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ARCHITECTURAL INNOVATION STRATEGIES UNDER AUTOMOTIVE ELECTRIFICATION TREND

Case Study of Chinese New Entrants Automaker

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Summary

With increasing emphasis on environmental protection and energy issues, many countries and companies have begun to attach importance to the development of new energy vehicles. Governments around the world are looking forward to new energy vehicles can contribute to solving the problem of environmental pollution and the shortage of traditional energy resources such as oil.

There are many types of new energy vehicles, including HEV, PHEV, BEV, and FCEV. Currently there is still uncertainty that which of these technologies for new energy vehicles will dominate this industry. But in the construction of these types of new energy vehicles, power batteries are an important core part. No matter which technology can occupy the dominant advantage in the future, electrification will become an important development trend. The electrification makes the traditional internal combustion engine with complicated mechanical structure and needs integrated technology no longer important. Power batteries, motors, and electronic control systems are expected to become the new three core modules of automobile, spurring the automotive industry to become more modular and having a major impact on the entire automotive industry chain.

Electrification of the automobile is the future development trend. This trend will prompt a great change in the competitive landscape of the automotive industry worldwide. From the perspective of product architecture theory, this change is to promote modular development. Promoting the development of the automotive industry from the integrated product architecture of

the traditional internal combustion engine era to the dominant direction of the modular product architecture of the new energy vehicle era.

In order to cater to the electrification and modularization trend in automobile industry, major conventional automobile companies have tried to develop new energy vehicle in recent years. For example, the launch of the first hybrid electric vehicle (HEV) by Toyota Motors in 1997. On the other hand, there comes many new entrants or latecomers who try to jump into automobile industry and seize part of the market shares in this transformation period. For example, foundation of Tesla and BYD in 2003.

The electrification and modularization trend in automobile industry will bring great changes in the architecture of traditional technology and organizaitons. And it need companies to have architecture knowledges to build up new architecture. According to the research of Henderson and Clark (1990), established companies will face lots of problems to build architecture knowledge and conduct architecture innovation. In the automobile industry, the electrification and modularization trend brought the conventional companies great challenges, but it also brought unprecedented opportunities for late-coming companies to achieve leapfrogging.

This paper will take the late-coming companies in China's automobile industry as the research object. And try to analyze the research question: Under the trend of electrification and modularization, how can China's late-coming automobile companies use architectural innovation to achieve leapfrog catch-up.

This paper introduces BYD's case and analyzes BYD's competitive advantages and its cost-leadership and differentiation competitive strategies based on architectural innovation. It is concluded that architectural innovation is of great significance for helping late-coming companies gain a competitive advantage and achieve leapfrogging.

Afterwards, the key factors that influence the success of architecture innovation of China 's late-coming companies are analyzed. First of all, seizing the opportunity window and introducing new technologies for technology integration in a timely manner are historical opportunities for latecomers to conduct their architecture innovation and achieve catch-up. Secondly, the accumulation of technological capabilities is a prerequisite for late-coming companies to conduct architecture innovation and achieve catch-up. Thirdly, based on the local market, making full use of China's low labor cost advantage is an important strategy for latecomers to carry out structural innovation.

Then suggestions are made for the future development of Chinese late-coming automobile companies in the field of new energy vehicles industry. The paper suggests Chinese late-coming automobile companies to focus on (1) Modularization of core technologies in development of EV; (2) Building new architecture and industry platform based on battery technologies and (3) Cross-industry integration and architecture innovation.

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CHAPTER 1. INTRODUCTION

Section 1. BACKGROUND AND RESEARCH QUESTION

With increasing focus on the environment and energy issues, many countries and companies have begun to pay more attention to the development of new energy vehicles. Governments around the world are looking forward to new energy vehicles can contribute to solving the problem of environmental pollution and the shortage of traditional energy resources such as oil.

Among new energy vehicles, there are many types, including HEV, PHEV, BEV, and FCEV. Currently there is still uncertainty that which of these technologies for new energy vehicles will dominate this industry. But in the construction of these types of new energy vehicles, power batteries are an important core part. No matter which technology can occupy the dominant advantage in the future, electrification will become an important development trend. The electrification makes the traditional internal combustion engine with complicated mechanical structure and needs integrated technology no longer important. Power batteries, motors, and electronic control systems are expected to become the new three core modules of automobile, spurring the automotive industry to become more modular and having a major impact on the entire automotive industry chain.

Electrification of the automobile is the future development trend. This trend will prompt a great change in the competitive situation of the automotive industry worldwide. From the perspective of product architecture theory, this change is to promote modular development. Promote the development of the automotive industry from the integrated product architecture of the traditional internal combustion engine era to the dominant direction of the modular product architecture of the new energy vehicle era.

In order to cater to the electrification and modularization trend in automobile industry, major conventional automobile companies have tried to develop new energy vehicle in recent years. For example, the launch of the first hybrid electric vehicle (HEV) by Toyota Motors in 1997. On the other hand, there comes many new entrants or latecomers who try to jump into automobile industry and seize part of the market shares in this transformation period. For example, foundation of Tesla and BYD in 2003.

The electrification and modularization trend in automobile industry will bring great changes in the architecture of traditional technology and organizaitons. And it need companies to have architecture knowledges to build up new architecture. According to the research of Henderson and Clark (1990), established companies will face lots of problems to build architecture knowledge and conduct architecture innovation. In the automobile industry, the electrification and modularization trend brought the conventional companies great challenges, but it also brought unprecedented opportunities for late-coming companies to achieve leapfrogging.

This article will take the late-coming companies in China's automobile industry as the research object. And try to analyze the research question: Under the trend of electrification and modularization, how can China 's late-coming automobile companies use architectural innovation to achieve leapfrog catch-up.

Section 2. THESIS LAYOUT

Chapter 1 first introduces the background of the electrification and modularization trends in the automotive industry. Traditional auto companies and new entrants in the industry have increased their investment in R&D in order to expect a leading position in the emerging field of electric vehicles. Although traditional automobile companies have strong technological accumulation, electrification has brought opportunities for new entrants. Then the research question of this article is raised: under the trend of automobile electrification and modularization, how can Chinese late-coming automobile companies achieve leapfrogging based on technological innovation.

Chapter 2 introduces the classification of innovation, leading design and innovation. And the innovation classification of the three mainstream new energy technologies is defined. All three technologies involve certain architectural innovations, but PHEV and FCV are more like improvements based on traditional architectures, while BEV is a more thorough architectural innovation.

Chapter 3 is specific to the automotive industry. On the basis of architectural theory, this paper introduces the modular transformation from integrated architecture to modular architecture brought by electrification. Based on this change, the paper analyzes the challenges that electrification poses to traditional auto companies and the opportunities it brings to new entrants.

Chapter 4 introduces the development of China's new energy vehicles. There are many emerging companies in China entering the new energy vehicle industry, actively carrying out structural innovation (such as BEV architecture) and have achieved certain results. China's new entrants have many similarities, for example, take advantage of China's low labor cost and actively carry out architectural innovation. Among them, BYD is the most representative. The following uses BYD as an example for specific analysis.

Chapter 5 takes BYD as a case study. Responding to the research question "How do Chinese late-stage enterprises achieve leapfrogging", it is concluded that architectural innovation is an important strategy for latecomers to achieve leapfrogging.

Chapter 6 discusses the key factors for the success of China's late-stage enterprise architecture innovation strategy. It also puts forward suggestions on the use of architectural innovation to leapfrog the Chinese automobile industry in the trend of electrification.

Chapter 7 is a summary and outlook.

CHAPTER 2. INNOVATION

In this chapter, first of all the definition of dominant design, innovation dynamics and the classification of innovation were introduced. Then the innovation classification of the three mainstream new energy technologies -HEV, PHEV, BEV- is defined. All three new energy technologies involve certain architectural innovations, but HEV and PHEV are more like some extend of improvements based on traditional architectures, while BEV is a more thorough architectural innovation.

Section 1. DOMINANT DESIGN

"Innovation encompasses the introduction of a new product or process whose design is substantially different from a past practice" (Abernathy and Clark, 1985).

In 1975, Utterback and Abernathy introduced the concept of Dominant design. "A dominant design is the one that wins the allegiance of the marketplace, the one to which competitors and innovators must adhere if they hope to command significant market following" (Utterback, 1996).

100 years ago, there were more Electric Vehicles (EVs) on the road than Internal Combustion Engine (ICE) Vehicles, which were powered by gasoline. "By 1900, there were around 8000 automobiles on the road. 40% were steam powered, 38% were electric powered and 22% were gasoline powered" ("Timeline of the Automobile Industry" 2016). However, after Henry Ford introduced the Ford Model T as the world's first mass production vehicle powered by gasoline, the Internal Combustion Engine (ICE) emerged as a dominant design. After that, the dominant design of ICE automobile has benefited from lots of incremental innovations until now. For example, the CVT (Continuously Variable Transmission) technology in transmission system and the VVT (Variable Valve Timing) technology in engine system are all examples of incremental innovation which furtherly promoted the development of ICE vehicles. Since the emergence of the dominant design promoted the development of incremental innovations, which furtherly increase the value of the dominant design, Electric Vehicles had gradually lost the market battle against ICE Vehicles by 1920

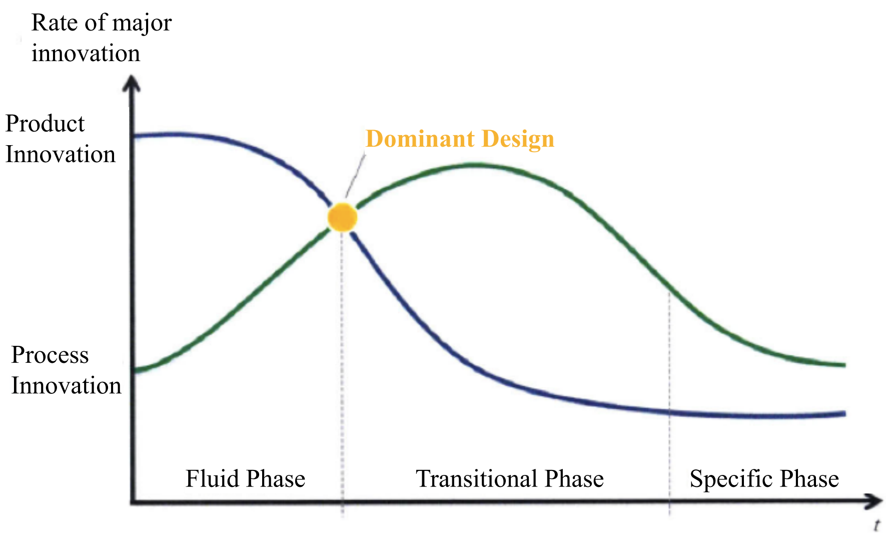
(Paine 2006).

However, Electric Vehicles (EVs) were more cost-saving, quieter and do not have an exhaust system releasing emissions to the atmosphere. In recent years, with the increasing importance of the environmental protection and the requirements of relevant laws and regulations on vehicle emissions, EV have regained widespread attention. Both academia and automobile manufacturers have begun to think about whether EV will replace ICT Vehicles as the next new dominant design.

Section 2. INNOVATION DYNAMICS

Utterback summarized the model of Innovation Dynamics, shown in Figure 1, exhibits the "interdependent rates of product and process innovation over time" (Utterback 1996). In the fluid phase, where dominant design has not yet appeared, there are lots of different kinds of products and technologies competing each other in order to get market acceptance and dominant the market. In this period, with the development of experiments, products have undergone frequent and significant changes. In the transitional phase, the rate of product innovation become small. As mentioned in last session, after the dominant design came out there is a process of incremental innovation around this established dominant design. The product innovation become stable and the product can be designed and manufactured in a more standardized process.

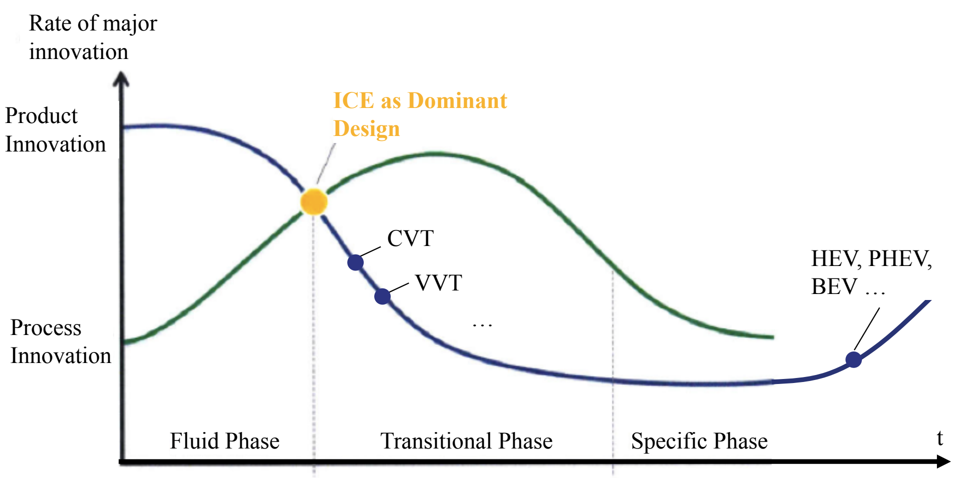
Figure 1 : Model of Innovation Dynamics



Source: The Dynamics of Innovation Model (Utterback 1996)

The technological development of the ICE that led into the proliferation and acceptance of ICE vehicles fits the Innovation Dynamics model and satisfies the definition of dominant design. The design choices and user needs shape the architecture of the dominant design. And this established architecture is not always changed in every subsequent design. "Once the dominant design of the automobile was accepted, engineers didn't reevaluate the decision to use a gasoline engine each time they develop a new design" (Henderson and Clark 1990).

Figure 2 : Model of Innovation Dynamics adjusted for automobile industry



Source: Author's edit based on The Dynamics of Innovation Model (Utterback 1996)

After the ICE vehicles emerged as dominant design 100 years ago, the automotive industry has experienced considerable development in the past several decades. Recently, the development of new technologies become faster and faster. At the same time, the requirement of regulation become more and more strict. Under this trend, the automobile industry has faced tremendous transformations in these years.

From the perspective of energy security, as of the end of 2016, the world's proven oil and natural gas are available for consumption for 50.6 years and 52.5 years respectively. In the future, the energy demand all over the world will continue to increase and the pressure on energy supply will further increase.

From the perspective of environmental issues, automobile’s exhaust emissions have become one of the main reasons of environmental pollution. The latest report of the United Nations Environment Program, "Towards a Zero-Pollution Earth," points out that approximately 6.5 million people worldwide die from air pollution each year. In addition, the increase in automobile energy consumption has increased the greenhouse gas carbon dioxide emissions year by year, and the global warming trend is obvious.

Low carbonization and renewable energy will become an obvious development trend in the automotive industry. One of the important ways to solve environmental pollution problems and energy issues, and to achieve structural adjustment of the automobile industry is developing the new energy vehicles.

In order to cater to the new energy trend in automobile industry, major automobile OEMs (Original Equipment Manufacturers) have tried to develop new energy vehicle in recent years. For example, the launch of the first hybrid electric vehicle (HEV) by Toyota Motors in 1997. On the other hand, there comes many new entrants who try to jump into automobile industry and seize part of the market shares in this transformation period. For example, foundation of Tesla in 2003.

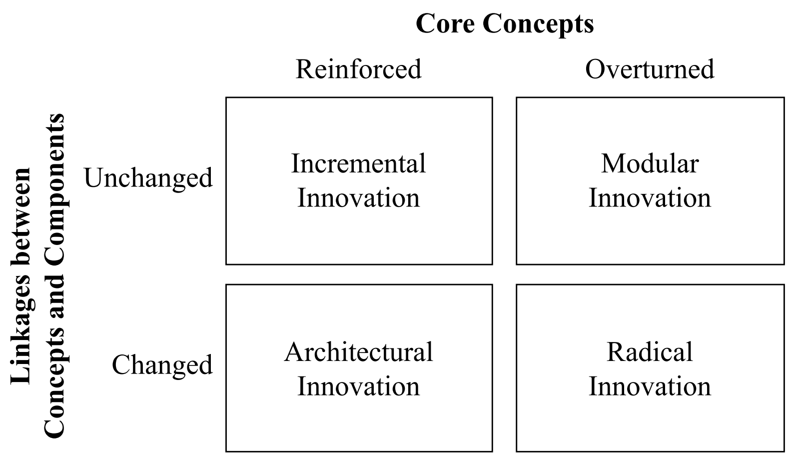
Many different kinds of new energy technology and innovation as the alternative scheme of ICE vehicle appeared in recent years. BEV (Battery Electric Vehicle) will possibly become the next dominant design.

Section 3. TYPES OF INNOVATION

Early literature examined the distinction between innovation that refine and improve an old design and innovation that introduce a new concept which is different from past design. Incremental innovation is the innovation that brings relatively small changes to the existing design, make full use of the established design, and often strengthen the dominance of established product and design (Henderson and Clark, 1990). “Radical innovation, on the other hand, is came from a different technical area and often creat new customers need and develop new applications” (Henderson and Clark, 1990).

However, this classification of innovation didn't take the linkage between components of a product or a system into consideration. Henderson and Clark divided innovation into four categories based on the degree of change in the components built around the core design concepts and the degree of change in the relationships between these components that create the system architecture. This idea is shown in Figure 3. The horizontal axis represents the impact on core concept. The vertical axis means the impact on the linkages between components.

Figure 3 : Types of innovation based on architecture

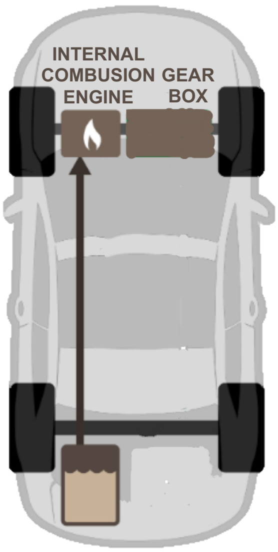


Source: Henderson and Clark, 1990

Section 4. INNOVATION OF HEV, PHEV AND BEV

In this section, the architecture of four main new energy vehicle technology will be briefly introduced. Then according to the classification of innovation based on architecture discussed before, the different between innovation of Hybrid Electric Vehicle (HEV), Plug-in Hybrid Electric Vehicle (PHEV) and Battery Electric Vehicle (BEV) will be defined. Before that, let us first have a look into the basic architecture of conventional ICE vehicles.

Figure 4 : Basic Architecture of ICE vehicles

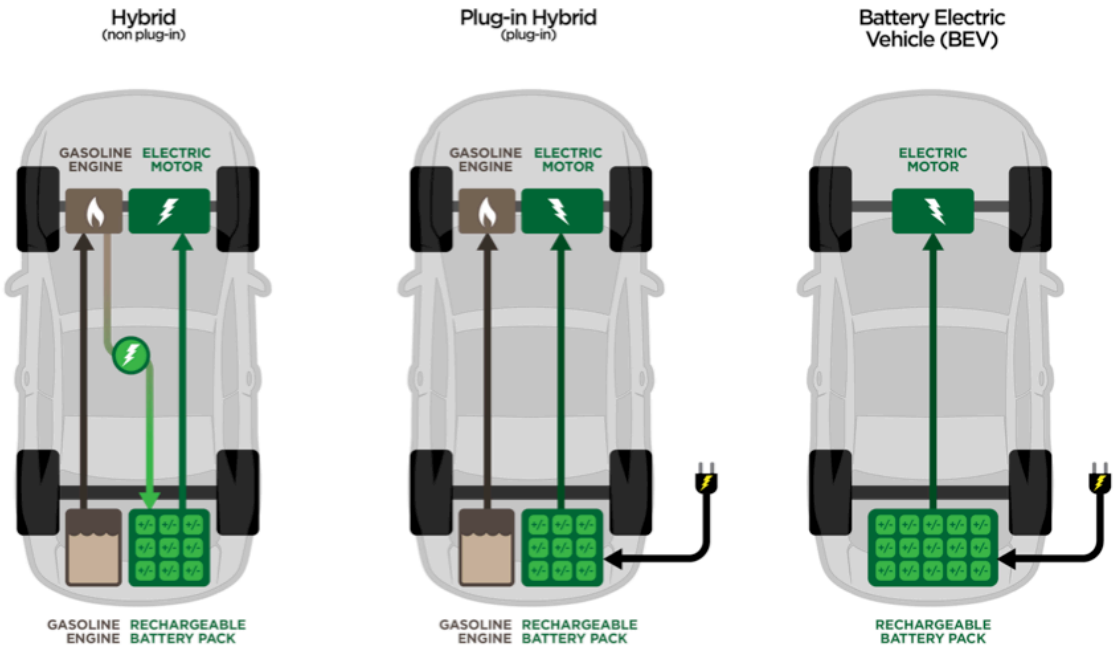


Source: Author's edit

In the traditional ICE vehicle, internal combustion engine and gear box are the core components of this basic architecture. On the other hand, new energy vehicle will use a different architecture because the core components of the vehicle are changed.

In brief, the system architecture of the three types of electric vehicles (HEV, PHEV, BEV) can be seen in the following figure:

Figure 5 : The system architecture of the three types of electric vehicles

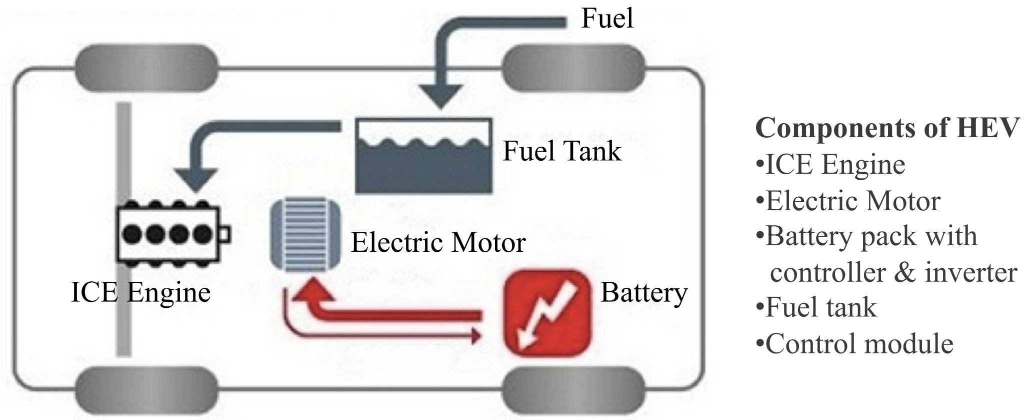


Source: https://create.piktochart.com/embed/38884229-electric-vehicles-australia

2.4.1. Hybrid Electric Vehicle (HEV)

Internal combustion engine still plays an important role in Hybrid Electric Vehicle as a core component. Internal combustion engine and electric motor together act as the power engine of this kind of vehicle. The kind of electric vehicle can be either driven by the fuel through internal combustion engine or driven by the electric power through electric motor. However, this type of electric vehicle has no charging port and cannot be charged from the outside.

Figure 6 : Architecture and Main Components of Hybrid Electric Vehicle (HEV)



Source: Author's edit

Because this type of electric vehicle does not have a charging port, it cannot be charged from the outside. HEV can only refuel like a traditional car, so it still need the fuel tank and the overall architecture of HEV is almost the same compared to traditional ICE vehicle.

It is obvious that the architecture of HEV still rely on the ICE and transmission system, which are core component design of conventional ICE vehicle. That means, the innovation of HEV is more like an improvement based on conventional ICE architecture. Even though it brings the new component, motor, to drive the vehicle, the relationship between engine, transmission and chassis is not changed. Therefore, this kind of technology development is more like modular innovation.

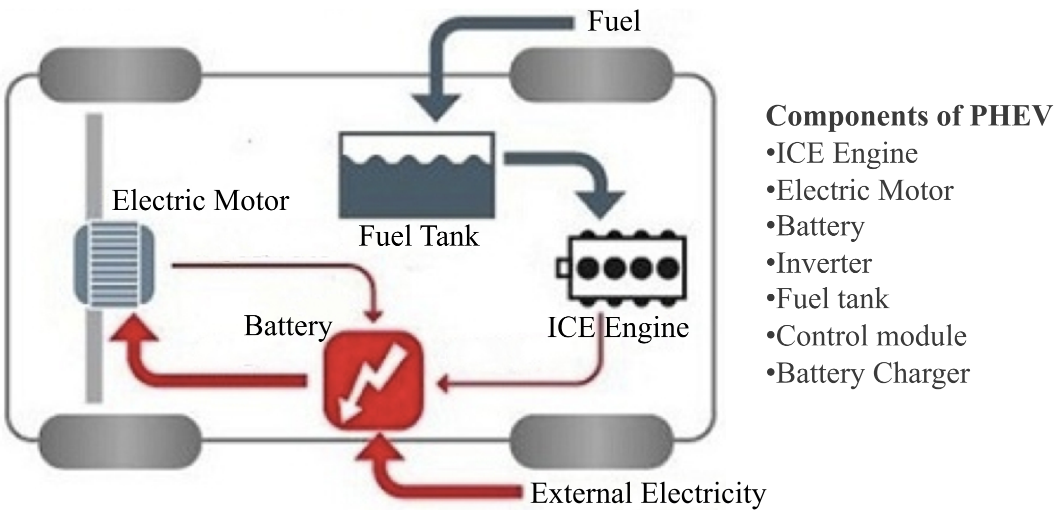
Examples of HEV include: Toyota Prius Hybrid, Honda Civic Hybrid, etc.

2.4.2. Plug-in Hybrid Electric Vehicle (PHEV)

As an intermediate transition product from traditional ICE vehicles to the electric vehicles in the true sense, PHEV have become an important product type for major auto companies to respond to increasingly stringent fuel consumption and emission regulations and improve product competitiveness.

This type of electric vehicle can be power by traditional fuel through the internal combustion engine and can be power by outside electric power through rechargeable battery and electric motor. There is an external charging port while retaining the fuel tank.

Figure 7 : Basic Architecture of PHEV



Source: Author's edit

PHEV can be seen as an improvement on the basis of HEV, which still needs to rely on traditional internal combustion engines and transmission systems. As discussion before, from the perspective of architecture innovation, it is similar to HEV, the relationship between engine, transmission and chassis is not changed. Therefore, this kind of technology development is still more like modular innovation. Not the complete new architecture innovation.

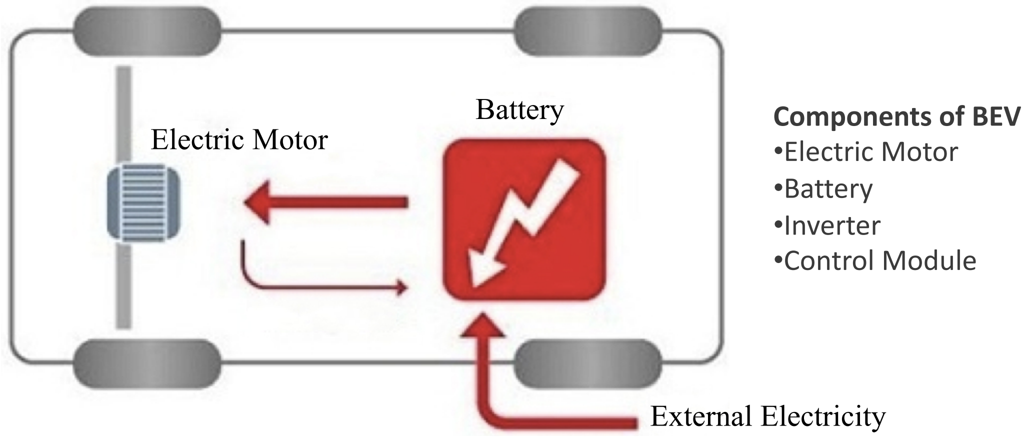
Examples of PHEV include: Mercedes C350e, Audi A3 E-Tron, BMW 330e, Chevy Volt, BYD Qin, SAIC Roewe e550.

2.4.3. Battery Electric Vehicle (BEV)

Battery Electric Vehicle is the pure electric car in the true sense. This kind of vehicle is driven only by the electric power through rechargeable battery.

The core components of BEV are electric motor, battery and electric control system. This new architecture constructed by electric motor, battery and electric control system is total different from the traditional architecture composed by internal combustion engine, gear box and chassis used in traditional ICE vehicle. In fact, thanks to the electrification and modulization, the new architectural of BEV is much simpler than the traditional ICE architectural. That is why industry barrier of automobile industry is become lower and there are many new entrants companies in recent years.

Figure 8 : Basic Architecture of BEV



Source: Author’s edit

This all new technology architecture is built around the new core component, battery. Battery motor and electric control system replace ICE and transmission system to become a totally new architecture. The relationship between existing dominant design is totally changed. Therefore, this kind of innovation is the real architecture innovation.

Examples of BEV include: Tesla Model 3, BYD e6, BMW i3, Volkswagen e-Golf.

CHAPTER 3. AUTOMOBILE ELECTRIFICATION AND MODULARIZATION

Section 1. ARCHITECTURE THEORY

Architecture in the field of engineering technology not only refers to the architecture of buildings, but also includes the architecture of physical products, software, computer networks, large-scale engineering systems, etc. (Grove and Baumann, 2012).

Researchers from MIT defined the system architecture as system entities and their connections, and believes that the system architecture includes one or more of the following four architectures (Crawley, 2004): (1) Functional architecture, reflected to meet system requirements Required activities or functions; (2) Physical architecture, reflecting the physical resources and the connection between them; (3) Technical architecture, specifically reflecting the matching, connection, and dependencies between the physical modules required to meet the system requirements; (4) The dynamic operation architecture reflects the dynamic evolution process of the interactive operation between modules in order to achieve the goals of the system.

System architecture can be commonly classified as two different types: integral architecture and modular architecture, which were clearly defined in system engineering theory (Crawley, 2004). The comparation between integral architecture and modular architecture is shown in Exhibit 1.

Exhibit 1 : Comparation between Integral Architecture and Modular Architecture

	Modular Architecture	Integral Architecture
Definition	The modular architecture contains multiple modules, and each module has one or more unique functions. The modules are connected together through a number of concisely defined interfaces.	The integrated architecture includes several conponents that interact through multiple interfaces and can perform multiple functions.
Features	The interaction between different modules occurs on a predefined interface. The system relies on module behavior and a predefined interface to run.	No identifiable modules.
Advantages	It is easy to deconstruct, and can be deconstructed and reconstructed according to functions, design rules, customer perception, etc .; it is conducive to enhancing the flexibility of enterprise's product manufacturing and strategic flexibility.	Higher operating efficiency
Disadvantages	Insufficient harmonious and coordination among modules; Insufficient transparency of complex modules.	Difficult to design and build.

Source: Author's edit according to related literature

When a system contains many modules, and each module has one or more unique functions, and the modules are connected together through a number of concise interfaces, we call this system's architecture a modular architecture (Hoetker, 2006). The extreme case of this architecture is that the interaction between all modules occurs on a pre-defined interface, and all behavior of the system revolves around module behavior and interaction based on the defined interface. Modular architecture is conducive to enhancing the enterprise's product manufacturing flexibility and strategic flexibility (Baldwin and Clark, 1997; Carliss et al., 1997; Worren et al., 2002), and can be deconstructed and reconstructed according to function, design rules, customer perception, etc. (Baldwin And Clark, 2000; Ulrich and Epinger, 2000).

The integral architecture contains a number of modules that can perform multiple functions through multiple interfaces. The extreme case is that there are no identifiable modules. The integrated architecture is conducive to improving the operating efficiency of the system, but it is more difficult to design and construct (Fixon and Park, 2008).

Section 2. FROM INTEGRAL ARCHITECTURE TO MODULAR ARCHITECTURE

Looking specifically at the automotive industry, Clark and Fujimoto (1991) and Fujimoto

Takahiro (2007) analyzed that the current integrated product architecture is the mainstream of passenger car design, and the modular product architecture is second. Conventional automakers accumulated huge advantages in the integral architecture, which need ICE, gear box and chassis work together closely and harmoniously. Automakers in the US, Japan, and Europe still have a huge competitive advantage in the traditional ICE automobile industry.

With increasing emphasis on environmental and energy issues, countries around the world have begun to pay more attention to the development of new energy vehicles. The transportation sector accounts for a big part of global carbon dioxide emissions, with cars accounting for the vast majority. Therefore, governments around the world are looking forward to new energy vehicles can contribute to solving the problem of environmental pollution and the shortage of traditional energy resources such as oil. Countries around the world have introduced policies such as tax incentives to support the development of new energy vehicles. All countries in the world formulate industrial policies in an attempt to win in this new field.

As introduced in Chapter 2, there are many types of new energy vehicles, including HEV, PHEV, BEV, and FCEV. Currently there is still uncertainty that which of these technologies for new energy vehicles will dominate this industry. But in the construction of these types of new energy vehicles, power batteries are an important core part. No matter which technology can occupy the dominant advantage in the future, electrification will become an important development trend. The electrification makes the traditional internal combustion engine with complicated mechanical structure and needs integrated technology no longer important. Power batteries, motors, and electronic control systems are expected to become the new three core modules of automobile, spurring the automotive industry to become more modular and having a major impact on the entire automotive industry chain.

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Section 3. IMPACTS ON AUTOMOBILE INDUSTRY

The traditional automobile industry system has formed a vertically integrated industrial structure centered on multinational automobile manufacturers, including those affiliated or independent automobile component suppliers and sales shops. This traditional vertically integrated automotive industry value chain is mainly composed of four major business links: R&D, procurement, production, and sales. In the process of the automobile industry gradually moving towards electrification and modularization, the four major segments in the industry value chain have undergone the following changes.

3.3.1. R&D

The R&D will undergo the transformation from integral technology development to modular technology development.

In the field of traditional internal combustion engine automobile manufacturing, the engine is the most important part. Although a small number of automobile manufacturers adopt a joint development model of cooperation or collaboration with powerful parts suppliers to develop and produce engines, the vast majority of automobile manufacturers in the world choose to develop and manufacture engine internally. The engines developed by each automobile manufacturer have their own characteristics, generally the engines developed and manufactured by one automobile manufacturers cannot be directly applied to automobiles of other brands.

In addition, the key components of the drive system such as the engine and gearbox are composed of thousands of mechanical components. It is necessary to ensure the coordination and durability of such a large number of components when the car is driving. The key to the research and development strength of traditional automobile manufacturers is their integrated vehicle and component design, development and manufacturing capabilities, which were continuously accumulated and internalized in their own companies. The accumulation of this unique integrated R&D capability has become an effective barrier that prevents other emerging companies from entering the automobile industry.

As introduced in Chapter 2, HEV and PHEV combine the driving power of engines and electric motors, and BEV rely on electric motors for power. Power batteries and electric motors will most likely replace internal combustion engines as core components. In the field of EV manufacturing in the future, the capability and expertise accumulated by conventional automobile manufacturers over the years in core components such as engines and gearboxes are no longer important. Because, power batteries, electronic control systems and electric motors will become the new three core components. At present, conventional automobile companies may face unprecedented challenges because they have not accumulated enough battery, motor and electric control technologies, and may need to rely on new external suppliers.

The development of new energy vehicles makes the automobile industry electrified and modularized. Existing conventional automobile manufacturers can not only let the accumulated internal combustion engine expertise that has exerted a huge competitive advantage to play a role. Even the existing human and equipment resources accumulated in order to develop the power system will become a burden. This will probably make traditional multinational automobile companies no longer have a competitive advantage compared with emerging companies.

On the other hand, the electrification of the automotive industry has brought opportunities to emerging companies or latecomers. The integrated design required for traditional engines, gearboxes, etc. is no longer important. Modular components will dominate. The core component system of the automotive industry can be simplified into three modules: battery, motor and electronic control.

With the modularization brought by electrification, the entry barrier for the automotive industry has been lowered. Many small and medium-sized late-coming companies or emerging entrepreneurial companies have entered this field of new energy vehicle industry. They have launched a variety of hybrid or electric vehicles into the global market.

For example, Tesla from US conduct most of the development through outsourcing. Tesla's power battery system is provided by Japan's Panasonic and China's CATL; While BYD from China has adopted an internal development mode, and the power battery system has achieved independent research and development. These emerging companies have gradually established new competitive advantages.

3.3.2. Procurement

The bargaining power of new core parts suppliers will be enhanced.

In the existing traditional automobile industry system, in order to meet the needs of automobile manufacturers for integrated product development, a cooperative system with a certain subsidiary relationship has been formed between automobile manufacturers and component part manufacturers. That is, automobile manufacturers control parts suppliers by means of partial investment and partial acquisition of stocks to form a close cooperation or collaborative relationship.

However, the increase in modularity and electrification of new energy vehicles has greatly reduced the number of companies that deal directly with automobile manufacturers. Emerging suppliers who master the modular core component technologies such as rechargeable batteries, electric motors and electronic controls system will have great bargaining power. Traditional automakers have to purchase core parts with less technology accumulation from these emerging parts suppliers, resulting in suppliers with modular core parts technology and products having great bargaining power. Therefore, in the era of new energy vehicles, the added value of the entire automotive industry chain will be more transferred to suppliers with emerging modular core component development and manufacturing technologies.

In order to regain the bargaining power, large automobile manufacturers actively promote the internal development and production of core modular parts technologies such as rechargeable batteries, electric motors and electronic controls system. In terms of batteries technologies, through the establishment of joint ventures to consolidate cooperation. For example, in the R&D and manufacturing of power batteries, Toyota Motor and Panasonic established a joint venture company, Honda Motor and Japan GS YUASA Company established a joint venture company, Nissan Renault and NEC cooperated to establish a joint venture company to learn and acquire power battery R&D and manufacturing technology.

At the same time, some emerging companies that fully master emerging modular core component suppliers and even fully master battery technology will have the opportunity to earn more added value. For example, BYD has accumulated a lot of experience and technology in the field of power battery development, which will help increase its competitive advantage in the field of new energy vehicles.

3.3.3. Production

Large-scale initial investment and assembly technology maybe no longer required.

Building a traditional automobile assembly plant requires a large amount of initial investment, and also requires the introduction of professional production technology and professional equipment that efficiently assemble a total of more than tens of thousands of automobile parts. The company also need to hire a large number of workers who are skilled in assembly techniques for automobile production lines. Therefore, the barriers to entry in the traditional automotive industry are very high. So that in the past few decades, no new automobile company emerged and grown into a large multinational auto manufacturer.

However, with the rapid development of electrification and modularization in the automotive industry, barriers to entry in the automobile manufacturing sector are reduced. This is because in the production of electric vehicles, the proportion of electrical components has increased. Since these electrical components are unitized and modular products, the number of components during vehicle assembly is greatly reduced. It also does not require professional component interface integration technology. This has led to the fact that the competitive advantages accumulated by the traditional internal combustion engine automobile manufacturers in the field of assembly technology are no longer obvious. And with the reduction of the number of auto parts and the reduction of assembly processes, the initial investment scale of automobile factory construction has become smaller. The high barriers constructed by to entry entered by conventional automakers so far have been significantly reduced. Emerging automobile manufacturers can more easily enter the field of automobile production and form a competitive relationship with conventional multinational large automobile manufacturers.

3.3.4. Sales

Traditional specialty stores lose their advantage.

In terms of sales in the automobile industry chain, all major auto manufacturers now adopt an authorized monopoly sales system. That is to establish closed sales channels that can only sell their own brands. The after-sales service department of the authorized sales shop must also use the professional technology and professional equipment designed only for the integrated specifications of each brand car manufacturer. Therefore, consumers generally can only go to the authorized dealers of car manufacturers to buy new cars and carry out repairs and maintenance.

The development trend of electrification and modularization of the new energy vehicle industry has made internal combustion engine and gearbox replaced by new motors, batteries, electronic control and other core components. Therefore, the inspection and maintenance of integrated and complex mechanical parts such as engines and gearboxes in traditional cars are no longer important. As a result, various maintenance and repair services, such as oil replacement, which are one of the important sources of income for authorized sales shop have also decreased, resulting in a decline in the revenue of authorized sales shop. The sales channels constructed by the nationwide sales network built by conventional automobile manufacturers are no longer their advantages in the era of new energy vehicles.

In short, electrification and modularization will bring huge changes to the automotive industry. Traditional automakers will face unprecedented challenges. The long-term accumulated integrated development capabilities will no longer be important. Organizations or knowledge forms that are compatible with traditional architectures will even become a burden. Emerging companies will embrace new opportunities to enter the automotive market and gain a competitive advantage. In the next chapters, emerging automobile company in China will be analyzed in detail to try to answer the question: under the trend of automobile electrification and modularization, how can Chinese late-coming automobile companies achieve leapfrogging.

CHAPTER 4. CHINA’S NEV INDUSTRY

Section 1. OVERVIEW OF CHINA'S NEW ENERGY VEHICLE INDUSTRY

The Chinese government made several supportive measures to help the development of new energy vehicles. Series of support policies about new energy automobile industry have been issued, and a complete policy system has gradually been formed. From the aspects of planning, promotion, industry support, fiscal and tax incentives, technological support and infrastructure, China made a great effort to help the rapid development of its new energy industry. Chinese policy for new energy vehicle industry is shown in Exhibit 2.

Exhibit 2 : Chinese policy for new energy vehicle industry

Macro Coordination	*<Automobile industry revitalization plan>; <strategic emerging industry development plan>; <industrial transformation and upgrading plan>; <Made in China 2025>; <energy saving and new energy automobile industry development plan>; <mid- and long-term plan for the automobile industry> …*
Promote application	*<Thousand vehicles promotion project in ten cities>; <new energy bus operation subsidy measures>; <expanding the scope of hybrid city bus demonstration promotion>; <notice on continuing the promotion and application of new energy vehicles>; <new energy vehicle government procurement program>; <strengthening demonstration promotion management> …*
Industry management	*<Regulations on product access management for new energy vehicle production enterprises>; <regulations on the management of newly-built pure electric passenger vehicle companies>; <parallel management methods for points>; <normative conditions for the automobile power battery industry>; <opinions on improving the management of automobile investment projects> …*
Fiscal and tax benefits	*<Notice of the pilot program for private purchase of new energy vehicles>; <notice of the four ministries and commissions on the continuation of the promotion and application of new energy vehicles>; <notice of the financial support policy for the promotion and application of new energy vehicles from 2016 to 2020>; <Notice on the tax exemption for new energy vehicles> …*
Technological innovation	*<13th Five-Year Technology Development Plan for Electric Vehicles>; <Interim Measures for the Management of Financial Incentive Funds for Technology Innovation>; <Safety Technical Conditions for Electric Passenger Cars>; <Notice on Launching New Energy Vehicle Technology Innovation Projects>; <Fuel Cell Technology Strategic Direction Planning Goals>; <"Nine Seven Three" plan>; <pilot project for major new energy vehicles> …*
Infrastructure	*<Guidelines for the development of electric vehicle charging infrastructure (2015-2020)>; <notice on incentives for the construction of new energy vehicle charging facilities; electricity price policies for electric vehicles>; <incentive policies for the charging infrastructure of new energy vehicles and the promotion of new energy vehicles in the 13th Five-Year Plan Notice of application>; <Guidance on accelerating the construction of charging infrastructure>; <Notice of the Ministry of Housing and Urban-Rural Development on strengthening the planning and construction of charging facilities> …*

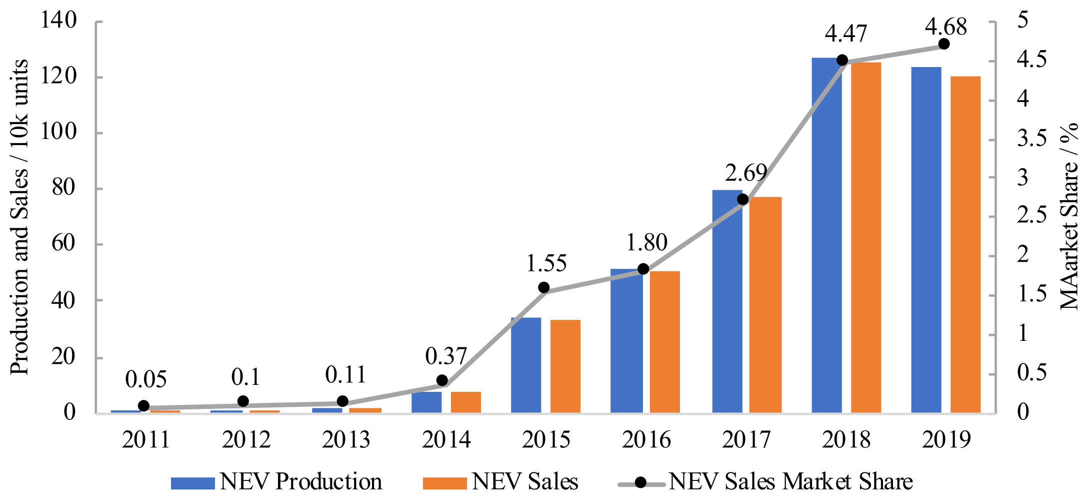
Source: Author’s edit based on government public information

Supported and guided by national policies, China's new energy vehicle industry experienced a rapid development period. The annual production volume and sales volume in 2015 reached 34.05

million units and 33.11 million units, making China the largest country in the production and sales of new energy vehicles. Since then, China has continued to maintain its leading position.

As shown in Figure 9, the annual production volume and sales volume in 2019 was 1.242 million units and 1.206 million units respectively, the production and sales volume decreased by 2.3% and 4.0% year-on-year. Despite the impact of factors such as the China-US trade frictions, the switch of environmental standards, and the decline of new energy subsidies, production and sales have declined year-on-year. However, the total number of production and sales in 2019 continued to rank first in the world. At the same time, the market share of new energy vehicles is also increasing year by year. The market share of new energy vehicles keeps growing every year and in 2019 the market share was about 4.7%.

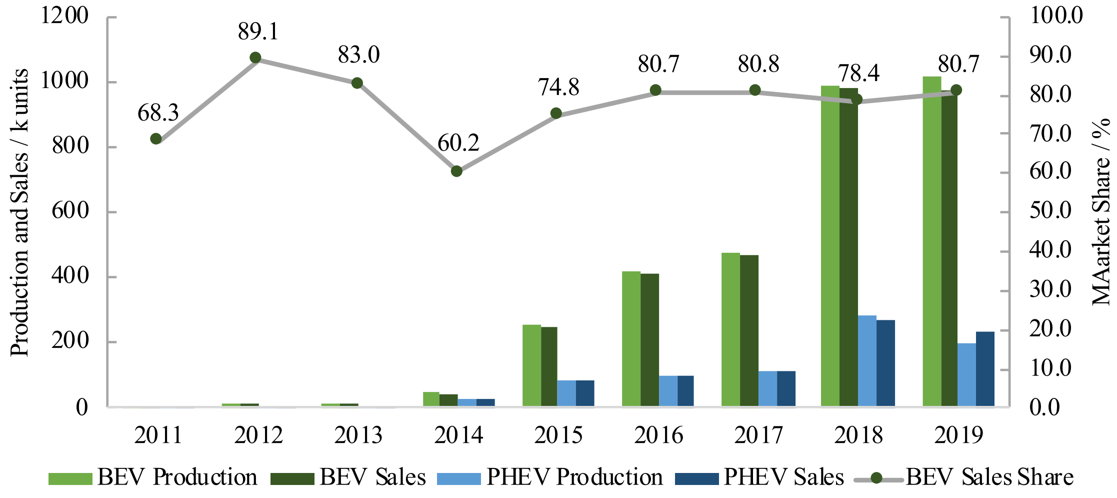
Figure 9 : Production and Sales Volume of New Energy Vehicles in China



Source: Author’s edit based on data from CAAM

Generally speaking, China's new energy vehicle industry has a strong development momentum and a relatively fast growth rate. Its market share has increased year by year, and the market scale has initially taken shape. From the perspective of vehicle type distribution, BEV are the main body of China's new energy vehicle industry, as shown in Figure 10.

Figure 10 : Production and Sales Volume for Different Types of New Energy Vehicles in China



Source: Author's edit based on data from CAAM

As of 2019, sales of BEV accounted for 80.7% of all kinds of EV. PHEV are still an important part of China's new energy vehicle market. In 2019, China market produced 1.02 million units of BEV, realized an increase of 3.4% year-on-year. The sales volume reached 972,000 units. The performance of PHEV in Chinese market is relatively weak compared to the performance of BEV. And FCV are still in their infancy, and only a few companies have carried out prototype vehicle development and demonstration operations, and the follow-up industrialization development needs to be followed up.

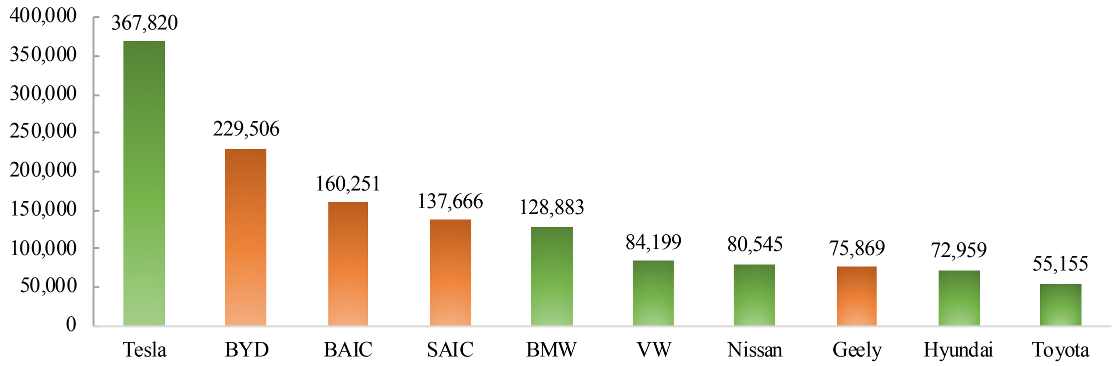
Section 2. CHINA'S LATE-COMER AUTOMOBILE COMPANY

In 2019, China's self-owned brands of new energy vehicles continued to maintain the dominant position in the industry. Several Chinese self-owned brands entered the top 20 global new energy vehicle sales ranking.

In 2019, Tesla won the championship with 367,820 sales. BYD ranked second with a score of 229,506 units. BAIC New Energy ranked third, selling 160,251 units in 2019. Also, in the top ten are BMW, SAIC, Volkswagen, Nissan, Geely, Hyundai and Toyota. The global sales ranking of new energy passenger vehicle in 2019 is shown in Figure 11.

In this list, China domestic car companies accounted for four seats, accounting for almost half of the country. Among them, BYD ranked second with many new energy models, and the Yuan EV / S2 was also ranked fourth in the TOP 10 models of global new energy vehicle sales. BAIC Group and SAIC Group also followed BYD in third and fourth places. This also proves that the strength of China domestic new energy models has been in a leading position in the global market.

Figure 11 : World's Top 10 EV Manufacturers in 2019



Source: Author's edit based on Global EV Sales For 2019

Among the models with cumulative sales of more than 10,000 in 2019, there are 6 plug-in hybrid electric vehicle models and 24 battery electric vehicle models. The model sales ranking for China domestic new energy passenger vehicle in 2019 is shown in Exhibit 3.

Exhibit 3 : Sales Ranking by EV Model in Chinese Market in 2019

Rank	Model	Manufacturers	Type	Sales
1	BAIC EU	BAIC	BEV	110,894
2	BYD Yuan	BYD	BEV	61,900
3	BAOJUN E100	SGMW	BEV	60,050
4	CHERY eQ	CHERY	BEV	39,401
5	BYD Tang	BYD	PHEV	34,014
6	Aion S	GAC	BEV	32,126
7	ROEWE Ei5	SAIC	BEV	30,550
8	EMGRAND EV	Geely	BEV	29,441
9	BYD E5	BYD	BEV	29,311
10	ORA R1	Great Wall Motor	BEV	28,498

Source: Author's edit based on company information

There are many emerging companies in China entering the new energy vehicle industry, actively carrying out structural innovation (BEV), and achieving certain results. China's new entrants have many similarities, for example, take advantage of China's low labor cost and actively carry out architectural innovation. Among them, BYD is the most representative. The following chapter uses BYD as an example for specific analysis.

CHAPTER 5. ARCHITECTURE INNOVATION STRATRGY OF CHINA'S LATECOMER COMPANY– CASE STUDY OF BYD

Section 1. INTRODUCTION OF BYD

BYD was founded in 1995 in Shenzhen, started with the business of battery and electric devices. In 2003, BYD expended its business into automobile industry through the acquisition of Qinchuan Automobile.

This paper focuses on BYD's new energy vehicle business. BYD is an innovative automobile company, which produce a wide range of different products, including traditional internal combustion engine vehicle, plug-in hybrid electric vehicle and battery electric vehicle. In the global market, BYD ranked No.1 in the global sales ranking from 2015 to 2018.

As a Chinese self-owned brand in an emerging country, BYD only entered the automotive industry in 2003. It is undoubtedly a latecomer to the automotive industry. But BYD took only about 10 years to become the global sales champion of new energy vehicles. It is obviously that as a latecomer automobile company, BYD has achieved a leapfrog in this traditional industry. Next sections will analyze BYD's competitive advantage and its competitive strategy.

Section 2. ANALYSIS OF BYD'S COMPETITIVE ENVIRONMENT AND ADVANTAGE

5.2.1. Porter’s Five Forces Analysis

(1) Analysis of existing competitors

There are two types of companies in the new energy vehicle market. First of all, the traditional automobile manufacturers that expand their business by developing the new energy vehicles, such as Toyota, Volkswagen, GM etc. The other is new entrants or late-comer in the automobile industry such as BYD and Tesla. The following Exhibit 4 is a comparison of BYD Qin, Tesla Model 3, Toyota Carola PHEV, which are common star models in Chinese market. The comparison is mainly focused on the power system, battery technology, recharge mileage and price.

Exhibit 4 : Comparison of main new energy vehicles in Chinese market

Model	BYD Qin	Tesla Model 3	Toyota Carola PHEV
Size (mm)	4675*1770*1500	4694*1850*1443	4635*1775*1470
Power System	BEV	BEV	PHEV
Power Source	Battery	Battery	Battery+ICE
Battery	Ternary lithium battery	Ternary lithium battery	Lithium-ion battery
Maximum power (kW)	100	202	100
0-100 km acceleration time (s)	5.9	5.4	11.7
Fast charging time (h)	0.5	1	-
Fuel consumption (L/100km)	0	0	1.3
Recharge mileage (km)	421	445	55
Price (RMB)	129,900	291,800	209,800

Source: Author's edit according to product information on company's homepage

From the above comparison, it can be seen that the dynamic performance of BYD's "Qin" is in a leading position among the four models. Its acceleration time of 100 kilometers is only 5.9 seconds. At the same time, from the perspective of overall usage cost, BYD Qin's overall usage cost is relatively low. Under the same performance conditions, BYD Qin is much cheaper than competitors.

In the new energy vehicles industry, many companies are still in the preliminary stage of the new technology research and development. Which kind of design and architecture of new energy vehicle will become the dominant design is still unknown. The competition in the new energy vehicle industry mainly focuses on the new technology and innovation, especially in core technology such as rechargeable battery technology. BYD has strong technology accumulation and R&D capabilities in this field. Therefore, BYD has a competitive advantage over existing competitors.

(2) Buyer's bargaining power

In chinses market, the market demand of BYD's products mainly comes from the government buyer and normal customer buyer. Among them, the government buyer mainly refers to the government and related public service agencies.

Government purchase is a reliable and guaranteed activitie. Sometime it has the function of guiding the consumption behavior of normal customers. Chinese government is very willing to buy new energy vehicles in order to support for the development of this industry. The Government purchasing is also one of the new energy vehicle polices of China. In these years, the bargaining power of government procurement is weak. Because government procurement is not a normal market behavior. Not only will the government not bargain with new energy vehicle companies, but it will also subsidize them. For example, the Chinese National Development and Reform Commission announced that priority should be given to purchasing new energy vehicles when updating official vehicles. Local governments of each province and city are also actively using new energy vehicles as vehicles for public transportation.

In the long run, market procurement demand plays a more important role. Whether the new energy vehicle will gain the acceptance of customers needs to be examined by the market.

The bargaining power of normal individual customers is relatively strong. Because, first of all, in the automobile market there are lots of existing and mature models which were already have developed through many generations and got high reputation and acceptance of customers. For example, the Toyota Corolla family and the Volkswagen Golf family. At the same time, during hundreds of years development, there comes various different kinds of body type of vehicles, such as sedan, SUV, sports-car. These diversify and famous models provide different functions to meet different needs of different kinds of customers and detail market segment. But in comparison, new energy vehicles are still having only very short history. The models provided by new energy vehicle companies are still very limited. It is difficult to meet every customers' needs. Therefor, customers will probably choose traditional model to meet their needs. Secondly, the using cost of electric vehicle is still relatively high. The infrastructure construction such as charging piles is not complete, which brings inconvenience to using electric vehicles. In summary, normal customer will have many different choices when they want to buy a car, the bargaining power of normal customers is relatively high.

(3) Supplier's bargaining power

The development of the new energy vehicle cannot be done without the cooperation with automobile suppliers. Here we make a classification and divide automobile suppliers into two different types. One is the automobile suppliers of parts and components such as tires, car paints, etc. that are common to traditional automobiles. The other is the automobile suppliers who provide special parts for new energy vehicles such as rechargeable power batteries suppliers and electric motors suppliers.

The bargaining power of suppliers of parts and components (such as tires, car paints, etc.) that are common to traditional automobiles is relatively weak. This is because with over hundred years of development, the traditional vehicle architecture and components are very mature. And the effect of scale of economics, the cost and price of many the parts have achieved very low level. For these kinds of common parts, new energy vehicle OEM can make full use of the existing mature suppliers system built by traditional automobile manufactures. Therefore, for this kind of suppliers, their bargaining power is weak.

On the other hand, for the automobile suppliers who provide special parts for new energy vehicles, their bargaining power is stronger. For example, the rechargeable power batteries suppliers such as Panasonic, LG and CATL. The performance of these new core component of electric vehicle directly determine the performance of the whole electric vehicle. So, they play a very important role in the development of new energy vehicle. Accordingly, these kinds of suppliers have much stronger bargaining power.

But BYD new energy vehicles reflects its differences here. Because BYD originally started its business from the research and development of batteries. After several decades' development, BYD built its core competence around the research and development of rechargeable battery and hold many several patents for the application for electric vehicle. Around the core battery technology, BYD's upstream and downstream integration capabilities far exceed that of its competitors, which lead to BYD's performance and selling price have advantages over its competitors.

(4) The threat of a potential intruder

The power of potential intruder is determined by the industry's entry barrier. In previous section, we discussed about that with the electrification and modularization trend, the entry barrier of automobile industry will become lower. But here I have to mention, the lower entry barrier is relative to traditional automobile industry. The overall entry barrier of new energy vehicle is still very high compare to most of other industry. The potential intruder will not so easy to jump into this industry.

Tesla and BYD are very few special cases if we look back in a long period. Almost every famous automobile company were found 50 years ago. That means for a very long time, there is no success potential intruder. So, we could conclude that the bargaining power of potential intruder is weak.

(5) The threat of alternatives

The alternative to new energy vehicles may be traditional internal combustion engine vehicles or other transportation tools. There are several factors that determine whether customers will change to use alternative product: the price of the alternative product; the conversion cost; and the technical feasibility of potential alternative product.

Now the price and using cost of new energy vehicle is still higher than common family used traditional vehicle. But In the long run, with the improvement of infrastructure construction, with the cost reduction of the rechargeable battery and electric motor, the price and using cost of new energy vehicle will definitely reduce. The threat from traditional ICE vehicle will get smaller and smaller.

The threat of alternatives can also be other transportation tools. As one of the most important means of transportation in today's society, its irreplaceability cannot be shaken in the short term. In short, the power of the alternatives is weak.

5.2.2. Summary of BYD's competitive advantage

As mentioned before, it can be seen that the technical parameter and performance of BYD's "Qin" is in a leading position among other models. Its acceleration time of 100 kilometers is only 5.9 seconds. At the same time, from the perspective of overall usage cost, BYD Qin's price and overall using cost is relatively low than other competitors. Under the same performance conditions, BYD Qin is much cheaper than competitors. It is obviously that BYD has built in competitive advantage in Chinese new energy vehicle market.

Because BYD originally started its business from the research and development of batteries. After several decades' development, BYD built its core competence around the research and development of rechargeable battery and hold many several patents for the application for electric vehicle. Around the core battery technology, BYD's upstream and downstream integration capabilities far exceed that of its competitors, which lead to BYD's performance and selling price have advantages over its competitors.

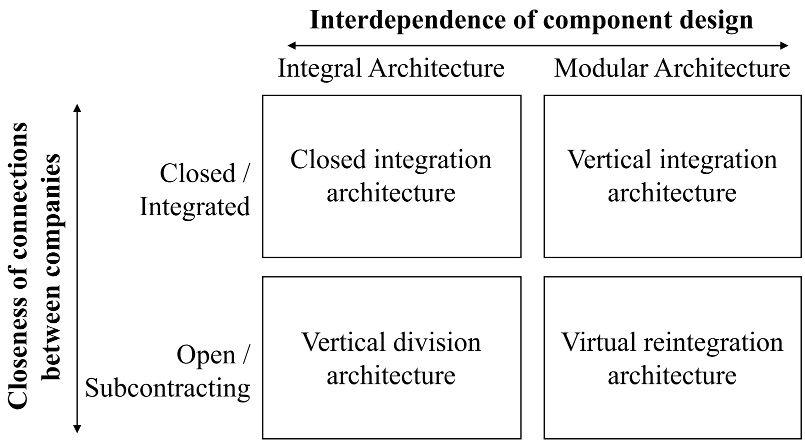
In this section, the competitive advantages of BYD was analyzed by using Porter's five forces model. Next section will introduce and analyze BYD's competitive strategy based on architecture innovation.

Section 3. ANALYSIS OF BYD'S COMPETITIVE STRATEGY

5.3.1. Cost Leadership Strategy Based on Architecture Innovation

This paper mainly studies how, under the premise that the first-mover companies have determined the mainstream industrial structure, the late-coming companies can improve their niche in the global industrial chain through structural innovation and then achieve leapfrog catch-up. Based on the research of Takamoto Fujimoto (2007), we divided the product architecture into four types based on the two-dimensional information of the interdependence of component design and the closeness of connections between enterprises (see Figure 12).

Figure 12 : Four Types of Product Architecture



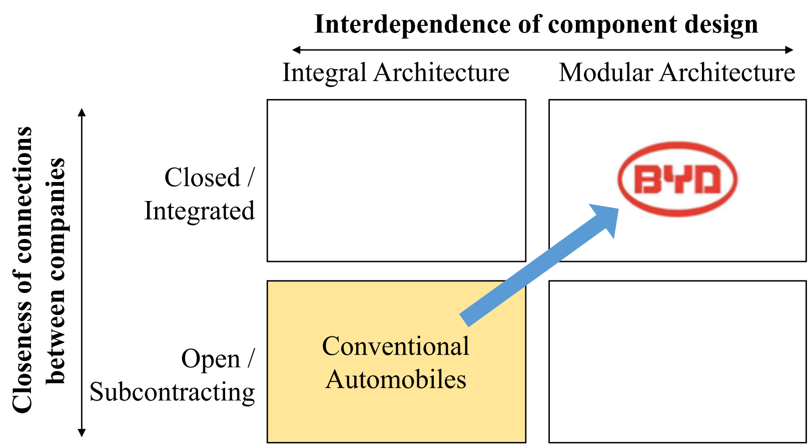
Source: Author's edit based on the research of Fujimoto (2007)

According to Fujimoto's study, "China, which has established low-cost production bases that depend on a virtually infinite supply of workers from its inland provinces, tended to be competitive in labor-intensive modular products". (Fujimoto, 2007)

For the automotive industry, the conventional automobile companies locate in the lower-left side of Figure 13. The architecture of traditional vehicle is relatively integrated since internal combustion engine became the dominant design 100 years ago. The relationship between core components such as ICE and gear box and chassis is very complex. On the other hand, the closeness of connections between companies is relatively open. One OEM will cooperate with thousands of suppliers to complete the R&D and manufacture of a car.

As a late-comer in the automobile industry, BYD try to use a different development trajectory to gain competitive advantage, then achieve leapfrogging and catch-up. First of all, the cost leadership of BYD is achieved by its architecture innovation. The essence of this architecture innovation adopted by BYD is to transform the integrated internal integration architecture into a vertically integrated modular architecture.

Figure 13 : The placement of the conventional automobile manufacturer and BYD



Source: Author's edit based on the research of Fujimoto (2007)

In the field of automobile manufacturing, BYD continued its vertical integration mode used in the battery manufacturing field, that is, a vertical integration mode that replaced a fully automatic production line with a large amount of labor and necessary machines. The automobile manufacturing industry is a traditional industry with a history of more than 100 years. Most parts, modules or production links already have fairly mature technologies and processes. In order to reduce costs, conventional automobile manufacturers generally outsource the production of parts to professional parts suppliers, while focusing on assembly, branding, and sales. Most manufacturing companies in China only do simple assembly steps or the production of general parts. Therefore, only low profits can be obtained. The supply of parts and components, especially the supply of core parts and components, is very important in the automotive industry chain, and the profit margin is also higher. Notooka Kentaro and Ueno Masaki (2005) also pointed out that Chinese companies have formed product development capabilities and international competitiveness centered on assembly capabilities. But assembly capacity alone has great limitations.

In response to this problem, BYD adopted a modular vertical integration model of the entire industry chain. At least 70% of the parts are produced by the company's internal business department. BYD not only manufactures its own molds, fixtures, production equipment, but even some parts such as some plastic parts, air conditioners, seats, audio, etc. are completely produced by BYD or its related sub-companies. In addition to the engine and gearbox of some models, most parts of BYD vehicles are self-sufficient. Especially with the acceleration of electrification, motors, batteries, and electronic control systems are gradually replacing the core components of traditional cars, which makes BYD's vertical integration further improved. Since turning losses into profit in 2006, BYD's sales have been growing at a rapid rate, with growth rates as high as 414%, 51%, 77% and 143% from 2006 to 2009. Since 2015 to 2018, it ranked top in the global sales ranking of new energy vehicles (PHEV and BEV).

By the architecture innovation, BYD turned the capital-intensive industry of automobile manufacturing into a capital-labor-intensive industry. It maximized the combination of technology and labor. Though this kind of architecture innovation, BYD obtained cost advantages and product performance that foreign competitors are difficult to imitate.

5.3.2. Differentiation and Focus Strategy Based on Architecture Innovation

Different companies choose different strategies to conduct the competition in the new energy vehicle industry and try to win in the future. For example, Toyota mainly focuses on hybrid vehicles and extends to hydrogen-powered vehicles. While BYD focuses on the battery electric vehicles because its accumulated technology in battery. In this section, we will analyze how the strategy of late-coming automobile company different with the strategy of conventional automobile company in terms of developing new energy vehicles. Then we will discuss how late-coming automobile company utilized architecture innovation to achieve differentiation strategy.

In order to cope with the development trend of new energy vehicles, traditional existing organization may spend lots of efforts on the R&D and innovation, but because of its old organization structure and business model, it is difficult for this kind of company to conduct architecture innovation thoroughly. But new entrants to the industry, such as BYD, may make full use of the new technology more easyly, since “they are not handicapped by a legacy of embedded and partially irrelevant architectural knowledge”. (Henderson and Clark, 1990)

Let’s start from conventional automobile companies. Since the internal combustion engine becoming the basis for the dominant design of automobile industry, the industry continued evolving by the addition of multiple inventions and new technologies in the form of new components and interactions. Through this process, the "core design concept" got reinforced, while leaving the architecture mostly unchanged with the addition of each advancement. After decades of development and even nearly a hundred years of development, traditional automobile companies have accumulated strong incremental innovation capabilities.

When these conventional automobile companies attempt to find a replacement for the ICE vehicles, we can argue that these attempts fall in the category of "modular innovation". Because, for the most part, the vehicle architecture - and the broader system architecture for sales, service and refueling remained unchanged. The addition of new components to develop HEVs, PHEVs and even some kinds of BEVs responds more to a "modular innovation" pattern. Even though the inclusion of an all-electric powertrain could have required a modification of the whole architecture, the latter remained mostly untouched, which implies that the architecture was "adapted" to the "established design", resulting in a "new" concept. This analysis applies to multiple alternative-fuel offerings built from the same vehicle architecture such as FFV (Flex Fuel Vehicles), CNG (Compressed Natural Gas), diesel-powered vehicles etc. It also holds valid for most of the HEVs, PHEVs and BEVs on the road. A good reference point that illustrates this well is the BEV from GM launched in

2017, the Bolt, which share platform with the GM Sonic. The Bolt and Sonic are both derivatives from GM's Gamma family of vehicle architecture platform for conventional ICE B-segment vehicles.

According to Henderson and Clark, established firms often faced problems about architecture innovation. First of all, they faced with problem to identify a particular innovation as architecture innovation; Second, they faced problems about the need to build new architecture, because the old organization and architecture can still bring enough profit for them. Thirdly, they faced with problem to apply new architectural knowledge effectively. That is why so many conventional automobile companies choose developing HEV and PHEV as their strategy to cope with the electrification trend. And why they move so slowly to develop and launch new pure electric vehicles.

Figure 14 : Differentiation of the latecomer and conventional automobiles

	Component Knowledge		Architecture Knowledge	
	Incremental Innovation	Modular Innovation	Architecture Innovation	Radical Innovation
Conventional Automobiles (estabished firms)	Strong	Regard HEV/PHEV as transition product; Adapted to the "established design" and exitsing platform.	Face problems to apply new architectural knowledge effectively. Launch of BEV is relatively slow.	not appeared
BYD (latecomer)	Weak	Utilize estabilshed firms' accumulated experiences and capabilities by cooperation with conventional automakers.	Easier to bulid organizaional flexibility and build new architecture knowledge; Build new architecuture based on battery technology; Activly developed BEV products.	not appeared

Source: Author's edit

On the other hand, new entrants company or late-comers, "with smaller commitments to older ways of learning about the environment and organizing their knowledge, often find it easier to build the organizational flexibility that abandoning old architectural knowledge and building new requires" (Henderson and Clark, 1990). For the new EV technical structure, new entrants or late-comers also need to construct their new architectural knowledge necessary to make full use of new architecture innovation, but since they have no or less existing assets, they can better optimize their organization and information processing structures to exploit the potential of a new design, such as the new architecture of BEV. Since they are not handicapped by a legacy of embedded and partially irrelevant architectural knowledge, new entrants or late-comers, such as BYD, can exploit the potential to develop the BEV much more effectively.

BYD actively carries out architecture innovation, focusing on the development of a new product architecture centered on battery technology. On the one hand, BYD invest a lot of resources for independent battery research and development, and vigorously develop a new product architecture based on batteries as the core technology. BYD focus on the development and sales of pure electric vehicles, a number of best-selling pure electric models were introduced to the market. On the other hand, through the cooperation with traditional manufacturers, BYD try to take advantage of the integrated and modular technology advantages accumulated by traditional manufacturers to develop their own electric vehicle technology.

BYD started in the battery business in 1995, mastering the core technologies of electric vehicles such as rechargeable batteries, electric motors and electric controls. It was not until early 2003 that BYD acquired Qinchuan Automobile and formally entered the automotive industry. It has become an enterprise that can provide new energy overall solutions including electric vehicles and power batteries. BYD launched its mass-produced PHEV in 2008, and in 2015,2016,2017 and 2018 it ranked the first in the global sales of new energy vehicles including PHEV and BEV.

In October 2011, BYD launched the first pure electric model E6300. The arrival of E6300 announced that BYD has officially entered the era of pure electric. The E6300 has an integrated cruising range of 300 kilometers. As a pure electric vehicle with zero emissions and pollution, it was the first choice of many cities at that time. At present, in Shenzhen and other places, there are still many E 6300 taxis put into use as taxis. The mileage of the first models has even exceeded millions of kilometers. BYD opened its own market in the new energy field at that time with its excellent three-electricity technology (battery, motor, and electric control). Until now, BYD has been in a leading position in the new energy vehicles industry. In recent years, the Chinese domestic new energy vehicle industry has experienced a period of rapid development. Many automobile companies have joined the field of new energy vehicles and have launched their own new energy vehicle products. However, BYD has always led the development trend of the entire industry with its leading advantages in battery research and development and technology. From 2016 to 2017, pure electric vehicles such as E5300, Qin EV 300, Song EV 300 and Yuan EV were launched one after another. Accelerate the application and promotion of new energy vehicles. Today, the pure electric family matrix has become the most powerful product layout of new energy vehicles. The range of all products has far exceeded 400 kilometers, and most models have exceeded 500 kilometers. The new generation of Tang EV, which has been launched recently, has exceeded 600 kilometers of battery life and has been ahead of the new energy vehicle field.

Based on its core battery technologies, BYD has developed a wide range of practical and economical EV solutions. It has launched commercial vehicles that cover ten market segments: buses, coaches and taxis; logistics, construction and sanitation vehicles; and vehicles for warehousing, port, airport and mining operations.

BYD enters the field of passenger vehicles and commercial vehicles through a differentiated strategy based on architectural innovation. Battery Electric Vehicles and other commercial vehicles using self-made batteries are the manifestation of BYD's differentiation strategy.

CHAPTER 6. DISCUSSION

Section 1. KEY FACTORS OF SUCCESSFUL ARCHITECTURE INNOVATION STRATEGY FOR CHINESE LATECOMER

(1) Seizing the opportunity window and introducing new technologies for technology integration in a timely manner are historical opportunities for latecomers to conduct their architecture innovation and achieve catch-up.

Due to the inertial understanding of the leading design technology by the first-mover companies, the original architectural knowledge is rooted in the organization and information screening process of the incumbent company (Henderson and Clark, 1990). Therefore, incumbent companies often find it difficult to recognize alternative technologies. Moreover, incumbent companies are often the leaders and biggest beneficiaries of old technology, and they hope to continue to gain more benefits from old technology. Therefore, when new technologies emerge, incumbents often turn a blind eye or are hesitant to invest more resources in exploring the commercialization of new technologies or new architectures. This provides a rare technical window for the latecomers to achieve catching up. BYD is an example who successfully seize the opportunity window of electrification of automobile. Through the architecture innovation and integration of new battery technologies and traditional automotive products, it has finally achieved a leapfrog.

(2) The accumulation of technological capabilities is a prerequisite for late-coming companies to conduct architecture innovation and achieve catch-up.

The opportunities provided by the incumbent leader are equal for all latecomers, but practice has proved that only a handful of latecomers can really seize historical opportunities. One of the common characteristics of these few companies is their strong technology accumulation and architectural innovation capabilities. Only with the accumulation of considerable technical resources will the latecomers have the opportunity to design new product architectures first and use this as a "fulcrum" to launch new products to the market first. Moreover, since latecomers “have no or less existing assets, they can better optimize their organization and information processing structures to exploit the potential of a new design” (Henderson and Clark, 1990). The core technology and architecture innovation capabilities formed by technology accumulation are very important for late-coming companies to enhance their competitiveness.

(3) Third, based on the local market, making full use of China's low labor cost advantage is an important strategy for latecomers to carry out structural innovation.

China's local market is a valuable strategic resource, and its value is not only to provide growth space for the technical and organizational capabilities of Chinese enterprises and industries, but also to provide development possibilities for new technologies and new industries that originate from local innovations. The low-end disruptive innovation theory of Christensen (1997) has also indicated the way for innovation for latecomers. The essence of architectural innovation is not whether to adopt an integrated architecture or a modular architecture. The key is that the adopted architectural innovation strategy can make full use of the comparative advantages of Chinese labor and other resources. The case of BYD proves that based on the local market, through architecture innovation and low-end disruption is an important strategy for latecomers to catch up.

(4) The founder's entrepreneurial spirit and ambition are the key to whether late-coming companies can persist in implementing the self-developed architecture innovation strategy for a long time.

Innovation is the essential characteristic of entrepreneurs and the soul of entrepreneurship. The self-developed architecture innovation strategy is a long-term and difficult system engineering. Whether the founder of the latecomer has the entrepreneurial spirit of "creative destruction" and the ambitious ambition of catching up and leapfrogging, determines whether the company can adhere to its independent architectural innovation strategy for a long time. The height of the entrepreneur's ambitions and pursuits determines the height of the enterprise. Wang Chuanfu has been committed to building the world's leading electric vehicle which is made in China since the beginning of his business. It is precisely because of the founder's innovative spirit and ambitious ambition that BYD has become bigger and stronger, and finally become the leader of EV in China and even the world.

Section 2. SUGGESTION TO CHINESE LATECOMER AUTOMAKER

(1). Modularization of core technologies in development of EV

Integration architecture is the area which conventional automobile companies are very strong. China's latecomers must find breakthrough by differentiation, such as focus on the modular architecture. Besides the power battery, electric engine and electric control system, there are also some important core system of EV, for example the driving system and transmission system. Both driving system and transmission system are core components either in conventional vehicle or in EVs. As a result, the development of these technologies plays an important role in EV program. Some China's EV manufacturers including Geely, Chery, FAW, Dongfeng and SAIC managed to acquire these core technologies by independent R&D, technology transfer or cooperation and established a modular product architecture. The modularization of core technologies in core system of EV enabled these manufacturers to switch easily to EV from ICE vehicles with a lower transfer cost.

(2). Building new architecture and industry platform based on battery technologies

The industry platform based on battery technologies is critical to the successful commercialization of EVs. The experience of BYD, a local leader in the production of hybrid and electric vehicles, explains how a latecomer company managed to build EV industry platform based on its original core battery technologies. As the world's second largest battery company in 2002, BYD's Li-ion battery technologies reached an international advanced level. In 2003, BYD decided to enter the automobile industry and acquired Shanxi Qinchuan Auto Company Limited as a way to get the license for auto manufacturing. Based on their strong technology capabilities in the field of battery technologies, BYD began its leapfrogging from a battery vendor to an EV manufacturer. In this process BYD has to address two major issues: one is to integrate battery technology into conventional dominant design of ICE vehicles, the other one is to establish a universal interface to re-architect the relationships between the battery and other components of the new electric vehicles. Fortunately, BYD succeeded in building the EV structure and platform based on battery technology and started to sell F3DM, the first commercial PHEV which did not requires a professional charging station in 2008, one year ahead of GM and Toyota. Thanks to the industry platform based on its breakthrough battery technology, BYD provided a series of innovative products in EV industry.

(3). Cross-industry integration and architecture innovation

How do latecomer firms manage to deliver cross-industry integration architecture innovation in a short time? M&A may provide an opportunity to acquire necessary technology knowledge and capabilities quickly. Electric engine technology is another essential component technology for EV manufacturers. However, this is a completely new field for BYD. In 2008, BYD acquired a local IC firm and built an electric engine industry platform, which is the major drive of the whole EV industry chain. Thus, BYD succeeded in establishing a complete EV industry chain including battery platform, automotive platform and electric engine platform, based on which BYD greatly promoted the industrialization of EVs. Although BYD had to absorb the new knowledge from other domains, these platforms, composed of core technologies which perform essential function within a system of use and are easy to connect to or to build upon to expand the system of use, in fact, create a wide range of opportunities for cross-industry integration and architecture innovation.

Considering the current situation of China's EV industry, automakers will have to produce both conventional cars and NEVs at least in the medium term. Thus, they firstly establish modular product architecture through development or acquisition of modular core technologies, which increase their independence in producing conventional cars and lower their switching cost to EV production. Moreover, a few firms build the industry platform based on their core components technology, which form the prerequisite for delivering architecture innovation. Lastly, to deliver cross-industry integration and architecture innovation, the firm has to integrate the new capabilities or knowledge from multi-fields into their existent ones.

CHAPTER 7. CONCLUSION AND FUTURE WORK

The electrification and modularization of automobiles have brought unprecedented opportunities for late-coming companies to achieve leapfrogging. This paper introduces BYD's case and analyzes BYD's competitive advantages and its cost-leadership and differentiation competitive strategies based on architectural innovation. It is concluded that architectural innovation is of great significance for helping late-coming companies gain a competitive advantage and achieve leapfrogging. Afterwards, the key factors that influence the success of architecture innovation of China 's late-coming companies are analyzed. Then suggestions are made for the future development of Chinese late-coming automobile companies in the field of new energy vehicles industry.

However, there are still some limitations in this paper, which need further research work in the future. This article only considers the situation of the automotive industry and points out that for the automotive industry in a period of change, architectural innovation is an effective way for latecomers to achieve leapfrogging. However, the impact of architectural innovation on other industries will require further research in the future.

This paper only conducts a qualitative analysis of the success factors of architectural innovation. As for how companies conduct architectural innovations and how to allocate existing resources for architectural innovations, more specific quantitative research is needed in the future.

This paper proposes countermeasures and suggestions for the latecomers of the Chinese auto market, assuming that China still has a human resource dividend. But with the impact of factors such as the increase in China's human costs, what should Chinese late-coming companies do to utilize architecture innovation to achieve catching-up needs further research.

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