, you start sharing cars, but it ends up with owning a car. | once a week.<br>5. It is possible that electric vehicles fully replace the traditional vehicles, if you have rapid charging, a vehicle suitable for rapid charging and people are happy to wait 20-30 mins.<br>6. The process inner the (electric) car is more efficient than petrol or diesel car, the energy transfer efficiency is higher up to 80% rather 35-40% in petrol and 40-45% in diesel.<br>7. You have to care the suddenly increased electric vehicle numbers as the demand on electricity surged | USE', depends on what you want and policy objectives.<br>3. At the first phase, it would be fewer cars, because they use it more intensively. The only problem is the availability problem because you cannot have all cars available at all time. So you need additional cars set there and waiting for somebody who wants them. There will be more cars at the end.<br>4. I think the aspects (of car culture) will change. I think cars will disappear from city centres for various reasons. In the first instance they are pollute, and secondly because they are dangerous to pedestrians and cyclists. That is a big change on car culture so cars will move outside of cities |
| **TP 1**<br>16 Jan 2019 | | | 1. We need the solution for charge points, share points and park points.<br>2. We have the peer to peer part of the business, and now we push forward to manage with land and dealing with hotels, we also arrange a space … nothing like a huge one that can cover 400 spaces in a car park. (Rather) … lots pockets spaces like 20-50 spaces.<br>3. Presumably the underly case can be replicated in any cases.<br>4. Airports would be another good start point for sharing of parking, charging. | 1. It is a public and political debate 2. Battery on bike and on the car are totally different things.<br>3. There is a range between car and truck, the vans are most diesel.<br>4. How zero emissions delivered is an issue.<br>5. Political issues and support are on the fundamental level. | 1. The much more aware the more realization from day-to-day perception that many fewer diesel cars and more restrictions.<br>2. The Paris shared cars, you have to back (return) to specific points.<br>3. Some cars/prototypes designed for shared use.<br>4. Different from car sharing, ride sharing may have a massive growth.<br>5. Making the |

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| | | | 5. UK is more resistant to the car share concept, partly culture thing, and reluctant to trust technology. | | electric infrastructure available (charging points) is more essential.<br>6. Chaoses happened in some locations and this may be relevant to the special occasions such as shopping industry car parking, even with parking online reservation. |
| **TP 2** 16 Jan 2019 | | | 1. A separated infrastructure (bike and cars) should be introduce. Cyclists are extreme vulnerable.<br>2. No returned vehicle would be difficult.<br>3. Most public business / organization do not own enough parking (space).<br>4. An added value services provide on vehicle hire or parking is a very good opportunity.<br>5. The parking could be used on monitoring traffic control. | 1. Electric bikes seem a good increase in the future, but UK market is sports bike oriented.<br>2. Electric vehicle was never mandated as zero emissions. | 1. Shared vehicle fleets have much higher proportions than electric cars in average.<br>2. It is value driven proposition rather profit driven proposition.<br>3. People like parking their car only outside of the door.<br>4. Removing the numbers of vehicles in circulation, or making car space usage more intensive, or taking some cars off the road, are all the positive impacts for sharing. |
| **BC 1** 17 Jan 2019 | 1. The autonomous and connected has a big part of overlap.<br>2. The major links, electric clearly takes you to clean, some part autonomous stuff helps cleaner drive modes by driving behaviour. | 1. Connectivity helps the productivity traffic.<br>2. The connectivity piece is debate also in the productivity because they are really good at the safety piece. | 1. From micro or individual level, shared means less vehicles, manufacturer foot print and end of life impact.<br>2. Basically less capital used to deliver the same effect and that is what shared places mean. | 1. The electric also overlaps with autonomous and connected but does not have to. | 1. CASE seems to be a helpful heading that the industry works for the boundary level, it helps to explain a number of parallel and in some cases overlapping trends that visible from outside of industry and very tangible from the inside of the industry, in practice they are quite complex. |
| **BC 2** 17 | 1. Autonomy increases the use of utilisation | | 1. The shared things are so much cheaper | | 1. Changing technology is |

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| Jan 2019 | and thus you get the best benefit out electric car rather substituting | | 2. One interviewed person from a famous car company, long time ago, says people they do not share their kitchen and bathrooms, why do they share cars? | | difficult for mass market. To make two changes in parallel is more difficult. Autonomous and electric is difficult; it makes sense from customer side (like a package) which make their life convenient but from an engineering perspective it does. It does not dramatically shift users behaviours<br>2. All elements will reframe not only technology but also in terms of benefits. |
| **IE 1** 17 Jan 2019 | 1. The process integrated car 18 months so far… (everyone else works like this) speed and efficiency where matters about more how you manage people how you manage process, how you look at the cycles.<br>2. They (iPads) did it faster and broke more rules, it is as fast as possible from the main business, because they could make decisions fast, a good team.<br>3. So the key is how do you change the culture broadly.<br>4. Here everything takes long time because everyone is far from decision. This also makes the industry lagging behind that currently setting a pace.<br>5. I think none of our vehicles can service in 10 or 15 years like autonomous. | 1. Our companies invest mobility service such as innovation for connected car service, studio provider the new mobility service, ventures for future footprint in car company, research for a better car.<br>2. We try to build a defendable business which can survive for a violent future. | 1. Why do you own a car if you have more choices.<br>2. We consider how to develop services for tomorrow's customers<br>3. There are so many technological challenges.<br>4. If company can involve the capability and maintenance since the start (design vehicles), effectively shape the shared mobility, I did not see many on autonomous vehicles.<br>2. xxx (a car sharing partnership company) gives us contains, customer behaviour, customer requirements, and you have to design around it and make it valuable.<br>3. The ownership case is still very valid one, I do not believe everything is shared mobility. As mobility only works if you have a deeply developed market place, which means that the service is immediately available in 5 minutes. So the platform investment is important. | 1. Engineers want to build things for themselves which is the best solution. | 1. The industry frontier is being reshaped and redefined from emerging consensus, and there are the certain types of businesses that would likely and will pass the future for shared mobility and freely autonomous vehicles. All these things will reshape the industry.<br>2. What you have is your brands, then you build relations with customers.<br>3. I think the concept of mobility is transferring people from A to B as cheap as possible .<br>4. The value of creation or the customer organization creation is not composite with the transportation (so car is just a car)<br>5. Car community is |

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| | | | | | more hierarchy and structure.<br>6. We buy different products in different stages (even the investment on the same company). |
| **AC 2**<br><br>22 Jan 2019 | 1. It is a radical change, laws and regulations, political system support, infrastructure, production information, also mind and attitude.<br>2. Prefer personal driving rather machine control.<br>3. But how to change and when, there is no precise prediction, only a reference for industry.<br>4. The definition of 'autonomous' is blur, the application of autonomous technology for years and in current vehicle models.<br>5. How about the error-tolerant rate and the entire correspondent scheme. | 1. When the mobile phone application is becoming an underlying support, autonomous vehicles could be shared.<br>2. How to upgrade traditional vehicle to correspond current development? If the subject of respondence is human, the rate would be lower than machine. | 1. Bicycle sharing is a pseudo-proposition, at least not applicable in Chinese market. It is not a real sense of 'sharing', rather under a cover of rental.<br>2. Rent market is prevalent.<br>3. Bike sharing is a pseudo-proposition. It should be lifting the use value in present fixed property. However, it is totally against the original intention and process which are manufacturing, purchase, then renting (rather rent the current properties).<br>4. It is a waste of resources of labour and material e.g. iron is non-renewable resource. It is not 'sharing'.<br>5. However, it could be achievable. All products are consumable with limited lifetime<br>6. The sharing of a house/flat means it with a high utilization rate.<br>7. Vehicle is a small, movable space with lower rampart of sharing. | 1. Petrol fuel powered vehicle still has a large proportion (in China).<br>2. There is a scarcity of charging points in first-tier cities, they are rare in second and third-tier cities. The same goes for new energy vehicles distribution.<br>3. It is a chicken-and-egg situation. Users, vehicles and charging points are mutually promoted.<br>4. The charging method is another issue: charging points or battery swap? Charging points may lead a longer time than traditional way (petrol station). If there is a disadvantage, consumers prefer to keep the original way.<br>5. What we need is a time-shorten and high-effective energy supplement method, which is a vulnerable point currently.<br>6. Public sector transportation (bus) would be easier and acceptable for becoming electric powered vehicles. Manipulation and motivation by officials would have a huge advantage, if they are supportive, sustainable and with a stable management and method. | 1. It is a process and issue from perceptual cognition to rational investment and development.<br>2. Vehicles and aircrafts are the integration of all elements which make questions more complex.<br>3. It is a fundamental revolution on driving habits and rules (autonomy). All driving mechanisms were around 'people', but in the future, 'system' will be the decision-making system, will you prefer hand over the right to a machine?<br>4. Methods to boost consumer market: close to or same as existent methods (refuel time), or a very fangled way.<br>5. The decision-making notions are distinctive via consumers and government. The former is myopia while the latter is providence.<br>6. The most meaningful of sharing is quick response at any time and that is the main issue on sharing. |
| **U 3**<br>22 Jan 2019 | | | 1. There are two ways to my destination: I share petrol powered car with another two neighbours or | | 1. Because I felt under-pressure the conversation. They are new neighbours, |

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| | | | catch the bus.<br>2. I had tried for three months but prefer to catch the bus.<br>3. There are not many differences between 'catch a bus' and 'share cars'.<br>4. I have not rent a car for a long while, I am worried about it. | | we had a big generation gap and I do not know how to deal silence.<br>2. If share, I prefer the same age with females and have the same topic. |
| **TS 1** 23 Jan 2019 | 1. It could be come true while in a long-term. It could be in a part of the road network, and a well-developed city.<br>2. It will inevitably spread in a long-term.<br>3. The challenge will be road complexity and citizen's quality.<br>4. Research in Google is more advanced than Tesla because Tesla's main pilot assistant system is not steering by machine.<br>5. The breakthrough for Google is the mass production. | 1. Vehicle connectivity is an inevitable part of the Internet of Things.<br>2. Tesla and Mercedes-Benz offer the best answer for connectivity. | 1. The future of vehicle sharing is not promising. It only benefits by financing.<br>2. Didi can be regarded as Taobao, a platform for placing and accepting the order and delivery.<br>3. It is only a very small scale of sharing (in China). | 1. It will lack a Northern market if the battery technology has not had a new breakthrough. For instance, the low temperature resistance, duration and natural hazard: flood.<br>2. The hedge ratio of electric vehicle is lower than the same price petrol vehicle.<br>3. If exercise in brinkmanship i.e. a vehicle powered by partial or pure electricity which would be much better (for sale).<br>4. Battery set is expensive around 1/5 price of vehicle sale price.<br>5. electric powered bus is a gimmick, the gradeability is awful. | 1. Hybrid plus connectivity is more promising in China.<br>2. Vehicle electrification is the future.<br>3. The cost of CASE is highly relevant while it can be perfectly achieved such as in Europe first and then US.<br>4. Environmental issues can be considered later than political achievements.<br>5. It is better to have a hybrid vehicle rather a pure electric one. |
| **AT 1** 24 Jan 2019 | 1. Autonomous vehicle firstly should focus on efficiency and safety issues and less hazard to others (road and vehicle users).<br>2. It will take 7-8 years (2026 afterwards) to be unmanned driven.<br>3. Three years from now (since January 2019), we will have L3 autonomous driving, while it will take an equally long time to reach L4.<br>4. However, it will be very soon (to have a L4 or higher autonomous vehicles) in specific areas.<br>5. It will pass the tests | 1. If the individual (vehicle) is intelligent, there is no need for connection with other vehicles and infrastructure.<br>2. V2I and V2V are more accessible.<br>3. Difficulty for V2V is lacking a standardisation e.g. 5G Internet network. And different standard on models.<br>4. Difficulty for V2I is a long-term intervention. Firstly, a necessity of a test on a small scale, and then extend to a wider scale. Then a standard on how to change the | 1. The core of electronic vehicle sharing is to balance the customer demand and the shipping capability on service platform.<br>2. Shared vehicle has a common issue on profit model. Shared bike has higher flexibility, covering larger area, while vehicle has less (flexibility). Didi has a better mode, which is end-to-end transport.<br>3. There is an urgent requirement on compromise proposals for vehicle sharing cost and flexibility. | 1. Travelling convenience is the priority on behalf of consumers' concern.<br>2. Electric vehicle should not be a burden as a travelling tool, rather, should be manipulated easier.<br>3. Battery techniques (in normal vehicles) cannot beat Tesla, while Tesla has a higher cost than others, it is not acceptable commonly.<br>4. The ratio of Tesla in Silicon Valley is much higher about 10%. 5. The connectivity on electric vehicles is the industry appreciation on commercial | 1. Mechatronics make intelligence possible and accessible.<br>2. Electric vehicle could apply in urban area, for short-term commuting; petrol vehicle for long-distance voyage.<br>3. Vehicle automation and vehicle connectivity are contradictory with each other, which are individual intelligence and coordination VS. systematic.<br>4. Electric vehicle connectivity and intelligence is a |

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| | and have a systematic design of operation and management on fleets, also need to consider benefits of scaled economic.<br>6. The robot taxi is far away from now. It lacks abundant tests and data support.<br>7. Waymo cut into the normal life by L4 automation is not appropriate, it could slowly increase from L2 to 3 to higher.<br>8. Vehicle is seen a symbolic of asset in Chinese family, if not utilisation on a large scale, it will not be beneficial.<br>9. Special lane on highway only for autonomous truck transport and test is appropriate, because carrying goods bring less danger and hazard than carrying people.<br>10. If the deviation is acceptable which tested by autonomous truck, then autonomous passenger vehicle would be acceptable.<br>11. It is possible if an autonomous, electric vehicle and share goods, in a limited range, would become true. | road infrastructure is needed and when will it be achieved.<br>5. The cost modification network or infrastructure for V2I seems lower than V2V. However, the cost of road and technique maintaince is higher than individual vehicle, and it is not committed to improving the traffic effect.<br>6. The application of vehicle connectivity is very hard to predict, there is no best solution so far. | | manufacturer.<br>6. Autonomous sharing would be a topic addressed after efficiency and safety. | governmental strategy, so everyone should keep pace with (could gain municipal support).<br>5. Commercial vehicle, logistics, wharf and intra-regional paths should be tested before all others (passenger vehicles).<br>6. The CASE is basically a political issue. Further, a tough issue is each element face different challenges. For instance, (issues on) electrification is energy consumption, material and techniques. While connectivity is about costs.<br>7. The possibility of CASE is in a small range, low-speed electric vehicle, controlled lanes. Therefore it decreases the journey's endurance and people are less worried about charging.<br>8. But this kind of high frequency in a limited area travelling pattern, is an abnormal commuting way.<br>9. Any integration of two syllables could process faster and become better, while CASE is harder. |
| **AM 1** 01 Feb 2019 | 1. Now we have L2.5 autonomy.<br>2. The quality and cost to give a birth of new technology is higher (than existed). | 1. It has beneficial side which is initiative safety. GPS tells you where you would go and predict the traffic in advance. | 1. Vehicle sharing is a financing project. It is convenient for on-demand travel but traffic jams would not increase (because of sharing), it | 1. Vehicle electrification has lots limitations. There are many invisible issues i.e. the location of a power station and its relocation, battery | 1. There is no such a big influence on new car market. (Passenger) Vehicle is a primary need, and it has seats |

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| | 3. There will be a fundamental change in 5 to 10 years.<br>4. If there is a degrowth of the cost of a (n autonomous) system, it can be equipped in any vehicles not only on high-end ones, like engine. Many techniques develop like this way.<br>5. The combination of autonomous vehicle with other different functions, could achieve the correspondent purposes.<br>6. There should be a very close coherence in the system self-judgment, road markings, environmental intelligibility, and its data collection, justification and reaction. | 2. It takes even longer than semi-automatic driving, as it asks agreement between vehicles and infrastructure.<br>3. It does not have a standard, maybe need a third-party to tailor a systematic standardisation.<br>4. Isolated frameworks are very hard to be integrated together, as one. For example, (the vehicle) lacks the unification of CPU or technical standardisation. | will get worse.<br>2. It is a travel friendly mode. It would be useful (for share) if a city has a highly advanced public transport system, while using vehicle once a while.<br>3. It is a bit awkward that a private vehicle shared seats with a stranger.<br>4. But it is a private consideration, may be relevant to the personality of the car owner, or the personal economy.<br>5. There are some ethical issues such as vehicle connect to Internet, is not acceptable for all users. | recycle and so many other subsequent issues.<br>2. We hope there is a new way of obtaining energy resources to release the pressure of environment. We used to use traditional fossil fuels in past many years, now we have new renewable energy production which is electric vehicle and others.<br>3. The main development (of electric vehicle) comes from supportive policy: tax reduction and exemption and licenses (pressure).<br>4. The major concerns on electric vehicles are mileage, cost, extreme weather, and outsiders such as environmental problems, unfulfillment of infrastructure, the self-protection of batteries (10yrs).<br>5. Electric vehicles are a different powertrain powered vehicle, there is nothing different with a normal vehicle, so it does not have to be automated. | limitation, which only could share with few people.<br>2. It is a good chance for manufacture transformation. The new market (CASE) is a challenge but also an opportunity.<br>3. They are not the same threshold for new car makers and traditional vehicle manufacturers. New players lack the experience of making electric vehicles.<br>4. The advantage in traditional car makers other than many ICT companies is the hundred years of cultivation. The tech companies may not pay much attention on drive mode, comfortable capability, breaking distance, stability, all safety reasons.<br>5. Traditional car makers may prefer acquisition rather collaboration with high tech companies, as scarce advantages.<br>6. (New techniques) It makes products better, shorten R&D time and launch them in the market quicker. |
| **AM 2**<br>01 Feb 2019 | 1. Autonomous technology which in high-end vehicles (above 1 million RMB) would be more reliable. (compared with lower cost and high-end vehicle) the equipment would be the same but the safety (on lower cost vehicle) is not | 1. One of the linkages on vehicle connectivity is vehicle and mobile phone. Applications via phones could open in-car air conditioner or other functions.<br>2. It can become true that the taxi company | 1. We have bike sharing scheme.<br>2. Our electric vehicle has lower cost and lower maintenance fees.<br>3. We have different configuration for vehicles sharing and sale. We hire specialists to check and maintenance our shared vehicles often. | 1. We have electric mode, in which passenger cars sales more than commercials.<br>2. The trends (to buy an electric vehicle) are: female customers took over 70 percent, additionally, the second household passenger cars. The most popular | 1. Future new mode of technological reserve will be based on newest standard which may take over 70% of our revenue.<br>2. It may take 10 years or more if all the required vehicles are new energy |

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| | guaranteed.<br>2. There are many autonomous vehicles in test yards, a sensor on the top of the roof, it can stop in 10cm to the barrier. | shares the user location with local taxis, logistics companies share locations in its distribution centres to manage vehicles. This function helps regular checks on fuel usage, transportation routes, and the health state of each part, if any maintenance is required.<br>3. The precision and accuracy of mapping (in China) is high, and it keeps a high and efficient update rate. We have very good navigation and map companies, Gaode, Tencent and Baidu, which connect all information in the vehicle with others. | 4. You have to pick it up and park on a specific area. Some parking areas are far to where you may go, this is less convenient. | mode chosen is normal vehicle mode, under 100,000 RMB, travel within 300 km only for commuting.<br>3. People who may take green taxis, OR who are living in the cities and because of the limitation of petrol fuel vehicles, they would buy electric cars e.g. Beijing, Shanghai and Guangzhou.<br>4. Users do not care about environmental issues. They buy electric vehicles because 1) price subsidies especially in 2017. EV has a very high cost, while subsidies help to half the price. 2) the average price of per km could drop down to 0.2 Yuan/km. 3) the sales in 2018 is going down. 2017 is tax free, April 2018, the threshold was growing up: lower subsidies. | powered. Another reason is that the first generation battery will be senescent in 10 years. The cost of battery swap is as expensive as a new electric car.<br>3. Another policy barrier (for electric vehicle) is to protect local manufacturers. Therefore the electric vehicles are only popular locally, it becomes a barrier for manufacturers outside of the area.<br>4. Municipal support on public transportation electrification such as electric bus and short-haul coach. |
| **U 4**<br>02 Feb 2019 | 1. I think the vehicle over 500,000 RMB has automated functions. The technology has not been such fully mature yet, (if to buy) I will choose the brand I familiar with.<br>2. Highly advanced cities also have heavy congestion issues which is not applicable for autonomous driving. Autonomous driving on highway is a good choice but along with higher danger.<br>3. The pure autonomous vehicle can be used for commercial, not limited on passenger cars.<br>4. The traffic rules and regulations, is very broad which gives a big barrier for developing autonomous vehicle. | 1. The moment I used connectivity functions are navigation, listening to music, picking up phone, and systematic upgrade.<br>2. GPS tracking would be applied in all vehicle perpetually.<br>3. The four-in-one vehicle (CASE) will become true very soon 3-5 years, I believe. | 1. Personalized share is not possible, like issues happened in Airbnb, which always connected to punctuation, personal quality, and other issues.<br>2. Didi are all lunched by hybrid vehicle, when using electricity, its limited by its power.<br>3. It is a win-win business on electric vehicle sharing both for vehicle manufacturers and sharing platform. | 1. Only new energy vehicle has subsidy, while manufacturers can get subsidies only from sold vehicle, it is very hard for manufacturers to pay all bills ahead. Therefore they need to finance from varied places.<br>2. I am living in an affluent community where charging points are reconstructed 3-5 so far, and will have 20 or more, but not available on every community.<br>3. However, all new created communities and scenic areas are equipped with charging points.<br>4. There are very limited new energy vehicles in third and fourth -tier cities. | 1. The license-plate lottery system limits petrol powered vehicle circulation in Chinese market and thus new energy vehicle is an excellent succedaneum of such commuting tool, as it is not on traffic control.<br>2. There is a perfect way for green vehicle sharing – new car only for renting. (so can get subsidy back quicker and push to launch green vehicles)<br>3. The green license plate (for new energy vehicles) is never under the traffic control. |

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| **AM 3** 02 Feb 2019 | 1. It is highly advanced in America.<br>2. The complex traffic system needs the autopilot system to work in an-emergency.<br>3. It is a costly supplementary system (on a fully autonomous vehicle): a radar on the top of roof, two car backing radars, 12 radars around the body, 2 on doors. | 1. The vehicle electrification needs Internet as its endorsement<br>2. Vehicle connection improved the whole vehicle configuration, adding the smart features, and comforting interaction with vehicle. | 1. For business travel and students, first and second - tier cities where traffic controlled are possibly using shared scheme.<br>2. Do they (the driver) upload their ID and driving license? What should we do if accident happens? Who will pay the depreciation and loss?<br>3. At moment, the vehicle sharing schedule has not affected the vehicle sale.<br>4. Our company has self-owned shared scheme, covering all first, second and third tier cities. It well operated, no deficit, good service. We offered all range of vehicles powered by new energy and traditional petrol, drivers could choose whatever they want. | 1. First and second - tier cities are doing pure electric vehicles while third and fourth - tier cities still stuck on traditional petrol vehicles.<br>2. It is good if shared vehicles are electric powered. It is not in the traffic control, they can stop on the appointed spaces, but locations are limited, less flexible than shared bikes which could return anywhere they want. | 1. If the shared electric vehicle could park in the parking stations, that would be brilliant.<br>2. For (shared vehicle) damage check, we could take example from blue-ray scanning technology. So taking a picture before it rents, and scan it when it returns, any flaws are obvious under the blue-ray scan, it resembles car washing process.<br>3. The future market (of share) looks a bit saturation.<br>4. It needs applications to manipulate (the vehicle connection and share). |
| **AM 4** 02 Feb 2019 | 1. Why do we need autonomous vehicles? It is not necessary.<br>2. The new technology will definitely appear with advanced safety. | 1. It is a vital process, the optimized data via cloud. | 1. How to maintain the car? The personal driving habits may depreciate the car in varied angles and drivers may not cherish the vehicle because it is not personal owned. | 1. It (the charging time) still takes longer than traditional vehicle i.e. 80% for half an hour.<br>2. The relevant technologies such as charging, electric power storage, Lithium battery technology, mileage, and electrification are all immature.<br>3. Two kinds of people will consider electric vehicle as their new choice: 1) traffic control in Beijing Shanghai Shenzhen and Guangzhou these mega cities; 2) the second car. They had a traditional vehicle, prefer to challenge the new production.<br>4. The demand of electric vehicle requires 1) low failure rate and acceptable quality 2) convenient and efficient | 1. Charging points are nonpopular enough, non-universal.<br>2. The connectivity lays the foundation of autonomous and share. It needs upgrade often, live data collection and detection, and many other functions.<br>3. What we need, is the down-to-earth work.<br>4. The technology breakthrough is our urgent aim to achieve in a long term.<br>5. All electronic features in electric vehicle consumes electricity, if it is on, will accelerate the consumption but it affects the driving mileage. When there |

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| | | | | 3) worriless. It is only a tool for riding instead of walk. | is no difference (on or off the features), voice control, intelligence will be very welcome in electric vehicle. |
| **AM 5** 02 Feb 2019 | 1. The functionality of autonomous vehicles are not obvious. Can they guarantee 100 percent safe?<br>2. The current auto pilot driving system has a high failure rate, it becomes dispensable.<br>3. (Pure) autonomous driving will never become true. The auto pilot system cannot replace a human, it brings too many hidden dangers.<br>4. It will have a huge impact to local economy, the driving school will shut and so there will be many job losses. | 1. Connectivity is intelligent platform, is a fundamental platform.<br>2. A new energy vehicle is an electrical structure which is superior than a mechanical structure in terms of its agility on data transfer and execution.<br>3. The cloud is not 100 percent safe, which has a certain of risk: all digital privacy could attack and obtain by another end of laptop.<br>4. It is a big trend specially on next generation of vehicles, all vehicles will have at least a feature of self-upgrade system. | 1. We do have our vehicle share scheme whilst using in logistics' short distance transportation.<br>2. There is not much conflict for vehicle sale. We can still rent whole vehicle to taxi (or other sharing platform or company).<br>3. The game (share of bike) is about to the end. | 1. The charge point protocols correlate its relevant test standard which are varied by companies, i.e. different protocol in a charging point, requires the correspondent vehicle models, otherwise will not be successful. However, domestic charging companies are having different protocols, it is a big barrier if charging in another place/city/province.<br>2. The unification of charging points are urgently required for electric vehicle charging system integration.<br>3. It is the same time cost about charging and battery swap technology. The battery swap is in a fixed location which cannot swap in anywhere and anytime.<br>4. The first and second tier mega cities would buy electric vehicle because the traffic control. As to under second tier cities, I do not believe the market will be boosted.<br>5. The depreciation of electric vehicle (battery) is very high, around 3.5 years.<br>6. If electric vehicle design and production based on time rather the rule and standard (GB), that is the time that we can develop good electric vehicles. | 1. Electric plus connectivity would be come true very soon, along with the explosiveness of 5G Internet.<br>2. The electronic products can never guarantee to decrease its failure rate.<br>3. (new energy vehicle construction) It has a lower threshold for the new entrant enterprise, while it is very hard to get a good progress.<br>4. When the new energy vehicle (performance) has no difference with traditional vehicle, that is the time of breakthrough.<br>5. There are few drawbacks need to be conquered when developing the electric vehicle: low temperature resistance, water-proof etc.<br>6. In the context of the same size, high energy ratio could save more power.<br>7. The ratio of battery weight and its capacity (can present the mileage distance).<br>8. Due to the imperfection of infrastructure, market is always go ahead of structure but this causes lots problems. |

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| **SE 1** 07 Feb 2019 | 1. Being able to communicate with the network, you can let them know how fast to go, how slow to go in advance of green light or red light, so you can coordinate the such way the maintaining regular speed, without having to have a stop and start until that light, and maybe even coordinate not having lights at all.<br>2. If those cars could communicate with one and another, so they can by-pass those lights the safe to do so, that could be another option. So think about the maximizing.<br>3. That could be a potential future where you get one company that becomes as monopoly in that sector in that area. I think competition is good for now just see how different people are approaching with different ideas, and then eventually see who wins, you know. | 1. We are trying to develop a network of sensors to go on infrastructure to help in the future, provide vehicle to infrastructure communication between the connected and autonomous vehicles.<br>2. It is a basic communication I see in China when I was in Guiyang, they all alarm the traffic lights that had a timer, that is just a basic to let the driver know, that is the infrastructure to vehicle in a communication way even if it is the visually.<br>3. when we have more sophisticated, it is more digital, we can send transmissions between the infrastructures to the car and affect the control of the car as a result in terms of the recommendations on what actions to do next, I think that is the future step. | 1. Rather sharing in the city centre itself, it could be shared in the area of suburb and outskirts to key destination points, and coordinating the whole system from that perspective.<br>2. And that becomes a case in your app, it says it will take 23 minutes to get from door to door, that is more feasible because everything is timed properly, in that sense. And in the connection, not just from a driving destination to the certain destination without thinking about to the consideration for parking, walking, to get to your destination, all of that time are not being taken into the accounting in the current systems. I think that is something can solve through the future apps.<br>3. I think the shared vehicle aspect is really good for maybe individual travellers or light packed travellers, I am not sure if it would overtake everything 100 percent, I think peoples till love to own their own vehicle | 1. Electric vehicles is highly efficient as the car system itself.<br>2. Electric vehicle would allow the efficiency of the car to be maximized. Now, that's going to be good if you want to also maximize the efficiency of the network, but I don't think that is the critical aspect, I think getting the autonomous vehicles with electric vehicle or combustion, you can still develop the communication aspect for connection the autonomous vehicle. Without needing electric vehicle to coming straight away.<br>3. Electric vehicles I think it would just push the pollution out, so rather being containing it city because it everywhere else, for example, power plans, that is why renewable engine becomes key for that sustainability. But also the mining for the resources to make electric vehicles to begin with. How do we ensure, either the materials source sustainably and humanely as well.<br>4. It also comes into the electric vehicle market because with the data we hope to collect, by known the precise location of certain vehicles on the top of the road, we can charge them perhaps wirelessly, as an example. | 1. I think the communication aspect are about maximizing the efficiency.<br>2. Right now to enter the market, we are trying to find the solutions located to other problems are the key problems right now. For example, managing traffic lights, detecting congestion and pollution all about data monitoring. It is all about passive rather than active with the communication between the vehicles.<br>3. The connectivity is not just for the cars with infrastructures but also other infrastructures aspect in terms of public transport, train times, bus times, maybe where the bike stations are. In the case of connecting, user maybe they live in a little bit far away from the train station, so the autonomous car takes them to that location and then goes back home and parks, where they can communicate to that train stations more easily , without having to a worry to finding a parking in that area and such. And again maybe that where is the share aspect comes in.<br>4. It's all about efficiency, if you |

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| | | | | | can maximize the efficiency in resources, revenue, time and people, it just be the natural, where it just progresses. |
| **AM 6** 11 Feb 2019 | | | 1. We have two types of shared vehicles in the market. For enlarging market, we hire drivers only for car-sharing service. All vehicles are new energy vehicles.<br>2. We have different versions, for personal usage and business. The business platform just like a travel based platform.<br>3. Another shared vehicle is easy to access, you need scan the QR code and access the car. It is a two seats vehicle and pilot project. It does not run as good as we expect, almost abandon it. | 1. Our electric vehicle sale takes 5-6% of overall sale.<br>2. It seems less possible to reach 80% of electric vehicle in total sale by 2020.<br>3. The domestic sales of electric vehicle is increasing but slowly, wouldn't decline.<br>4. There are so many companies that produce battery in resulting of high volume in the entire market. So the production and market is (almost) saturated. | |
| **AC 3** 18 Feb 2019 | 1. It could be full of energies, but I am talking from many aspects like industrial, technological, behaviour aspect and so on, or it could be full of conflicts, I think at least, government policies and regulation these kind of top-down factors, so it could go either way.<br>2. Industry commercial side, need government policy support, especially private, small companies, they do not want to invest something they goanna to lose<br>3. Technologically, you can use pilot/assistant functions to other industry as well. (social aspect) it is useful to have these innovations, it gets people familiar with automation. Parking, autopilot, and | 1. I do not think it (4-in-1 vehicle) will become true in western country, it is clearly not economical, in terms of materials, in terms of energy in a holistic sense | 1. There are a lot of synergies on autonomous, shared and electric vehicles, they are not competing, they are complementary to each other, so far. I think all three is very good. Fewer cars, good environment, with less congestions, within 10 years would be getting better.<br>2. The targets and horizons are never become true, they settled the time while it is never achieved, it is a show, functions are not integrated as one, they are separate or only available on the show<br>3. I think this one is the hardest predict, I mean what extend we can have shared mobility by when etc. it mostly depends on the context | 1. The most success electric cars are shared models, big companies for example, they acquire them as you own individually is relevant high. It does not mean you want to give up the diesel cars, you can find if you want to drive an electric car only go for car sharing clubs. If you take this step of transition, you can see other ripple effects on other behaviours.<br>2. I do not know what is would be, but it will boost electric vehicles, it needs a catalyst event for 3-in-1 vehicle. Which way you go, it depends on a lot of other factors | 1. It is really depends on which area and policies there. For example, Norway and China, again, it is top-down and encouragement<br>2. The policy in this country (UK) can be changed quickly, so it lacks policy continuity. (The industry people) We want government's stability.<br>3. The policy should be stable and clearly stated what they would support and how to support, from a more blurry to a more certainty thing.<br>4. You learned trust progressively along with (technologies), and you only will be realized when it is taken away<br>5. The four in one, if |

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| | when you keep adding these things up, I think you give more sense of trust on those technologies, trust it more over time. | | | | there is a policy, it would be possible |
| **AC 4** 21 Feb 2019 | 1. So how autonomous trucks to deal with these outside issues other than a box like car.<br>2. Cars are not varied as much as trucks, e.g. the safety regulations and rules, they are transferable. While truck regulations varies country by country. The road situation is also varied: Germany and UK are much narrower than others, incidents happened easier.<br>3. Autonomous trucks in wet weather are even worse than cars, they cannot catch the white lanes.<br>4. Trailers are another story.<br>5. Also truck takes a long distance to stop it, 100 meters. | 1. Truck's height is an additional parameter to consider but you never have problems on that. | 1. I think the best policies are multi-prone policy, you don't rely on only one thing, the high-occupancy vehicle is effective. | 1. The electric powers for cars is with to stay.<br>2. But transfer it to electric truck is a big leap because the power required, the torque, because the trucks are so heavy, the range becomes very limited if they go electric. The power supply for truck is real real real challenging.<br>3. It also depends on what they carrying. If it is volume-metrically driven, it works, it is something we forgot with. | 1. Trucks are much more varied than cars. Cars are much easier standardized to car, there are many variations of cars, engines, seats, power output of speed, the height, width and length of cars are not much varies. But trucks are huge variations not much to weights, but much about length and widths.<br>2. The automatic reroute may miss the low bridge, or narrow road, which cannot cope with.<br>3. I suggest starting with smaller/smallest size, 7 1/2 tons in the UK, but it is still 5 times of a car, the weight penalty is massive, even it is the smallest truck e.g. breaking distance. |
| **LE 1** 15 Mar 2019 | 1. To minimum the unit of achievement, which makes autonomous driving conceivable, e.g. autonomous delivery vehicle in the campus, the snack minivan, or auto-taxi in Phoenix, US.<br>2. Another example is shuttle bus, tour bus in a district, which size is around a sedan. Or light truck, 5 meters length, 2 meters width.<br>3. Most autonomous testing surroundings are too Utopian and highly | 1. Connection, with electric and autonomous are the same thing (concept of future).<br>2. It also has a higher requirement on technicist and peripheral business who support such technology testing such as cities of Wuzhen and Hangzhou. | 1. The share is based on autonomous, electric and connectivity, which will develop later than all three. | 1. Our logistics van are mainly petrol powered while in recent years we have electric powered vehicles gradually but not many. Still, most vehicles are fuel based then add electronic features.<br>2. The electronic vehicle and new energy vehicle are not always mutually aided.<br>3. Electric vehicle is more suitable for autonomous driving (than petrol).<br>4. The electric vehicle is | 1. The express industry is developing faster (than other industries). It adapts new technology, the e-commerce relevant companies are always good at adapting new technologies.<br>2. However, as the limitation of cross-boundary for logistics (to others), it is a hassle if a loop becomes adaption-modify- |

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| | controlled. If (the same vehicle) were taking passengers, it would not be commercial. All requirements are double or even higher, for accuracy, speed, safety and the solution to the emergency situation. | | | the practical application of connectivity.<br>5. Precision on traditional vehicles is lower than electrics. However, on the basis of steer-by-wire (SbW) technology and electronic control technology, the requirement of precision on fuel powered autonomous vehicle does not that matter. | revolution-readapting. For doing better, to test a new technique on a range of permitted road is more suitable on logistics. |
| **AC 5** 10 May 2019 | 1. Older people quite like this idea, they think they might be losing their mobility, that is the way goanna be forwards, but they may think this would be business as usual, they can own their cars but not driving part, so they can do exactly what they do now.<br>2. What do we really want for our automation? what do we really want for my mobility transport? Let's start there then technology fits. | 1. It lays together with autonomy. | 1. We do not share.<br>2. (older) People used to do it yourself, look after yourself, they are happy to share a vehicle with family, but they decide (with whom).<br>3. They do not trust technology, they need to do things. themselves and they do not like sharing.<br>4. You can rent one which is you may never afford. | 1. The older people would take an electric car as they think environmental for younger.<br>2. Car manufacturers have to use regulations to push forward. | 1. When cars serve for them, listen to people, would be good, if machine takes control over, people will get frustrated.<br>2. They own a car, is called potential for travel , they probably not use it often, just in case. It is like a comfort blanket.<br>3. I think it all about be in control. If they can be in control with the autonomous vehicles, they can be in control to share their cars, they can be happy with that. And they can chose not to share the vehicle, if they wish. |
| **AC 6** 16 May 2019 | 1. It is almost impossible, to have a fully automated vehicle which is not connected.<br>2. It has self-operating capabilities.<br>3. Those technologies who believe that the vehicle self-sufficient would have very detailed mapping structures on board, and that mapping would be shared, by wifi updates, but it doesn't necessarily continuedly | 1. The only get the room benefits justify the whole project if it is connected system, and is managed system.<br>2. Ultimately there be some connectivity, but there is a big difference between offline with vehicle out of service updating.<br>3. Autonomous and connected can work side by side, or | 1. You do not have to be responsible for vehicle anymore, you liberated from the difficulties of ownership you just ride where you want to.<br>2. I personally doubt that person willing to share small vehicles with unfamiliar people<br>3. You cannot take share to overall picture: is it cheaper? Is it significant? Is it goanna be quicker? Is it goanna be significantly quicker? | 1. And another area is there are specific niches, the rise of concerned about air quality, so having electric, small shuttle vehicles that can operate in pedestrian areas which encourage people to walk and cycle<br>2. They (the company) recognize the demand.<br>3. The electric setup on fully autonomous vehicles would be much easier, but it is not necessary. | 1. There are some synergies in that respect between the autonomous, shared and electric vehicles.<br>2. Conflicts are the same with synergy but another way around.<br>3. Everyone wants money from data but nobody wants their hands dirty to run the service, this is the problem I see. |

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| | connected to support infrastructure to function.<br>4. The autonomous, not connected because they do not need too much worry about cyber security problem.<br>5. If you are a car owner or driver, you are not that bothered by autonomation, could be nice to have on a long journey, but those people fairly happy to have such system, the real need that excluded, old people, people disability, young people, people living in rural area without cars, but poor public transport, these people are really interested in automated vehicles, because they think it goanna give them something. | government choose one or another, but it is not completely black and white. All vehicles will have to be capable of surviving somewhere if network infrastructures goes down. | 4. As soon as you allow people to specify, they want to pick up right from start point, you create a lot of inefficiency a lot of detouring that other people do not want, if you persuade people to walk to pick up point that is much more efficient and that would be attractive and it could be important. | | Problems: high capital funding to make autonomous or other technologies working, reduced revenue cost to enhance the income but they never make profit.<br>4. We have aging population and certainly connected with driving, assistant technologies could help those people in one area.<br>5. For sensor manufacturers develop their sensors on autonomous vehicle is only one of the circumstances of sensor application. |
| **J 1**<br>24 May 2019 | 1. You could send you kids to the school while you go to work, so there would be two vehicles rather one, but also, because along these things will drive them empty, because they will be driving two people who want them, or people drive them to the city centres, they cannot park there so they send their vehicle back home again.<br>2. They will need whole operating backup, so they will get stuck whatever the reason, road works or something unexpected happens, they will need a lot of control, you cannot just expect.<br>3. I think the concept has been developed, because the difficulties of having a personally owned autonomous | 1. It is suggesting that rather owing a car, you going to have an app, and every time you need your car, you have to use your app.<br>2. Connectivity between the cars, is incredibly difficult<br>3. You cannot squeeze in to a couple of cars on motorway as autonomous cars, but human driver looking at other cars doing and gradually into the lane, and that is the car connected and technically difficult, and how expensive they are going to be. | 1. When people want cars that is at 0830 at the morning and 1730 at night, they don't want them at days rather of course that is empty during the day or three o'clock at morning<br>2. They are going a slow market in the UK like Zipcar, and driveforyou. We got a small market, 5-10 percent of market but that is. Nobody else wants babysit in their car, they want their car to be available every day, they want small car, they want big car<br>3. It doesn't work as a model rather everybody can share their cars. | 1. We know that there are problems about that fail of the range, that is the biggest issues, we need the technology to improve, and either improving that or we need improving further, we need charging points network to be probably set up.<br>2. The only problem is that it depends how sustainable, depends on how you generate the electricity obviously. And also the issues about battery disposal, battery manufacture whether they are particular metals you need, and a good of soil price for making it. And it will solve in 20 or 30 years' time, and a good percentage of the market will be electric cars but I don't think that is necessarily has anything to do with | 1. They would have to add their cost, rather a driver, but they have to add the cost to depreciation of these cars that is what don't see why these being any cheaper.<br>2. That is an idea you need cars by its not backed up by the logic of looking at that we use vehicles. Perhaps some people they are not app friendly.<br>3. The predictors to say they are going to be 30 percent of driverless cars by 2030 I think that is completely nonsense. We will have a lot of difficulties even have 20 or 30 percent of electric |

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| | vehicles. So the idea I don't think something that people necessarily want. | | | driverless objective. | cars.<br>4. It is probably in the communist country like China but never possible in New York or Paris. Even in China, I do not think that would be very efficient and a very good way to getting around. |
| **TC 1** 17 June 2019 | 1. I think it is coming clear to work from autonomous and connected vehicles field is fully autonomous cars we known today, we are pretty much to expecting the private ownership to reduce stress from the coming decades, probably will be decades rather than years, and the first the sort of can application of services the roads will be shuttle services most likely with increasing area, control the environment, like Heathrow shuttles, then moving up to limited environments and then probably starting with the lowest speed applications. | 1. One of the reasons I think not automotive anymore is that I think automotive industry has been slow to switch to this sort of motive thinking.<br>2. Another barrier is two (business and services) model services work together, is very challenging. | 1. (for workers) If you share, you can guarantee the space. | 1. I think it mixed, the city adapts electric buses and conduct charging and lots of sensors around this smart city. The sensors have down to train station and they completely rerouted the traffic and bus stations just outside the train station, so pots coming to do the last/ first mile to connecting to the city where city centres and shopping centres within a mile. | 1. We have academia engagement programme with us, which is the start point of the strategy that we try to bridge the gap of the businesses, product services… going through with which, we are trying to work with universities to know what is going on in the UK's universities, trying to establish where the best field what the best partners are, we need to work together to help accelerate the UK in terms of jobs growth. |
| **TC 2** 17 June 2019 | | 1. We are in the transform stage so we are thinking around what is the perfect transport system in the future, where your multiple transport modes are, things integrated you can optimized everything cross all over the transport modes. | 1. The electric vehicle works as trucks so it is easier and viable in trucks. | 1. It also links with smart housing, the infrastructure goes in the electric vehicle charging as it goes up. | 1. Our job is fundamentally to make sure that we catalyse technologies that develop in the academia, in businesses as well but make sure that join through the academic benefit, at the end we have academia network. |
| **TC 3** 17 June 2019 | 1. I think the whole idea of shuttle service combined the demand of transport, so the two models come together.<br>2. There are a lot of overlaps, you cannot | 1. We were transformed systems, so very much about the movement of people of the goods, places and we focus on the large cities | 1. What we look at is not only the technologies, so one of the areas we focus is the mobility services, as part of that, we look at the new business models, so what sort of business | 1. The micro mobility has pros and cons.<br>2. People will use these technologies as long as there are some smart charging kinds of things that enable slow balance, | 1. Our office is transport mobility focus, another branch in a city which is more social aspects, policy and urban planning, and |

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| | talk about big smart cities without talking about how goods get around. So these two are very interconnected. | especially smart cities, Internet of Things sort of stuffs. | models in the future that goanna to enable the new tech, disruptive network put the legislations and regulations around that need to be changed. | we have got a lot compacity. | it's how to bring together. |
| **TC 4** 17 June 2019 | 1. We started informed technology rather than ground zero, so that we could build upon it and save time.<br>2. So if you buy these new electric trucks or autonomous trucks or vehicles, who are you going to sell to, because many many our buyers only think I am goanna hold my asset for three years or five years.<br>3. The infrastructure won't be there for many years and that will be the constrain for developing the freight infrastructure (for trucks). | 1. The local council can monitor 200 pots at the same time, but they need 5G.<br>2. The extended smart traffic system here is debatable, but a lot of work has been done in Cambridge with smart traffic lights, because a number of manufacturers like Audi already have technology in the car which very often is turn down but enables car to talk to the infrastructure, so the traffic lights know an Audi car is coming along and struct the lights | 1. We need to know the entire supply chain and how to make it, then we can solve the first and last mile problem, completing in different ways.<br>2. No, there are a huge constrain trucks in particular shipping because it is all very well to make someone initially investment but who you going to selling to. | 1. The sale on electric vehicles are going significantly in the UK, but we do not know the second-hand market that affects a lot of people's decisions to buy or not. | 1. Because we are in the transition stage, our supply chain team has been required in the project… largely, our key focus of interest at moment 1) around supply chain market failures and our ability is to diagnose of those failures and value them. i.e. what the impacts cost, and communicate that value to the industry financial service sector 2) another project we are considering at and can gain in terms of financial services is that to help smaller organizations obtain investment. |
| **AC 7** 18 June 2019 | 1. Autonomous connected shared vehicle is a technology which will naturally fit current transport regulations.<br>2. Making autonomous to fit into the current technology is more difficult.<br>3. There is 'something everywhere or everywhere something'. Something everywhere is the approaching automotive industry's taking, add technology to the existing vehicle lane assist, and it will operate everywhere; you go to Milton Keynes and pots everywhere, everything | 1. The machine response based on experience, if experience changes, you may no response to that. The circumstances may vary in the future.<br>2. The code is not individual, it links with previous codes, if one added in, it may change the behaviour.<br>3. Vehicle behaviour is not a single system, which is a combination of many many different decisions going on the same time. | 1. Tesla they do not up to European standard and in terms of their build quality and materials they use, it is an American way, they buy a car 2-3 years they want to buy another car, that is the American way's consume! | 1. There is no definition of PHEV, they want that power, but they work with combustion engine side.<br>2. If you have policy, is protection of road users, people in the car and people outside of the car, and you can enact a policy from various different instruments, one of these can be regulation, and the only reason you use regulation is where the system is not responding the way you expect to respond, or responding too slow, or you bring into a conflict into the system which you have to manage. | 1. There are three levels of driving: strategic level, I want to go from there to there, and road plan etc. and the one below that one is tactical, is basically what lane I should be in and next roundabout etc. I can see the trucks and distances, traffic queueing, and the immediate reactions in front of you, what reactions you need do. |

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| | is there, but only operating in that certain area. | | | | |
| **AC 8** 18 June 2019 | 1. Different markets may have different interests.<br>2. This element starts in an urban areas in 2020's but full autonomy is still a long way. | 1. You already got media like Apple or Google, but Tesla already knows its cars are connected and collected automatic data (so) they are slowly increasing their degree of automation to make the car mature so even though an true autopilot is long way off, but I can see how the car connectivity and the automation that the drivers feature forced. | 1. Current mobility as a service model that is driving now basically you have a driver/taxi driver so you are picked up and dropped off rather to find a car somewhere.<br>2. It will have impact on car sale, as cars used more intensively. | 1. As seen in traditional smart curve, aspect of value chain that traditionally on the developed things value-added, the marketing is high value-added, and manufactures are low value-added, so the big revolution is this thing will be changed? The thing you see used to see is big platforms, but it might have scope for the small scale cities or regionally assembly. So the new technologies you might see in small scale. | 1. I think they probably force each other (4 elements).<br>2. I think technology will come eventually, from social view is how we goanna use it.<br>3. 90-60-30 benefits, so 90 percent fewer accidents, 60 percent less traffic and 30 percent less pollution, this is a very positive narrative how benefit on society. |
| **NPO 1** 27 June 2019 | 1. The most synergy would be autonomous and connected, I think it will fit well with shared mobility. It is a lot more practical to manage, which you can connect to your autonomous vehicles, I think the main area is safety and efficiency<br>2. The most benefit of autonomous vehicle is safety.<br>3. I am very confident that the future of autonomous vehicle would be electric powertrain pure electric or maybe hydrogen for large vehicles or longer-range vehicles. | 1. The connectivity is a part of safety piece, the mobility in general for disable and that kind of citizen side, the free of mobility, connectivity forms important part of safety piece (autonomous vehicles) for vehicle to pass the information by infrastructure vehicle to vehicle. | 1. It may help to reduce the second car households.<br>2. That is a natural step, when you have a vehicle it can drive itself then it can be out earning money whilst.<br>3. Once you got autonomy, you look at a completely new model, the majority of car ownership will remove requirement from many cases. | 1. Obviously electric vehicle is bringing the environmental benefits, that is an additional advantage of technology, I could say we could have a ton of autonomous vehicles without electric.<br>2. The available range of electric vehicles would be extended in a couple of years, it goanna be double from traditional (range), but we still have to wait for the costs of electric vehicles come down.<br>3. It is inevitable that autonomy and zero emission vehicles will grow together, as restrictions from access in cities due to air quality. | 1. Connected, autonomous and shared go well together, I think electric vehicles are fairly evitable now in the passenger car market<br>2. The conflicts are more. acceptance, how you manage these transitions, the social and conflicts with the ways we own vehicles and use vehicles and purchase vehicles, is try to get mindset change, but then also make how ideally vehicles would be used kind of connect with autonomous share mobility way making that acceptable needy from people, I think lots of barriers both from managing and introduction technology and around social barriers. |

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