B2C Battery Swapping Model:

A Supply Chain Innovation Perspective

by

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Abstract

Battery Swapping Model (BSM), a new form of electric vehicle (EV) replenishment, has been widely employed in the Business-to-Business (B2B) EV market to complement the charging model. Nio, a Chinese EV manufacturer, is one of the few but most representative in the Business-to-Customer (B2C) BSM, yet there is no literature that provides insight about it. This thesis builds a theoretical framework from supply chain innovation (SCI) perspective and uses a case study to answer (1) why Nio chose B2C BSM; (2) what SCI Nio has done; and (3) how Nio and other supply chain stakeholders have achieved SCI.

Through semi-structured interviews, this thesis finds that in addition to external motivators such as policy incentives and rapid EV market expansion, Nio's pursuit of user experience, value-added battery assets, and energy replenishment efficiency are also important internal motivators. For innovation content, the B2C BSM is rooted in Nio's user-first business strategy and provides value-add for supply chain stakeholders through business model innovation, specifically in lowering EV purchase prices, eliminating battery depreciation, providing flexible battery leasing solutions, and maximizing battery value through gradient utilization and large-scale recycling. Also, battery, swapping station, and cloud-based battery data platform are the three main directions of technology innovation. In terms of innovation process, supply chain learning and supply chain collaboration play an active role in SCI, and their breadth and depth are dynamically changing with the development of SCI.

This thesis is the first case study to systematically analyze B2C BSM, bridging the gap that academia has lagged far behind the rapid development of the B2C BSM. This thesis suggests the inclusion of government roles, implicit competition in supply chain collaboration, and implementation costs in SCI theoretical discussions, and highlights the importance of dynamic capability theory, stakeholder theory, and competition-cooperation theory to the SCI literature.

Keywords: Battery Swapping Model; Supply Chain Innovation; Battery Electric Vehicle

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Thanks to my co-advisor, Dr. Paul D. Larson, for his insightful comments on the thesis' background and theoretical framework, particularly for the inclusion of green electricity generation. I also learned more about sustainability in the course.

Dr. Changmin Jiang, thanks for reminding me to analyze the Nio case critically and dialectically in order to objectively evaluate its innovation capabilities. Thanks also to Dr. Nathan Greidanus for his ongoing support with my thesis and for encouraging me to compare and reflect more on Nio with past failed cases. Thank you, Dr. Srimantoorao Appadoo, for being a new committee member. I admire your deep knowledge of quantitative analysis and operation optimization algorithms. I would like to thank Claire and Siobhan for their help. Without their patient answers and assistance, my thesis could not have been successfully completed.

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Contents

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Abbreviations Table

BSM: Battery Swapping Model

SCI: Supply Chain Innovation

BSS: Battery Swapping Station

EV: Electric Vehicle

BEV: Battery Electric Vehicle

PHEV: Plug-In Hybrid Electric Vehicle

ICV: Internal Combustion Vehicle

B2B: Business to Business

B2C: Business to Consumer

NEA: National Energy Agency of People Republic of China

CAAM: China Association of Automobile Manufacturers

MIIT: Ministry of Industry and Information Technology of People Republic of China

NDRC: Development and Reform Commission of People Republic of China

BAMC: Battery Asset Management Company

ERBV: Extended Resource-Based View

CNIPA: China National Intellectual Property Administration

BP: Better Place (The first operator trying B2C BSM)

AC: Alternating Current

DC: Direct Current

BaaS: Battery-as-a-Service

1 Research Background

Currently climate change has become one of the most serious threats and challenges to humanity, and carbon neutrality has basically become a global consensus. After the European Commission proposed a net zero-carbon emissions target for the entire EU by 2050 in March 2020 (ECII, 2020), China also proposed a sustainable development goal of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060 (Zhao et al., 2022). The carbon neutrality target provides direction for China's rapid economic and social development in the current to the middle of the 21st century, while forcing it to make a comprehensive low-carbon transition and reshape future industrial production and lifestyles. Some scholars also agree that this will mark China's move from a demographic dividend to a sustainable "zero carbon dividend" (Dong et al., 2019).

Carbon emissions are influenced by multiple factors, including economic development, industrial structure, and technology level (Zhou et al., 2017), but essentially, the two main contradictions of energy production and energy consumption must be addressed. Only through the combined effect of clean energy production and electrification of energy consumption, as well as the synergistic promotion of green transformation on both the supply and demand sides, can we finally create a modern energy system that is clean, low-carbon, safe, and efficient (Zahnd and Kimber, 2009). The main fronts of energy production and consumption in China are electricity generation and transportation, which account for more than 60% of the carbon emission breakdown (General Office of the State Council, PRC., 2020).

Electricity is the backbone of the entire energy system. Reducing fossil energy in power generation and significantly increasing the share of renewable energy use is a prerequisite for reaching carbon neutrality goals. In fact, China is also planning and undergoing a revolution in its electricity system. According to China's National Energy Administration (NEA, 2021), by the end of 2020, China had 930 million kilowatts of installed electricity capacity from renewable sources, including 370 million kilowatts of hydropower, 280 million kilowatts of wind power and 250 million kilowatts of photovoltaic power. China's renewable energy generation accounted for 42.4% of total installed capacity, an increase of 14.6% compared to 2012. The significant increase in the proportion of renewable energy can be attributed mainly to the cost reduction brought by technology innovation and large-scale production (Zhou et al., 2017). For example, the average cost per kilowatt of onshore wind power projects fell by about 30%, and the cost of photovoltaic fell from 50 yuan/W to the current 4.5 yuan/W, a reduction of more than 90% (NEA, 2021). The "visible hand" of the government also plays a critical role in this process, such as providing financial subsidies, tax credits, and cheap land (Ming et al., 2013). Finally, the ultra-high voltage technology also makes it possible to transport large-scale, low-loss electricity (Chen and Cui, 2015). Concentrated photovoltaic stations, large wind power plants, and large hydropower plants distributed in western China will be transported by this technology to developed cities in the east where is the main electricity consumption market.

The transportation sector, on the other hand, consumes about 60% of China's total crude oil consumption each year and accounts for 15% of the final carbon emissions, with an average annual growth rate of more than 5% in the last nine years (NEA, 2011). With the carbon neutrality objective as a motivator, all aspects of the transportation sector will be upgraded and iterated, and China is expected to achieve full road transportation electrification around 2050. (General Office of the State Council, PRC., 2020). In the public transportation sector, for example, new energy vehicles have made significant progress. For several years, the percentage of new energy vehicles in buses has topped 90% (CAAM, 2020). The truck and construction machinery industries are also undergoing rapid electrification (CAAM, 2021). New energy vehicles is also demonstrating good rising momentum in the most significant consumer market - passenger cars.

In fact, this is not just happening in China, the worldwide new energy passenger vehicle market has entered a rapid expansion era, with market size topping 1 million units for the first time in 2017 and 2 million units in 2018 (MIIT, 2021). In 2020, as per Figure 1.1, despite a significant decline in the global automotive market due to the pandemic, the new energy vehicle market grew strongly, with sales increasing 41.6 percent year on year to 3.07 million units and the penetration rate (the percentage of the relevant consumers that has purchased new energy vehicles at least once in a year) increasing to 4 percent, up

1.6 percent from 2019. It can be seen the new energy vehicles are injecting new momentum into the development of the world economy (MIIT, 2021).

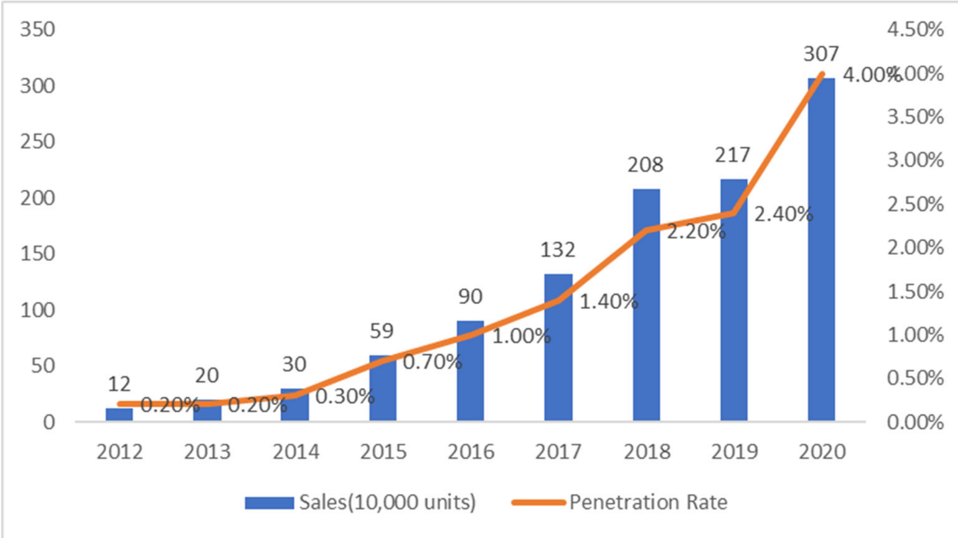


Figure 1.1. Global New Energy Vehicle Sales and Penetration Rate (Source: CAAM, MIIT and Marlines)

In terms of the global new energy vehicle industry growth, China, Europe and the United States are the main driving forces (Marlines, 2021). With 44.6 percent of sales, China is the world's largest market (MIIT, 2021). This can be attributed to policies such as tightening carbon emission regulations (Hoen et al., 2014), maintaining tax credits for new energy vehicles (Yuan et al., 2015), and accelerating industrial clusters (Wei et al., 2016). Another notable point is that the Chinese new energy vehicle market is dominated by BEVs, which together with Plug-in hybrid electric vehicle (PHEV) sales account for 70.6% and 29.1% of total sales in the country (CAAM, 2020b). Research on BEV is important for the development of the whole industry and for achieving global sustainability goals.

However, this dazzling market achievement cannot conceal the fact that internal combustion vehicles (ICV) still occupy a high penetration rate of 96% (CAAM, 2020b). What is holding back the development of BEVs? Or, from a supply chain perspective, what characteristics of related supply chain do not yet meet the needs of final consumers? By reviewing the related literature, this thesis suggests two main stumbling blocks.

The first challenge is range anxiety (Neubauer et al., 2014). Consumers have concern that their BEVs do not have enough range to reach the destination. While this phrase can be used to denote both ICV and BEV owners, BEV users are significantly more frequently cited (Scott-Parker et al., 2011). ICVs, with their densely laid out gas stations and accessible refuelling options, can swiftly supply consumers' energy replenishment needs when gas is nearing a scarcity (Ministry of Commerce, 2020). Battery charging periods for BEVs, on the other hand, can take hours (IEA, 2019). In addition, due to variations in charging station voltage, battery anode materials, capacity, and charging/driving conditions, the actual range after a full charge is 5 to 30 percent less than what BEV manufacturers advertise (Bobba, 2018).

The second factor that discourages consumers from purchasing a BEV is the battery (Zeng et al., 2015). Due in part to higher battery costs, BEVs in the same class have a higher selling price than ICVs. For example, a 70kwh battery takes over 30 to 40 percent of the total material cost of a vehicle (CAAM, 2020a). Although BEVs have lower operating and maintenance costs compared to ICVs, the higher purchase prices deter potential buyers. In addition, the significant reduction of Chinese government subsidies for BEV battery packs after 2019 reduces the market advantage of BEVs (Li et al., 2020). In addition, the battery energy density is gradually rising as new materials and battery management systems (BMS) are developed (Beaudet et al., 2020). On the one hand, technological advancements result in the depreciation of older batteries, so the three-year residual value of the most commonly used BEVs is 41.5%, which is 15% less than that of ICVs (CADA, 2020). Continuous battery innovation, on the other hand, is detrimental to BEV owners. In a very short time, they may be able to obtain higher-performance batteries for the same price, which will affect the brand identity of a new consumer product that is slowly and steadily gaining traction (Li, S. 2016).

In summary, the carbon neutral consensus has created enormous opportunities and potential for the BEV market in China and abroad. However, range anxiety and battery limitations prevented it from meeting customer expectations and ensuring the continued growth of the industry (CAAM, 2020a). In response to these issues, the Battery Swapping Model (BSM) was developed and implemented as an alternative method for recharging

BEV batteries. However, this model has received less research than direct AC/DC charging (Bobba, M. 2018).

BSM can essentially be interpreted in two ways. Firstly, BSM separates the battery from the BEV in terms of ownership. The user purchases the BEV minus the battery pack and leases it on a monthly or annual basis, which reduces the price of the BEV and gives consumers additional options (MIIT, 2021). When greater capacity or technologically advanced batteries are introduced, it is easier and more convenient to change the battery lease plan than to sell the BEV outright (Zheng et al., 2012). Second, the battery swapping station (BSS) is introduced as the physical location of BSM implementation. Swapping the BEV battery pack takes between 3 and 10 minutes, whereas slow AC charging takes over 8 hours and quick DC charging at least 30 minutes (IEA, 2019). Additionally, BSS enables the large-scale management of battery packs, which aids in battery maintenance and service life extension (Zhang et al., 2014). Besides, the rapid growth of BEV charging places stress on the grid (Li and Bai, 2011). After all, the majority of charging station usage occurs during the day, when the grid is at its peak capacity. In contrast, BSS can take advantage of the abundant and inexpensive nighttime electricity resources (Yan et al., 2019).

China's B2B (Business-to-Business) sector (including commercial vehicles such as taxis, logistics trucks, and time-sharing BEV) is increasingly relying on BSM to supplement energy (Rao et al., 2015). These commercial vehicles are customized with fewer battery brands and specifications, as well as more stringent requirements for battery life and maintenance, all of which meet BSM's technical requirements. Furthermore, AC/DC charging is inefficient and does not align with the efficiency- and results-focused business logic of commercial vehicles (Revankar and Kalkhambkar, 2021).

Compared to B2B, the development of BSM in the B2C (Business to Consumer) sector has been slower and more gradual. This may be due to the failure of Better Place (BP), the first company to introduce BSM to individual consumers (Christensen et al., 2012). BP was founded in Israel in 2007 with a focus on building BSM and charging infrastructure, and its first BSS went live in 2008. (Noel and Sovacool, 2016). In May 2013, only seven years after its inception, the company entered bankruptcy and its assets were auctioned for $450,000, the price of a single condominium in Tel Aviv. (Kloosterman, 2013). The reasons for BP's failure are likely to be manifold, with Woody (2013) suggesting that BP's financial failure stems from a technological disadvantage, namely the failure of both range and battery technology to meet the minimum requirements for large-scale commercial deployment. Kershne (2013), on the other hand, blames the founder Shai Agassi's personal mismanagement and executive's blindly high expectations of their own model. Kloosterman (2013) argues that BP has wasted too much effort in promoting BSM in multiple countries, where the acceptance and promotion policies for BSM vary from one country to another. Noel and Sovacool (2016) mention that a lot of investment has been put into charging as well as infrastructure for BSM, neglecting consumer experience as well as service standards establishment. Sovacool et al. (2017) note that Better Place failed because it "stretched" notions of design and functionality to the point it "broke" (overstating its own product as well as its business model) and that its overly high-profile publicity elicited defensive responses from competitors (e.g., GM and Tesla began to focus more on fast charging as a major direction). In all, the visionary scripts of BP overestimated customer expectations and ignored chronic concerns.

Some, but very few researchers have analyzed BP's failures from a supply chain perspective. These studies suggest that BP lacked experience in the automobile and swapping station, which means it did not have the capability to produce and operate BSM supply chain on its own (Sovacool et al., 2017). At the same time, there are shortcomings in knowledge sharing and collaborative innovation between BP and BSM supply chain stakeholders (Sovacool, 2016). With its battery standards still incompatible with other automakers and poor initial vehicle sales, the vehicle manufacturers that should be working closely with BP have little incentive to refine vehicle body and battery designs (Kloosterman, 2013).

However, the failure of BP does not negate the potential value of B2C BSM entirely. As suggested by Sovacool et al. (2017), BP seeks to reinvent mobility and the automobile itself. This is not an incremental effort, but a revolutionary effort to alter consumers' conceptions of "electrically powered." In other words, B2C BSM itself may not have failed, but rather the era in which BP existed. Specifically, neither the BEV supply chain nor consumers were prepared for such revolutionary innovations. Some scholars have praised Better Place for its putative creativity and expected future success. (e.g., Christensen et al., 2012; Kley et al., 2011)

Are there any organizations willing to implement B2C BSM in the after the BP failure? The answer is yes. Nio, a Chinese manufacturer of BEVs, released its "Battery-as-a-Service" (BaaS) (the commercial name of its B2C BSM) and the first version of a Battery swapping station (BSS) solution supporting all of its vehicles in September 2018. Figure 1.2 illustrates the rapid evolution of Nio's BSS since 2019.

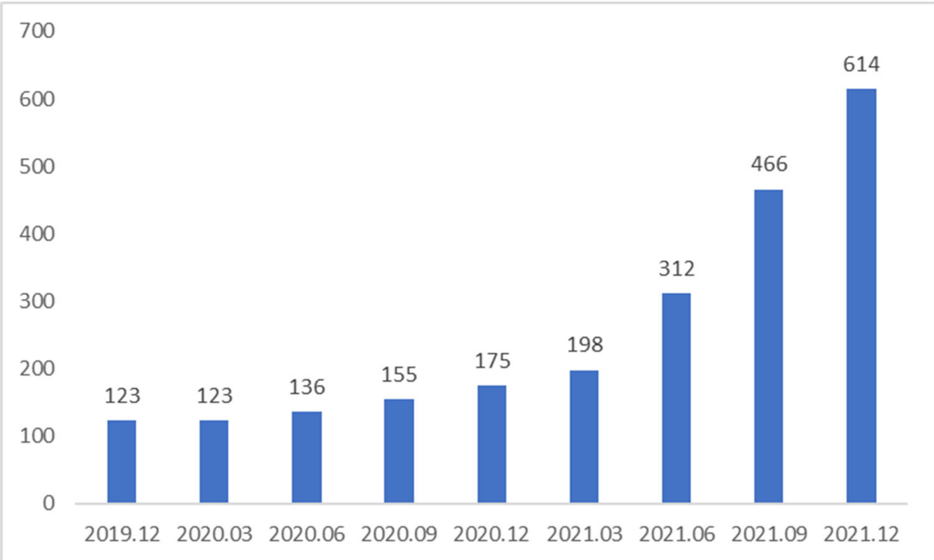


Figure 1.2. Number of Nio BSS between 2019 and 2021 (Source: Nio)

Nio's first generation BSS was officially installed and opened in Shenzhen on May 20, 2018. 869 days later, Nio announced that it had surpassed one million battery swaps, while reaching two million took only 170 days more. As of 11 November 2021, Nio has constructed 613 BSSs in China and one BSS in Norway, its first station on an international market (Nio, 2021).

The rapid expansion of BSM reflects the fact that academic research has lagged behind industrial application. The automotive industry is closely related to the growth of supply chain innovation literature (SCI). The SCI theoretical perspective provides a clear theoretical framework and a common terminology set, which together increase conceptual understanding consistency and provide case study researchers with a narrative logic (Gerd and Hahn, 2020). Arljrn et al. (2011), on the other hand, noted that in the context of supply chain management, there is a large gap between the application of innovation and the systematic academic research on the concept. Melese et al. (2009) argued that industry and academia do not share the same conception of innovation. Therefore, according to this thesis, the theoretical perspective of SCI can bridge this gap and more accurately reflect cutting-edge applications.

Until December 2021, however, there is no case study that examines the innovation tactics and strategies in the field. For example, how have B2C BSM stakeholders implemented innovations in the supply chain, and in what context have these innovations emerged. Not to mention the potential bottlenecks in their supply chains and how to overcome such obstacles. In addition, given the rapid expansion of the Nio BSS network and the continued focus from BEV consumers (Li et al., 2020) and industry experts (CADA, 2020), academia lacks empirical studies to summarize and attempt to theorize the industry's SCI strategies, which may hinder the expansion of the applications boundaries of SCI literature and the development of the B2C BSM industry.

To fill the aforementioned voids, the following research questions are posed in this thesis:

1. Why question:

Why did Nio opt for B2C BSM, and how does its supply chain differ from B2B BSM and fast charging on the current Chinese market?

2. What question:

What are the roles and responsibilities of each stakeholder in the B2C BSM supply chain, and what are the most important interactions?

What innovations have been implemented by Nio and other B2C BSM supply chain stakeholders? What effect does this innovation have on the overall performance of the supply chain?

3. How question:

How do the B2C BSM supply chain stakeholders initiate and facilitate SCIs, and what are the key processes involved?

To answer these questions, this study employs the theoretical perspective of SCI to determine which themes and dimensions are present in B2C BSM-based supply chains and how they relate to one another in order to develop a suitable theoretical framework for B2C BSM SCI. Subsequently, an in-depth case study of Nio is anticipated to generate SCI strategy propositions and additional key findings regarding its B2C BSM supply chain.

2 Literature Review and Theoretical Model

2.1 Supply Chain Innovation

The study of innovation has a long history. According to Schumpeter (1934), innovation is defined as the introduction of new goods and industrial processes, the discovery of new markets, the creation of new raw materials, and the formation of new organizations. The basic aspects of innovation are incorporated into the idea of SCI when innovation and the supply chain are united. First, SCI is by nature dynamic. This parallels the perspective of organizational learning (Levitt and March, 1988). Members of the supply chain are initially immature; however, as time progressed and they gained, absorbed, and accumulated new knowledge systems and functional structures, their innovation-related capabilities increased. Furthermore, SCI might range from incremental to radical in terms of innovation efficacy (Norman and Verganti, 2014). The incremental SCI entails the optimization of current supply network, technological, or commercial practices. Radical SCI, on the other hand, denotes a paradigm shift, as such innovations typically involve new and highly complex technologies, alter the market structure, and necessitate user education (Lettl, 2007). SCI can also be used in a wide range of corporate tasks, such as forecasting, distribution, and procurement. It can occur within companies, between companies, and across entire supply networks, as well as across an entire industry. Consequently, these various functions and levels may vary within a single innovation (Arbjrn et al., 2011). Fourth, the concept of SCI cannot only be an invention or an new idea; it must also be applied to the actual supply chain, or SCI members will be forced to take on the position of daredevil or pioneer. New value must be created as a result of innovation. This also suggests that SCI's objective is to add value to the firm or other stakeholders (supply chain partner or final consumer).

However, if the academic field of SCI places an excessive emphasis on "innovation," the understanding of SCI will become too comprehensive and complex to be encompassed by a general definition or simple explanation. To establish a more exact definition of SCI, it is necessary to consider innovation from the standpoint of the supply chain. Supply chains are often characterized as vertical sequences of interdependent transactions that provide value to the ultimate user (Lazzarini, 2001). Supply chain management (SCM) encompasses two primary responsibilities (Janvier-James, 2002): (1) planning, implementing, and controlling the primary activities that create and deliver value to customers (especially purchasing, manufacturing, and logistics); and (2) integrating business partners into the value network and coordinating the corresponding business processes within and between companies.

According to the first definition of SCM, the dimensions of SCI may encompass the classic areas of innovation management, such as innovation strategy, organizational and process innovation. For the second definition, however, SCI focuses more on innovation networks and innovation content (Mentzer et al., 2006). In fact, Kim et al. (2011) and Yusuf et al. (2014) concur that the supply chain should be viewed as a complex and continuously evolving network of organizations, rather than a linear route between enterprises. To put it another way, the underlying assumption of the supply chain as an organizational network is that today's rivalry is between supply chain networks rather than between individual firms. As a result, by merging suppliers and consumers or building horizontal partnerships, innovation networks can develop new ideas (Roy et al., 2004). And, in most cases, this progress is followed by supply chain collaboration and learning. Innovation content, on the other hand, refers to the end result of the innovation process. Innovation content may be regarded of as the "what" of innovation, whereas the innovation process focuses on the "how." Arlbjørn et al. (2011) identify three interactive content dimensions of SCI: supply chain business model, supply chain technology, and supply chain network structure, and the validity of this conceptual model has been verified by 36 cases.

SCI is described as incremental or radical changes to a supply chain network, technology, or business model (or a mix of these) that can occur inside a corporate function, firm, or supply chain to produce new stakeholder value. As more companies rely on SCI to compete successfully and efficiently, the requirement for a trustworthy and reliable SCI evaluation instrument becomes increasingly important. According to Gregor (2006), theory building begins with content analysis and progresses through explanation and prediction. The empirical scope of SCI has not yet encompassed B2C BSM, possibly due to the absence of such innovative practices in the current market or because researchers have overlooked the necessity and significance of a comprehensive analysis of B2C BSM from a SCI standpoint. Studying the constitutive dimensions of BSM SCI, particularly in the emerging scenario of B2C, and how they interact and evolve with one another could potentially fill the aforementioned void.

2.2 Theoretical Model

Through the review of 2.1, to systematically explain B2C BSM SCI, two aspects should receive the necessary attention: one is the innovation content ("What"), and the other is the innovation process ("How"). However, for complex supply chains, it may not be sufficient to simply consider innovation content and process; for instance, the innovation content may influence the organization of the innovation process, and vice versa (Arlbjrn et al., 2011). This study as a single case study has relatively few uncertainties, allowing it to follow the theoretical framework relatively clearly and logically in describing Nio's innovation process and the innovation content that was achieved.

Integrating Arlbjørn et al. (2011) and Silvestre's (2015) insights on SCI, this paper builds the theoretical model suitable for explaining B2C BSM SCI (will be elaborated in detail afterwards). It is shown in Figure 2.1.

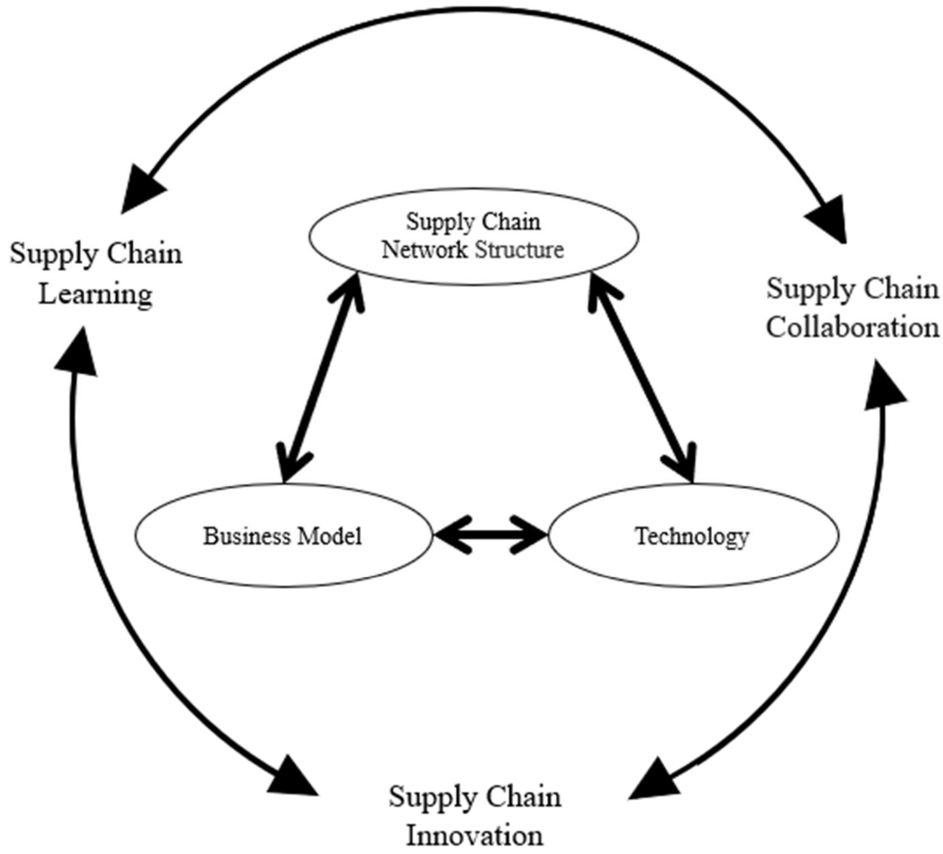


Figure 2.1. The Theoretical Model

Inspired by: Arlbjørn et al. (2011) and Silvestre (2015)

2.2.1 Innovation Content

Using the conceptual SCI model of Arlbjrn et al. (2011) as a foundation, this thesis proposes three interdependent SCI innovation content dimensions: (a) Business Model, (b) Technology, and (c) Supply Chain Network Structure. Detailed descriptions and explanations of the three SCI content dimensions are provided below.

a. Business Model

The business model reflects the established ways and processes by which the focal company and other stakeholders collaboratively create, deliver and capture value (Teece, 2010). In terms of organizational content, structure, and transaction governance, choosing the right business model allows focused organizations to manage their resources from a macro viewpoint to give the most value to their consumers (Teece, 2010). Moreover, modern supply chains operate in an environment that is constantly changing, and in order to respond to external dynamics, not only focal companies but also upstream and downstream companies in the supply chain must constantly restructure or even alter their business models (Zott and Amit, 2010). The business model requires a method for enhancing, replacing, or introducing new business models (Storbacka, 2011). Furthermore, focal companies frequently employ multiple business models simultaneously (Martnez-Olvera, 2009).

Business models may be inspired by new technologies, such as 4G technology, which has enabled many business models for the mobile Internet, including mobile payments such as PayPal and short-video social platforms such as Tiktok (Lu and Liu, 2016). (Lin, 2020). The emergence of blockchain technology in the SCM industry ensures privacy security, information traceability, transaction compliance, data authenticity, and supply chain efficiency (Saberi et al., 2019). A trust-based business model has been developed (Morkunas et al., 2019). Simultaneously, continuous improvements in business models generate new ideas and requirements for technological advancements, such as the demand for customized online advertising, which has contributed to the improvement of user profiling algorithms (Ahmed et al., 2011; Trusov et al., 2016).

Alternatively, business models and supply chain network structures may be interconnected. According to the observations of Trkman et al. (2015), SCs should focus not just on enhancing the maturity/efficiency of their present network architecture, but also on carefully designing their current business models and developing dynamic capacities for future changes. In other words, a continuously improving supply chain business model necessitates a corresponding supply chain network structure, and the modification of the supply chain network structure is frequently a prerequisite for business model transformation as well.

According to Chesbrough and Tucci (2020), business model innovation is essential but challenging to achieve. To consider this, it may combine business models and stakeholder theory (Matos and Silvestre, 2013). On the one hand, new business models must create value and competitiveness for supply chain stakeholders, but this is typically impossible without a change in network structure (Duke et al., 2021). New business models must, nevertheless, accommodate for external risks. These external stakeholders (e.g., administration, community, press) may pose a risk to the supply chain if the new business model exacerbates or fails to resolve their concerns over the old business model (Matos and Silvestre, 2013).

b. Technology

The second dimension of SCI content is technology. Technological innovation is the development of new knowledge and technical abilities that permit the creation of new services and/or goods for clients (Lee et al., 2011). In addition, technology is employed to improve the existing supply chain management standard. In order to manage products and operations, automate transactions, and optimise inventory levels and other supply chain decisions, focal organizations have made large investments in the development of information technology, such as enterprise resource planning(ERP) and material resource planning(MRP) (Chae et al., 2014).

Technology and SC structures have been shown to be inextricably linked. As per the resource-based view (RBV), enterprises with valuable, scarce, unique, and irreplaceable resources can establish a durable competitive advantage by applying techniques that rivals find challenging to imitate. (Barney, 2001). Recent study challenges RBV's internal concentration and highlights the fact that certain resources may exist beyond the company's borders: competitive advantage is obtained from both internal and external assets. This concept is known as the extended resource-based view (ERBV) (Yang et al., 2019). By conceptualizing how organizations might obtain a competitive edge in a supply chain context, ERBV emphasizes the relevance of network connectivity. (Lavie, 2006). Consequently, the unit of analysis in ERBV shifts from the company in RBV to binary or SC network structures (Squire et al., 2009).

Technology and business models, on the other hand, are closely intertwined. Technology lacks a single objective value. A technology's economic worth is not recognized until it is commercialized via a business strategy. (Yun et al., 2016). From this perspective, determining the technology-business model fit is extremely valuable and illuminating for supply chain innovation research.

c. Supply Chain Network Structure

The third dimension of the SCI is the supply chain network structure. (Arlbjrn et al., 2011). It covers not only the direct links between the central firm and its supply network partners (such as suppliers and consumers), but also its indirect ties with the secondary partners. (Farahani et al., 2014). Using the Toyota case study, Dyer and Hatch (2004) showed that properly controlling the network structure of the supply chain offers operational advantages in terms of inventory turns, higher product quality, enhanced delivery performance, fewer supply chain interruptions, and greater profitability.

The supply chain network structure is one of the sources of innovation. For example, Huston and Sakkab (2006) discovered in Procter and Gamble (P&G) case that 50 percent of P&G's technologies and products are sourced from its supply chain partners. Bellamy et al. (2014) examined two fundamental structural elements in supply networks (supply network accessibility and supply network interconnectivity) and shown that both had a positive effect on SCI performance.

Supply network accessibility refers to how effectively the focal company can access the network's information and knowledge resources. The (geographic or conceptual) distance between each member and the central organization impacts the availability and efficiency of access to information and knowledge (Holl and Mariotti, 2018). Additionally, businesses with a high degree of supply network accessibility can reach supply network members with fewer connections or steps (Bellamy et al., 2014).

In contrast, supply network interconnectivity describes how these information and knowledge sources are structurally interconnected in the network (Bellamy et al., 2014). A supply network is said to be densely interconnected when there are numerous shared connections between partners, including the focal company. In other words, network interconnectivity is low if all direct partners are only connected to the focal company (Pathak et al., 2007). According to Ciampie et al. (2020), supply chains based on big data enable more information sharing between non-focal companies, which facilitates personalization and co-creation strategies.

2.2.2 Innovation Process

Supply chain is replacing the individual organization as a measure of competitive advantage. Innovation is also becoming increasingly important as a true driver of competitive advantage. As a result, research that connects these two themes, also known as SCI, becomes even more critical (Zimmermann et al., 2016). Arlbjørn and Paulraj (2013) mentioned the importance of conducting learning by the focal company and other participants in the innovation process. In addition, various studies have demonstrated that technologies are increasingly seen as a collaboration including both within and outside the supply chain stakeholders. (Kahn, 2013； Arlbjørn et al., 2013).

This thesis considers three groups of inter-conceptual relationships that can be adopted into the discussion of SCI processes, namely a. Supply chain learning and SCI; b. Supply chain collaboration and SCI; and c. Supply chain learning and supply chain collaboration.

a. Supply Chain Learning and SCI

The study, inspired by Silvestre (2015), agrees that the supply chain learning is highly correlated with organizational learning. Supply chains, like organisations, are learning and evolving, as attested by their initial immaturity, However, they learn, absorb, and acquire new knowledge and new capacities throughout time, allowing them to engage in new activities and inventions while also developing new talents. (Hall et al., 2012).

That is, supply chain learning can be considered a prerequisite for SCI, which might be explained by the dynamic capabilities theory (Defee and Fugate, 2010). This theory indicates that supply chain learning can be considered as a capability for managing supply chains because of its dynamic and complex nature. It allows supply chain members to foresee and address difficulties in order to obtain a competitive advantage. Some companies have looked into ways to leverage internal and external market data to acquire a long-term competitive edge, and they have put in a lot of effort and money to become learning organizations. (Spekman et al., 2002) As an example, Toyota's knowledge sharing network consists of supplier alliances, consulting groups, and learning teams, and they have allowed Toyota to be widely recognized as a leader in organizational learning and continuous improvement (Dyer and Nobeoka, 2000).

SCI can also have an impact on supply chain learning. This thesis argues that no innovation is perfect despite the lack of empirical evidence for this relationship. Grand proclamations from SCI may be followed by mediocre results and execution, and innovation teams may be quietly disbanded due to cost-cutting concerns (Bloodgood, 2013). Moreover, from the perspective of continuous improvement, no problem is problem (Bhuiyan and Baghel, 2005). Supply chain learning must be restarted and realigned to ensure the long-term viability of SCI, as SCI may present new challenges.

b. Supply Chain Collaboration and SCI

Like organizations, supply chain networks improve information sharing and responsiveness to improve supply chain collaboration focused on the demands of supply chain stakeholders (Wong et al., 2013). A positive synergetic effect makes enterprises join technological cooperation innovation alliance (Jiang et al., 2021). Collaboration and effective resource allocation enables setting procedures for dealing with partners, sharing knowledge and processes, and then planning and investing with them to improve operations and innovation in the supply chain (Soosay, 2008). Collaboration with suppliers led to more radical innovation, whereas collaboration with customers led to more incremental innovation, according to Yunus (2018). Therefore, supply chain collaboration is able to build or acquire innovative capabilities, reduce overall costs, and improve responsiveness (McCarthy et al., 2013).

SCI, in turn, will have an impact on supply chain collaboration. For example, radical SCI establishes new rules (Oakes and Rogers, 2007), which may change the way interests distributed in the original supply chain (Jiang et al., 2021). Based on the stakeholder theory, each stakeholder group expects the focal company to prioritize their interests in strategic decision-making (Freeman et al., 2010); However, due to the turbulence caused by SCI, stakeholders' expected benefits may differ from reality, resulting in conflict. As a result, focal companies will be forced to make trade-offs to determine interest distribution priorities and manner based on their reliance on certain types of stakeholders (Yuen and Thai, 2016). This process may also need to be regulated by the new supply chain collaboration. Also, the technological upgrades (e.g., information technology) brought by

SCI support information communication and business synergy among stakeholders (Zeng and Ma, 2010).

c. Supply Chain Collaboration and Supply Chain Learning

Supply chain collaboration promotes supply chain learning. Learning is a capability as well as a bonding aspect in supply chain partnerships (Hult et al., 2003). The accumulation of knowledge assets that drive innovation in a company comes from two main sources, namely internal generation and external acquisition. The way to generate knowledge assets from internal sources is mainly from R&D, which includes data and fact-based experimentation, prototyping, simulation and testing in the product or service development process (Gaimon and Bailey, 2012). On the other hand, external knowledge acquisition is part of learning, i.e. the organization acquires knowledge and experience from external environment or other organizations (Freedman et al., 2010), such as suppliers, customers, supply chain through formal communication processes, open communication sessions or private communication for information and knowledge sharing (Yli-Renko et al., 2001).

The converse is also true: supply chain learning may counteract supply chain collaboration. Supply chains acquire new capabilities that enable them to co-develop innovative technologies, organizations, and business models, therefore enhancing their collaborative capacities (Bruno, 2015).

3 Methodology

3.1 Research Design

In this study, a qualitative exploratory research methodology was employed, which helps describe, compare, assess, and interpret critical features, meanings and implications of research questions, particularly when the distinctions between phenomena and contexts are not clear (Yin, 2015). The purpose of considering Nio as a single case is to deeply analyze and gain experience with SCI related to the field's context and link them to the existing literature to form a strong argument (Ozcan et al., 2017). The current electric vehicle manufacturers, represented by Tesla, rely on fast charging as the primary energy replenishment method (Botsford and Szczepanek, 2009) Coupled with the fact that BSM is mainly applied in the B2B market, the single case of Nio shows its scarcity and importance. In addition, Yin (2003) noted that a single-case research method is ideal when it is possible to observe and examine a previously unstudied scientific phenomenon. Consequently, the developing Nio BSM is deemed acceptable for a single-case examination.

The exploratory case study method employs the underlying assumptions of current literature to analyze the case (Goulding, 2005). It seeks to explore a phenomena by concentrating on a smaller sample size and gathering participants' specific experiences and intuitive data about the phenomenon (Brahma and Chakraborty, 2009). In order to specifically describe real-life experiences and facts and to extend the current theoretical framework, this study employs a grounded theory methodology across all phases of its investigation (Sbaraini et al., 2011). Findings from the study and existing theories are continuously analyzed, compared, complemented, and summarized to refine concepts and develop categories and relationships between them (Tian et al., 2019). Using an inductive theory-building strategy, a developing model of linkage between the components and the case study was identified (Silvestre, 2015).

3.2 Case Selection

Nio's BSM was chosen for two main reasons. First, Yin (2003) suggests choosing a representative case, which makes Nio a good fit, as it is currently the only B2C BSM provider and is considered an emerging force in domestic electric vehicles in China. In addition, as an emerging electric vehicle manufacturer, Nio is significantly different from traditional fuel vehicles in the construction and operation of its supply chain and is better able to bring insights and understanding to the academic community in terms of SCI content and SCI processes. As of 2021, its American Depositary Receipts (ADRs) have risen about 11 times. Its market capitalization has increased to nearly $70 billion, making it an emerging car company that compares favourably with traditional car companies such as GM and Ford (Nio, 2021).

Second, the present literature suggests that more study on the characteristics, obstacles, and methods of successful or unsuccessful SCI cases in the BEV business is required (Wells and Nieuwenhuis, 2012; Noel, 2016). As Nio is an innovative case on how to implement SCI to change the business landscaping, exploring "what", “why” and "how" Nio shapes the future of the industry in a country that has one of the most vibrant economies in the world is particularly necessary, especially when there are already multiple cases of companies that have attempted B2C BSM and all have failed.

3.3 Data Collection

The majority of the data for this study came from two distinct sources. First and most importantly, from semi-structured interviews with Nio B2C BSM supply chain stakeholders. Second, from secondary data. The details of data collection efforts from these sources are detailed below.

3.3.1 Semi-structured interviews

The semi-structured interviews were based on web-based video conferencing software (e.g., Zoom, WebEx) and were conducted with Nio B2C BSM supply chain stakeholders between December 2020 and January 2022. Archibald et al. (2019) and Reñosa et al. (2021) stated that the remote data collection method represented by Zoom not only has relatively higher accessibility and cost-effectiveness but also ensures efficient storage and security of the interview data.

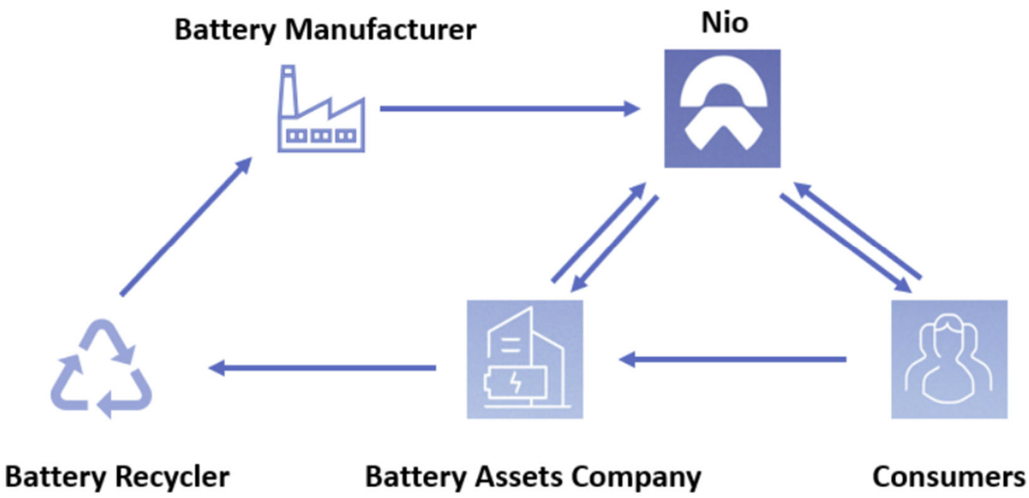


Figure 3.1. Nio BSM Supply Chain Stakeholders

In qualitative exploratory case studies, the selection of participants is important because the participants are considered to be the experiencers and narrators of the phenomenon (Cohen and Crabtree, 2006). That is, interviewees should not only be deeply involved in Nio's SCI process (or have in-depth research and impressive insights into BSM), but also be able to clearly integrate their more subjective personal views and more objective industry experience (Creswell et al., 2007). Therefore, this study's semi-structured interviews were conducted with academic researchers focused on China's BEV supply chain strategy and policy and with front-line Nio supply chain participants and managers, mainly from Battery Asset Management Companies, Battery Manufacturer, Consumers, Nio Energy Services Operations Team (As shown in Fig. 3.1). Consumers were also stakeholders among the interviewees, as supply chain innovation aims to add value that final consumers define (Morash and Clinton, 1998). Consumers demonstrate a higher recognition of the flow of money, materials, and information through their shopping behaviour (Davé et al., 2018).

The selection of interviewees followed a snowball technique (Bhattacherjee and Anol, 2012). Initially, several interviewees who meet the scope of the study were found, interviewed, and then asked to propose others who satisfied the criteria for selection. Telephone calls, emails, and repeated invitations were used to find interviewees willing to be interviewed. Considering the potential risk of rejection, some former employees of the company were also considered. Consumers were primarily selected by public solicitation from the Nio mobile app community and random selection during BSS field visits.

This study adopts and integrates Eisenhardt's (2007) and Yocco's (2017) recommendations on data saturation, the core idea of which is first to specify the minimum sample size for the initial analysis (initial analysis sample)—second, specifying how many more interviews to conduct without new ideas emerging (stopping criterion). Specifically, the expected sample size is initially determined based on a formula (shown below) that increases the likelihood of reaching saturation. Multiple interviews were then conducted until information saturation was reached where no new information could be obtained.

Sample size [N] = (Scope [S] × Characteristics [C]) ÷ Expertise [E] + / - Resource [R]

Scope represents the interviewed supply chain stakeholders. In this study, scope was defined as the five stages of the entire battery swapping process, i.e., battery asset management companies, Battery Manufacturer, consumers, Nio energy service operations teams, and researchers, so S=5.

Characteristics represent the characteristics of different positions within the same organization (Yocco, 2017). For example, when interviewing battery asset companies, the interviewees could be internal employees in various positions, such as warehouse administrator, purchasing analyst, manager, etc. Whereas each position requires at least 2-3 interviewees with potential personality differences, these may be adjusted depending on the actual situation. This paper assumes that each organization will interview 3 positions with 2 different respondents for each position, so C=3*2=6.

The significance of expertise is that experienced researchers can extract more information from a small sample size than inexperienced researchers. According to Yocco (2017), the value of expertise (E) should range from 1 to 2. For example, an amateur researcher should have a value of 1 because they will need the full sample size. As the project progresses, they will gain experience. With a value of 2, the sample size would be reduced by half (in the formula), which is the most extreme. This value would also increase by 0.1 for each additional five years of experience. This paper presupposes that the average experience of the respondents is five years, so E = 1.10.

Mathematically, if time/budget is sufficient, resource [R] = 0, which means there is no need to compromise on sample size because of time and cost. Since the time and budget of the study are under control, resources [R] = 0. The individual parameters of the study so far are S = 5, C = 6, E = 1.1, and R = 0. Sample size = 27.273, which implies an initial analysis sample of 27 individuals.

Each interview was designed to take 30-60 minutes. In addition, the video conference had the camera on throughout, which made it similar to a face-to-face interview, providing the researcher with the opportunity to analyze relevant nonverbal expressions of the participants, which is consistent with the exploratory nature of this study (Gray et al., 2020).

Creating an interview guide before a formal interview might help keep the interview process organized and seamless (Garcia and Gluesing, 2013). The final interview guide consisted of semi-structured interview questions covering the different levels and attributes of innovation implemented in the Nio B2C BSM supply chain and the development of such innovations, challenges, and continuous improvement solutions. Interviewees were invited to discuss general and specific topics related to the Nio BSM SCI, closely related to the previously proposed theoretical framework (as shown in Figure 2.1). For the general topic, they were encouraged to discuss BSM SCI implementation motivations and history, organizational learning processes and experiences, supply chain stakeholder collaboration and integration, and their perspectives on key success/failure factors in Nio BSM SCI implementation. Specific topics include the following: BSS technology development and cloud computing, battery leasing model operation, operation of various joint ventures in the supply chain, consumer relationship management, and the motivation and process of continuous innovation. (Please refer to the appendix for details)

The interviews were also designed to capture the actual performance of the B2C BSM using industry-relevant language (rather than academic jargon) (Yin, 2015). Participants' comfort level was maintained during the interview as they were encouraged to stop the discussion for a break when needed (Gill et al., 2008). Participants were given the option of refusing to answer questions if they were uncomfortable doing so.

The interview process was carried out according to the following procedure. Initially, interview requests were posted by the researcher on the Nio APP community or in offline BSS and direct stores, where interested participants were invited to contact the researcher. The sample was then gradually increased using the snowball method, which allowed identified participants to contact any potential responders they thought might be interested in participating and ask them to contact the researcher.

The authors also actively reached out to researchers with deep insights into the Chinese electric vehicle industry or the BSM through LinkedIn and Google Scholar. Each potential participant was given an informed consent form to read through the interview's confidentiality and ethical issues. A link to the online videoconference was issued via email once participants approved the rules and agreed the structure and timing of the interview. The informed consent form was signed by each participant and returned to the researcher. To limit the danger of data loss in the event of network instability or any other data loss, interviews were recorded utilizing Zoom and Webex's session recording capability.

Participants discussed the goal of the interview with the researcher after the initial introduction. The job titles and years of experience of the interviewers were recorded to ensure that the sample requirements were satisfied. Within the same stakeholder team, the researcher asked the necessary research questions based on the interview guide, and the interviews were conducted in the same order. The responder was asked if they wanted to offer any further information regarding Nio B2C BSM, which was the in-depth exploratory interview, after the last question. The researcher concluded the session by thanking the respondent for their cooperation and contributions when the respondent had nothing further to say or contribute.

3.3.2 Secondary Data

Secondary information is also an essential source of research data (Hox and Boeije, 2005). The study collected publicly available documents related to Nio BSM, such as

BSM-related patent data from the China National Intellectual Property Administration and other public information from Nio and its BSM supply chain stakeholders' websites (e.g. 2016-2020 annual and quarterly financial results, NYSE stock infomation,news releases).

3.3.3 Triangulation of Findings

The thesis drew on the opinions of five Nio supply chain stakeholders - Battery Asset Management Companies (BAMC), Battery Manufacturer and Recycler (BMR), BSS Strategic Partners (BSR), Consumers (C), Nio Energy Services Team (NEST), and relevant Researchers (R) - and collected triangulated data from them to obtain different case experiences (Vogt et al., 2012). Specifically, it refers to the interweaving of perspectives from several different interviews. Unstructured talks with supply chain stakeholders, policymakers, and academics, for example, as well as firsthand observations during site visits (Silvestre, 2015). Taken together, this is consistent with the study's exploratory nature (Heale and Forbes, 2013).

3.3.4 Description of the Sample

Finally, 18 interviews were conducted, and Table 3.1 shows the interview codes, their job titles. The specific SCI elements and insights they mentioned are recorded.

No.	Stakeholder Group	Interviewee Code	Job Title
1	Battery Asset Management Company	BAMC1	Operation Manager
2	Battery Asset Management Company	BAMC2	Battery Data analyst
3	Battery Manufacturer/Recycler	BMR1	Battery Delivery Specialist
4	Battery Manufacturer/Recycler	BMR2	Project Manager
5	Battery Manufacturer/Recycler	BMR3	Energy Storage Operation Specialist
6	BSS Strategic Partners	SP1	Sinopec Coordinator
7	BSS Strategic Partners	SP2	Macalline Coordinator
8	Consumers	C1	ES6 Owner

9	Consumers	C2	ES6 Owner
10	Consumers	C3	ES8 Owner
11	Consumers	C4	EC6 Owner/ Nio Dealer
12	Nio Energy Services Team	NEST1	Business Operation Specialist
13	Nio Energy Services Team	NEST2	Battery Operation Specialist
14	Nio Energy Services Team	NEST3	Chengdu BSS Operation Specialist
16	Nio Energy Services Team	NEST4	Chongqing BSS Operation Specialist
17	Researchers	R1	Scholar/Technical Analyst
18	Researchers	R2	EV Industrial Policy Researcher

Table 3.1 Semi-structured Interview Respondent Coding Information

3.4 Data Analysis

3.4.1 Exploratory Analysis

The data analysis will be based on the theoretical framework of this study, with the first level of analytical aspects being innovation content and innovation process. Three additional parts make up the Nio BSM supply chain's innovation: Supply Chain Network Architecture, business strategy, and technology. Supply chain learning, supply chain integration and cooperation, and supply chain innovation all represent this process. Several distinct components from the interviews were incorporated in each dimension. When a new identical component appeared in numerous interviews, it was enlarged into a new aspect that drew greater attention and debate. When there was any uncertainty, these concerns were resolved with key informants by email, phone, or web conferencing, which improved the data's authenticity (Hartley, 1994). For example, although supply chain collaboration is one of the innovation process dimensions, three of the interviewees mentioned the existence of potential competition between supply chain stakeholders and Nio, such as a battery manufacturer also planning to launch its own B2C BSM. we then identified potential competition as a new area for theoretical exploration.

3.4.2 Interview Data Analysis Process

A four-step data analysis technique was used in this research. Figure 3.2 depicts the analytical procedure in detail.

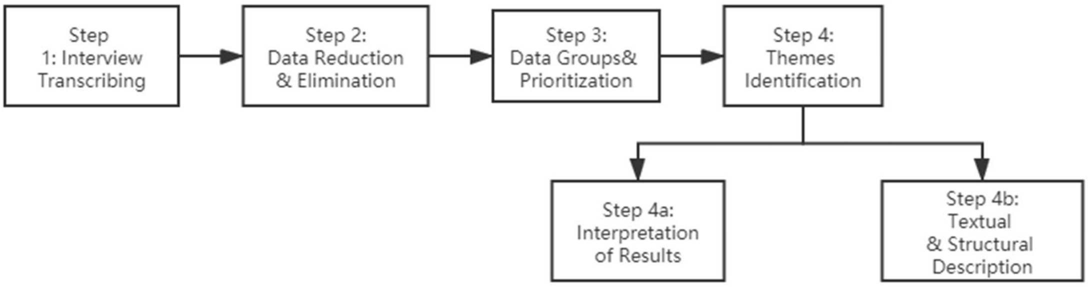


Figure 3.2. Four-Step Data Analysis Procedure

In Step 1, the researcher transcribed all of the interview transcripts and imported them into NVivo 12, a program that could identify and cluster the emergent expressions (sentences, words) from the transcripts. Because the interview was conducted in Chinese, prior translation was necessary. In the second phase, the researcher reads the data more carefully to ensure that it is understood and that any extraneous remarks are eliminated from the transcripts. Meaningless words, unclear or irrelevant responses to interview questions, and repeated phrases were among the removed utterances. Step 3 involved evaluating the remaining assertions. Statements that were mutually meaningful were gathered, classified, and labeled. Step 4 involved identifying and evaluating themes in relation to the study questions and objectives.

The study began by creating textual descriptions that followed the study's objectives in order to characterize and communicate the participants' experiences. The emergent themes and patterns are integrated into the textual and structural descriptions, which are confirmed by the researcher's experience during the interview process. Based on the synthetization, structural descriptions are developed, reflecting and linking the researcher's understanding of the B2C BSM SCI phenomena.

Steps 1 and 2 of the data processing procedure ran virtually concurrently with the interviewing. The first was to assist the researcher in evaluating the quality of the interviews and identifying areas for improvement. The second purpose was to find the data's saturation point. The interview procedure was able to conclude when no new information was discovered since each interview was transcribed and examined before the next one. The researcher was also able to get a deeper understanding of her own interview participants' life experiences, particularly their nonverbal reactions, thanks to the practically immediate data analysis.

3.5 Bias and Ethical Considerations

The integrity of a study may be harmed by researcher bias. As a result, in the present investigation, a deliberate attempt was undertaken to eliminate bias. This bias might be due to the researcher's experience in the Chinese BEV business, or it could be due to the economic and psychological reasons of home country bias (Verlegh, 2007). To avoid bias, the researcher made sure that his past experiences did not impact the participants' replies to the interview questions, either directly or indirectly. Furthermore, researcher bias may be reduced by remaining attentive throughout the interview and taking notes and transcriptions (Purkiss et al., 2006).

The researcher is in charge of anticipating and controlling any risks that may develop as a result of the study (Escande et al., 2016). The protocol for the research was approved by the University of Manitoba's ethics board. During the data collecting phase, each participant was given an informed consent form that outlined the study's goals. Participants were given the opportunity to read the information thoroughly before deciding whether or not to participate in the research.

4 Case Study

This section first discusses the development of BSM in China, then explains the rationale for Nio to bring BSM to the individual consumer or the B2C market. After that, the charging model, B2B and B2C BSM are compared in terms of supply chain network structure. The business model and technology innovations are also described and summarized in detail. The takeaways and insights of the innovation process gained from the semi-structured interviews, which involved collaboration and supply chain learning, are demonstrated. Finally, a summary of the current challenges is analyzed. All discussions are intended to give a solid and comprehensive overview of Nio's SCI motivation, development, achievements, and challenges in China and provide a context and factual basis for the discussion in the next section.

4.1 The Tough Journey of BSM in China

As indicated before, BSM is not a novel concept, as it has been attempted several times in the North American and European markets, with most of them failing. Tesla, for example, has issued a warning to newcomers. First, BSM implementation is costly. Without considering the BSS construction cost (a single Tesla BSS costs around $500,000), Tesla users need to pay approximately $60 - $80 for a single battery swap, in comparison to Tesla's V3 Supercharger, which can reach 50% capacity in 20 minutes and costs nothing (Tesla, 2014). Widrick et al. (2021) also note from a technological standpoint that Tesla's batteries cannot be shared across various vehicle models and that the BSS is similarly difficult to implement on a broad scale. To make matters worse, Tesla failed to adopt a revolutionary business model such as battery leasing. Consumers are limited to their batteries and must swap them back after travel. Alternatively, Tesla may send the battery back to their client, which will also be charged (Tesla, 2014). In all, Tesla BSM is not a commercially viable application but rather a technical reserve for its EV energy replenishment solution.

Time Periods	Phase I (2009-2012)	Phase II (2012-2019)	Phase III (2019-present)
Development Features	State-owned enterprises lead the development of BSM on many pilot programs.	Charging becomes mainstream, BSM is hampered.	With the introduction of favorable policies coupled with the expansion of the EV market, BSM is recovering.

Table 4.1: Three Phases of BSM Development in China

While western players are engaging in BSM R&D, Chinese participants are also actively promoting the commercial practice of BSM. Moreover, this process can be broadly divided into three stages (refer to Table 4.1). First, from 2009 to 2012, State Grid Corporation of China (SGCC), the state-owned grid giant, demonstrated BSM for buses at the Beijing Olympics and Shanghai World Expo. It prioritized BSM ahead of charging and carried out the infrastructure building of BSS together with the battery leasing pilot test (Zhang, 2014). Led by energy giants, more companies are participating in the BSM market, most of which operate commercial vehicles that are more concerned with economic returns, such as buses, taxis, and car-hailing (Rao et al., 2019).

The situation deteriorated dramatically between 2012 and 2018, and BSM suffered from market desertion. The EV market shifted to accommodate the charging due to high BSS construction costs, infrequent swapping orders, insufficient standard systems, and innumerable succession of problems arising from daily operations. One interviewee BAMC1 recounted the nightmare during this period:

Despite our efforts, the overall development of BSM remained poor before 2019. My career hit a snag and I almost quit... The BSM had many issues: low user numbers, massive BSS investment, and rare daily swapping orders... BSS site selection and everyday operation are also troubled…

Faced with such challenges, China's BSM players did not give up but continued to explore and finally waited for the opportunity of revival provided by government incentives. In the interview, industry researcher R2 said.

"Subsidies for new energy vehicle-related infrastructure were mostly focused on charging facilities such as charging piles/stations before 2019, but since then, phrases such as BSM and BSS have frequently appeared on policy documents……This is an essential stimulant for BSM recovery…… In China, policy is normally a precondition for an industry's success and a signal for its transition."

Governance Level	Issuing Department	Issue Date	Policies and key information related to BSM
Central Government	National Development and Reform Commission (NDRC), National Energy Administration (NEA)	2019.01	Encourage enterprises continue to explore the application of EV BSM in specific areas such as taxies and car-hailing (NDRC, 2019)
Central Government	Ministry of Finance (MF), Ministry of Industry and Information Technology (MIIT)	2020.04	Passenger vehicles costing more than 300,000 yuan will no longer be eligible for government subsidies, although BSM vehicles will be exempt from this policy. (MF, 2020)
Central Government	State Council of People Repblic of China (SCPRC)	2020.05	Increase the number of charging stations and BSSs. (SCPRC, 2020)
Central Government	National Standardization Administration Committee (NSAC)	2021.04	China's first BSM general national standard was approved and published, which details the BSM EV's safety requirements, test methods, and inspection rules. (NSAC, 2021)
Central Government	Ministry of Industry and Information Technology (MIIT),	2021.1	Launch of EV BSM pilot test in 11 cities. (MIIT, 2021)
Local Government	Hefei	2020.09	Promote the construction of BSS and fully establish the complementary mode of "charging + BSM". Plan to add 40 BSS from 2020-2021. (Hefei, 2020)

Local Government	Beijing	2021.01	Provide BSS financial subsidies based on BSS battery capacity and operation assessment audited by the government. (Beijing, 2021)
Local Government	Chongqing	2021.1	Considering the battery capacity, BSS receives a one-time construction subsidy of 400 RMB/kW, with a maximum of 500,000 RMB for a single station. (Chongqing, 2021)
Local Government	Shanghai	2020.05	BSS receives a maximum of 2,000 kWh/year of subsidized electricity and enjoy extra subsidies based on regular evaluations. (Shanghai, 2020)
Local Government	Hainan	2021.11	BSS provides a one-time construction subsidy equal to 15% of the equipment investment. (Hainan, 2021)

Table 4.2 Part of Chinese Central and Local Government Policies On BSM

According to Table 4.2, the central government incentivizes BSM from the macroeconomic, standard system, and industrial strategy perspectives, whereas the corresponding local governments emphasize specific BSS network construction and operational efficiency incentives. For the central government, promoting EV infrastructure investment will not only ease the pressure on the carbon neutrality target, but also promote the EV consumption market and provide high value-added employment opportunities. For local governments, setting a technical threshold and standard system can also limit the speculative entry of enterprises and prevent the abuse of subsidies. It is undeniable that the growth of BSM in China has always been pushed and influenced by the visible hand—the government (Doleac et al., 2013). Likewise, the massive demand for replenishment energy brought by the rapidly prospering BEV market is another reason for BSM's recovery. A scholar well-versed in BSM (R1) described:

2020 opens the golden era of EVs. For example, my hometown, Shanghai is adding 20,000 to 30,000 EVs per month. With so many electric cars, people will have bigger and more diverse electricity needs…... AC charging is preferred by people who have their own parking spaces and a lot of spare time. If you're busy, you'll want to choose a DC charger…… Some people use BSM. e.g., taxis and e-hailers need to make more

money every minute they are on the road……A fully charged battery can also be swapped at the BSS along the highway, which is very useful for people traveling long distances.

BSM is more widely used commercially in China's B2B sector. Take the taxi sector as an example. Our study on the taxi operating in Chengdu (a city in Southwest China) indicates that the daily mileage of a typical urban taxi is 400-500 kilometres (the mileage is about the same for the small and medium-sized trucks of certain courier companies). One distinguishing characteristic is that the driver rests, but the taxi never does, operating in two shifts every day at almost full capacity. Currently, charging a taxi takes at least three hours of rapid charging to operate throughout the day, which substantially influences the operation's efficiency and revenue, but BSM can effectively handle this issue. In comparison to B2C BSM, B2B BSM is more financially feasible and less unpredictable since it deals with fewer and more reliant business customers, which results in higher profitability. In comparison, B2C BSM for the ordinary individual customer in China has significantly fewer players and promoters, while Nio is their most famous representative. As noted by NEST3:

Nio is not the first company in the world to experiment with B2C BSM, but it is the one that has established the most widespread BSS network and invested the most... Nowadays, when people in China hear the phrase "BSM," the first thing that comes to their minds is Nio!

4.2 Why Nio chooses B2C BSM?

So why did Nio choose to move forward when BSM was almost abandoned? Why did Nio invest heavily in the B2C market for the general consumer? In addition to the external factors like policy incentives and EV market growth mentioned before, other internal insights were gained through the interviews.

4.2.1 Enhance User Experience

First and foremost, user experience is a top priority for Nio, where respondents believe that through B2C BSM, Nio can provide value-added services to consumers, thereby generating market share. The improvement of user experience firstly comes from the satisfaction of consumers whose needs are met by innovation. In other words, through business models and technological innovation to help users solve the challenging problems they face, for example, if consumers do not have private parking spaces and charging piles, how can they meet replenishment demands? The average life of an EV is now 8-10 years, so if consumers want to drive it for more than 15 years, how to make it happen and deal with the end-of-life battery? How does a 400km-range EV take a western journey without spending most of the time on meaningless charging? By resolving these issues, businesses and their supply chain partners boost the value of their products and services. As BAMC2 put it:

"We cannot underestimate the role of energy services for the competitiveness of EVs. If we cannot meet users' energy replenishment needs and help them overcome range anxiety, it will be difficult for EVs with high sales to thrive. We prefer to provide the best service possible to encourage more users to choose Nio and EVs more frequently."

As early as the founding, Nio had already noticed the dissatisfaction of EV users with the difficulties in charging, like the extended waiting time and the high price of batteries. Even though the industry generally did not consider battery swapping as the mainstream way to replenish energy, Nio believed that B2C BSM was still a viable path for user experience and product competitiveness. Nio's three current models all support BSM, and the three upcoming models will also ensure that BSM development to the greatest extent. Additionally, BSM is a critical component of Nio's energy network. Along with the BSS, Nio has established a variety of energy replenishment solutions, including mobile charging vehicles, charging piles, and third-party destination charging stations. To improve the efficiency of this massive system, Nio created NIO Power Cloud, a cloud-based recommendation algorithm that can optimal replenishment solutions flexibly and quickly based on user demands (Nio, 2021). 4.3.2 and 4.3.3 has further information about it.

Of course, the user experience may be increased not just by addressing current demands but also by exceeding consumer expectations through innovations. NEST3:

Our 2nd-generation BSS now supports autonomous driving, so users do not have to get out of the car during swapping. In a few years, maybe EV will swap batteries automatically every day…… Exceeding user expectations and creating a new user experience is our goal…… If charging can achieve the user experience at 80 out of 100, adding BSM will bring it to 90.

4.2.2 Enhance Battery Lifecycle Value

Nio also wishes to raise the battery lifecycle value through B2C BSM, or, to put it another way, to maximize the value of the battery asset, a word constantly highlighted by multiple interviewees. In other words, Nio views the battery as a split, valuable asset rather than an integral part of the EV. This is accomplished in two ways: by prolonging the lifespan of the individual battery pack and by enhancing the value of recycling. First, many EV users lack the training and expertise to properly maintain their power batteries, resulting in battery testing occurring only approximately 12 times a year (Li et al., 2020). Additionally, DC fast charging is frequently employed to maximize charging speed, which utilizes a high charging voltage and current, significantly reducing the number of battery cycles and ultimately shorter battery life (Botsford and Szczepanek, 2009). However, on the other hand, BSS can charge and manage batteries collectively and in scale, which benefits battery lifecycle. Simultaneously, consistent charging, draining and the rigorous inspection performed at each battery swap may help ensure the battery's safety (Rao et al., 2015). This was evident in SP1's discourse:

In fact, BSS is a very good scenario for sequential charging since it places each swapped battery within the charging room at the same temperature, humidity, and power... Temperature loss for any battery cells can be recognised and corrected in real time…As a result, we have not had a single swapped battery in the BSS burn out, nor has a BSS exploded… BSM battery is safer and enjoy a longer life.

Extending the lifetime of individual batteries also includes gradient utilization. According to interviews and secondary data gathered, Nio has employed retired batteries for energy storage systems and electric bikes (Xinhua, 2021). If retired batteries are utilised in energy storage stations, or if the BSS itself is considered an energy storage station, B2C BSM can help lower the danger of grid load inequity and contribute to the long-term aim of carbon neutrality (Revankar and Kalkhambkar, 2021). As a result, increasing the battery's life takes precedence over recycling, and properly harnessing the profit potential of energy storage in BSSs may be the key to BSM's long-term viability. This opinion was echoed by BMR1 and BAMC2, they both agreed:

There are a dozen batteries inside the BSS, which is essentially an energy storage station(BMR1)…... We are working on this, but the future holds even more tremendous potential (BAMC2).

Second, recycling is also a way to contribute lifecycle value. Many EV manufacturers currently focus exclusively on EV sales and neglect battery recycling. However, the battery asset is a mobile mine distributed throughout the country with an enormous collective volume. NEST2 mentioned:

We estimate that more than 500 tons of lithium, 700 tons of cobalt and 2,000 tons of nickel can be recycled from EV batteries throughout China…… With BSM, we may lease and manage a batch of batteries collectively and then gradually phase them out or recycle them on a vast scale...It is also our social responsibility.

For a long time, battery recycling lacked regulatory oversight and a standardised procedure. High-value cathode materials have a low recycle rate. With a considerable number of EVs already on the road, the number of batteries that will need to be changed in the near future will skyrocket, as will the demand for environmental protection and resource reuse. Almost all interviewees expressed confidence in BSM's potential to recycle valuable metals from batteries on a large scale. This confidence is based on the potential value of economies of scale. Also, one interviewer also revealed that due to the more consistent management of BSM, the batteries are generally in better condition when recycled than those of ordinary EVs, and therefore have a higher recycling value.

4.2.3 Improve Energy Replenishment Efficiency

Faster replenishment efficiency is another reason why Nio chose B2C BSM. The BSS has an overwhelming efficiency advantage over public charging stations (including AC/DC charging), which is reflected in just a few minutes of swapping for users, However, for replenishment network operators, BSS can theoretically supply twice the amount of power per day as a charging station for the same parking space. A BSS operator (NEST3) disclosed that:

Our 2nd-generation BSS currently occupies four parking lots and has a theoretical maximum of 320 swaps per day. But, in terms of charging, how can a parking lot service 80 EVs each day? Now that there are only a few million EVs in this country, this efficiency will be critical and meaningful when there are 100 million.

Although from actual observation, the current Nio BSS replenishment demand is also far lower than the theoretical design of 320 times per day, basically maintaining at 40-50 each day. However, considering that the average single charge volume of Chinese EV is 25.2 kWh, and the average single charge duration is 49.9 minutes (CAAM, 2020a), it can be calculated that for charging mode, one parking lot may theoretically support a maximum of 28.8 vehicles. This is also substantially less than the BSM.

In summary, the interview results indicate that Nio, as an emerging force for the EV industry, is promoting B2C BSM on a large scale for three main reasons: 1. to enhance user experience and meet diversified replenishment needs, it is also considered as a core corporate value; 2. to consider battery as an explorable, recyclable asset to maximize its lifecycle value; 3. to achieve a higher replenishment efficiency than charging, which is significant in the context of China's growing EV market share.

4.3 What Nio Has Done

4.3.1 Battery Asset Management Company-Based Supply Chain Structure Innovation

Through interviews, this study also found that Nio developed a new set of supply chain network structures for B2C BSM, which is a critical component of SCI and a precondition for achieving business model and technology innovation.

a) Supply Chain Structure for Charging model, B2B BSM and B2C BSM

The manufacturer is the undisputed heart of the conventional charging-oriented EV supply chain, responsible for designing, sourcing, manufacturing, and delivering EVs. Additionally, apart from a few vertically integrated manufacturers (e.g., BYD), the battery as a fundamental and most crucial component is mainly manufactured by specialized third-party battery manufacturers like CATL, Panasonic, and LG New Energy. Eventually, the generated EVs are offered to individual or enterprise users through sales channels. Due to the complexity of the EV supply chain and the critical role of batteries in this industry, this study creates a simplified version of the battery-based EV supply chain. (As seen in Figure 4.1)

In this supply chain, the relationship between EV manufacturers and battery suppliers and consumers can be seen as a simple supply-purchase relationship. While battery suppliers and EV manufacturers will work closely together on battery technology innovation, the business model will still operate under the absolute control of the EV manufacturer. It is also worth noting that despite the relatively simple structure, after-sales service and maintenance of their batteries need to go through the distribution channel due to the geographical difference between consumers and EV manufacturers.

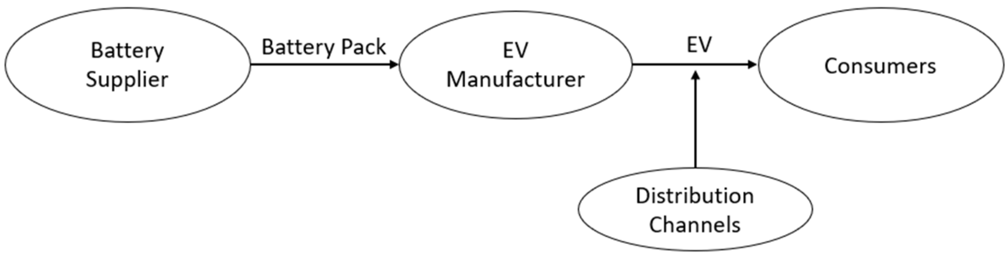


Figure 4.1 Simplified Supply Chain Structure of Charging EV

The key stakeholders in the B2B BSM supply chain are slightly different from the conventional charging EV supply chain. Due to the operational difficulties, R&D challenges and increased costs associated with the ownership and physical separation of EVs and batteries, third-party BSM operators dominate the entire supply chain structure instead of EV manufacturers; BSM operators are responsible for the day-to-day operation and management of battery packs, BSS design, site selection and maintenance, and offering BSM service to commercial EV drivers. The significance of BSM operator domination is also reflected in technology development. As R2 indicated:

As far as I know, Aulton New Energy (a B2B BSM operator) has been researching BSM technology for over ten years and has over 300 BSS nationwide…… They

collaborate with various automakers to support numerous car models in BSM technology and provide BSM services for multi-brand EVs.

In this scenario, the EV manufacturer would need to concentrate on body manufacturing. Enterprise-level customers acquire EVs in bulk from EV manufacturers under a sales contract that excludes the cost of the battery. At the same time, they sign into a service contract with a BSM operator to rent the battery on a monthly or yearly basis or charge a per-use fee based on the difference in electricity before and after the battery swap plus the single service fee. In other words, the BSM operator resolves all battery-related concerns, while the EV manufacturer provides after-sales support for the EV. Figure 4.2 illustrates the simplified supply chain structure of B2B BSM.

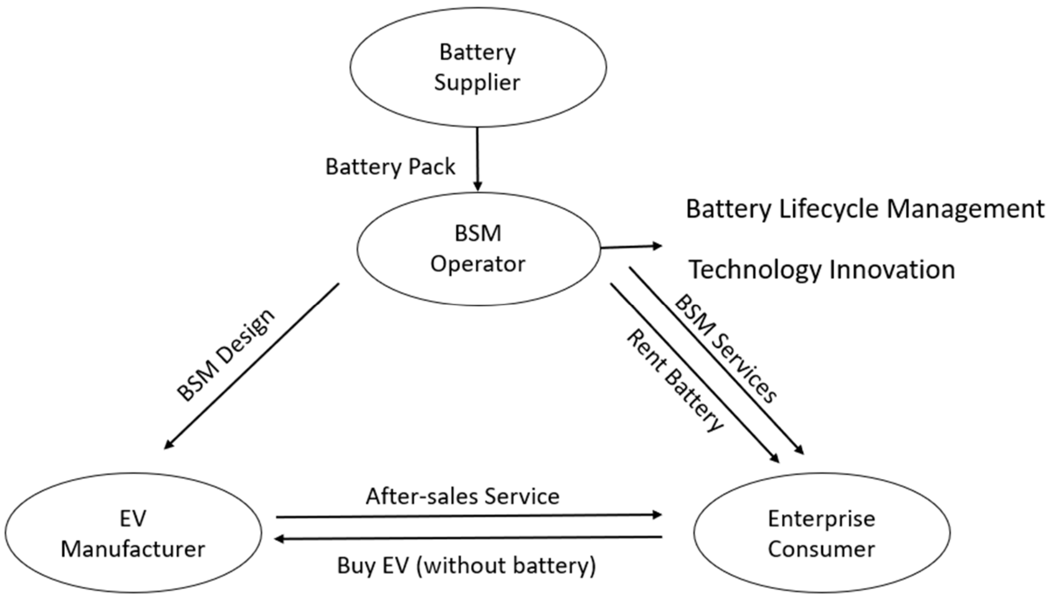


Figure 4.2 Simplified Supply Chain Structure of B2B BSM

Finally, unlike in B2B BSM, the vehicle manufacturer (e.g., Nio) is the unambiguous B2C BSM supply chain leader. This is because its own Nio Energy Services team is responsible for developing the BSM technology, the planning and building of the BSS network, and its operation and maintenance. Each Nio EV is also fitted with lithium batteries from the battery manufacturer. These batteries are physically identical (supporting all Nio models) but provide more flexibility in battery capacity and material composition (currently available in 75, 84 and 100 kWh). In addition to this, Nio has formed the Battery Asset Management Company (BAMC) as a joint venture with battery manufacturers, financial institutions, and state-owned capital, which forms the basis of the B2C BSM supply chain structure innovation. This newborn organization is responsible for leasing batteries and managing their lifecycle, including daily maintenance, gradient utilization, and recycling. Why create a separate external joint venture to manage the battery business instead of creating a department within Nio? BAMC1 revealed Nio's internal thinking.

We (BAMC) are now adding between 3,000-4,000 subscribers per month, which is accelerating. If Nio covers all the batteries, the cash flow pressure and financing risk will become hard to ignore. You know, financial reports are vital to us. Our existence also means close relationships with local governments, battery giants, and financial moguls, indicating that everyone is bullish on BSM's growth.

As can be observed, the BAMC's primary objective in B2C BSM is to share the cost and financial risk. Simultaneously, BAMC actively develops battery lifecycle management to generate additional revenue, completing the closed-loop of the BSM business model. From the user's perspective, Nio provides all after-sales and BSM services, whereas BAMC is the party they sign the battery leasing contract and the owner of the battery assets. Again, Figure 4.3 illustrates a simplified supply chain of B2C BSM.

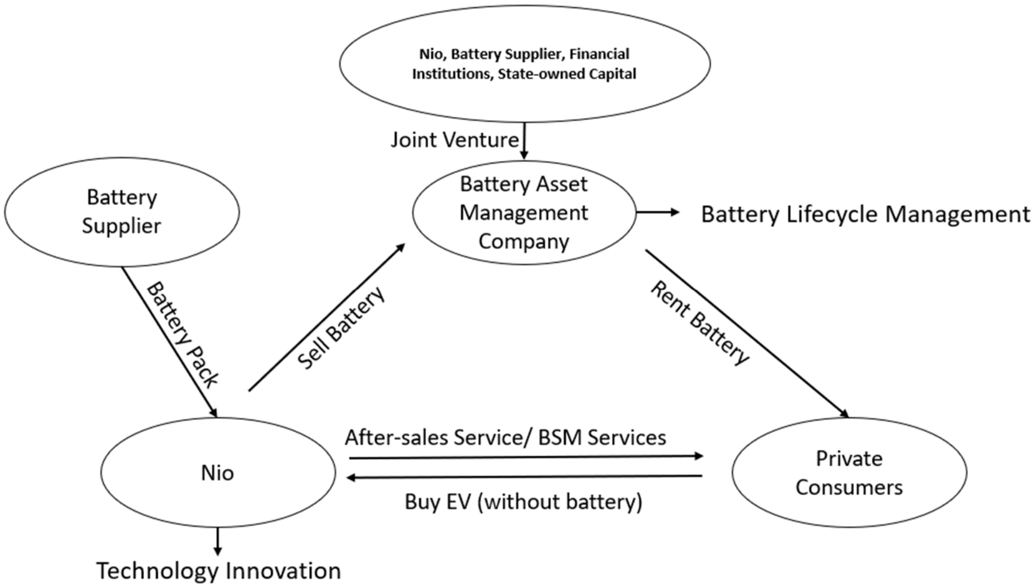


Figure 4.3 Simplified Supply Chain Structure of B2C BSM

b) Why Battery Asset Management Company?

BAMC, a unique organization in the B2C BSM supply chain, deserves special attention. On the one hand, it is a joint venture involving internal supply chain stakeholders (for example, Nio and battery manufacturers), while on the other side, it includes external stakeholders (e.g. state capital, financial institutions). Why establish this joint venture, and what is the significance and value of this to them? Combining secondary information and interviews, this study tried to explore the motivations behind the four decision-makers.

To begin, as a founding stakeholder of BAMC, Nio thinks that BAMC is a critical component of BSM. The power battery contributes around 30%-40% of the total cost of an EV in its present cost structure. If this heavy "asset" is divested, the product's competitiveness at the same level as the EV market will increase. Second, Nio is a more asset-light Internet firm than a typical carmaker with heavy assets, relying primarily on stock market funding to grow and enhance its supply chain capabilities. Achieving favourable cash flow performance is one way to acquire market appreciation. Additionally, B2C BSM is possible via the BAMC, resulting in increased sales of Nio's products and better supply chain negotiation power and potential for improved corporate gross margins. Finally, in addition to the financial rewards, Nio is attracted to the massive amount of data created by the batteries. According to BAMC1 and BMR2:

Every day, hundreds of data points are transferred from each battery. Over the course of a year, that is a wealth of data. We need to compare these data horizontally (across batteries) and vertically (overtime for the same battery) to assess the health and lifecycle of the battery (BAMC1) … This data will be shared with Nio's internal technical team and battery suppliers for possible improvements (BMR2).

As can be seen, BAMC can monitor, assess, and alert batteries' real-time state through extensive lifecycle management. Later, by constructing dynamic valuation models for battery performance, life, safety and residual value, it provides quantitative support for classification and reorganization in the phase of gradient utilization. All the above will considerably minimize the time and expense of handling retired batteries. In addition, two/three-wheeled electric vehicles, low-speed electric vehicles, and energy storage stations are the main scenarios of battery gradient utilization, which will contribute to upgrading the lifespan value chain.

In short, with BAMC, Nio can unload a large number of heavy assets - batteries; it can also continuously paint a picture of battery assets or digitally improve the ability to manage and operate them in order to maximize their lifecycle value. The data continuously supplying is a goldmine for Nio, and there is still a lot of information and value waiting to be discovered.

Second, the primary takeaway for the battery manufacturer is increased sales. To guarantee the smooth functioning of BSM, BAMC will handle a more considerable number of batteries than that EVs, which also enables an improved market share. Additionally, investing in Nio's BSM can create a viable roadmap for future business growth, as specific experience and technology can be acquired through this collaboration. According to an interviewee from the BMR3:

Even though our domestic market share of batteries was more than 50% last year (2021), raw material prices have risen by about 15% so far this year. Some of our suppliers have even raised their prices by 20% to 30%, which means our profits are

being cut. We have to think about other ways to grow… For BSM, the car-to-battery ratio is about 1:1.2-1.4, which means there could be more orders in the future… The data from BAMC is also crucial for us to improve the battery's safety, durability, cost, energy density, and other things……

The B2C EV industry is proliferating; thus, demand for power batteries is surging. However, the scarcity of upstream raw materials has driven up the cost of battery procurement. In comparison, cost reductions attributable to economies of scale and technology innovation are insufficient at least in the short term. Thus, it is interesting to note that the cost curve for batteries is inching higher, compelling battery manufacturers to investigate the potential possibilities given by BSM. Nio's battery manufacturer did announce its B2C BSM service in 2022, but it is temporarily not a direct competitor for Nio. Because EVs offered by battery manufacturer are priced at 80,000-120,000RMB, which is not in contradiction with the Nio market, where the average price is above 300,000RMB. Additionally, both sides have a long history of collaboration; for example, they collaborate in batteries and BSS, BSM technologies. To some extent, both sides agree that they face a typical competitor - fuel cars. In other words, they are allies rather than rivals, at least for now.

Third, the state-owned capital is also an essential contributor to BAMC. The settlement of BAMC in Wuhan, a central China city, is an extension of Nio's cooperation history with the local government. Their cooperation can be traced back to 2016, when Nio partnered with local development zones and industrial funds to design and build EV manufacturing plants and introduce and incubate innovative R&D and manufacturing enterprises upstream and downstream of EV's supply chain (Sina, 2016). Then, considering the excellent geographical advantage - making a circle with a radius of Wuhan to Beijing (about 1,000 km), the most important cities of China are included. Nio also placed its energy service team in this central city (Nio, 2021). In addition, for local governments, EV projects generally mean high-quality and vital governance performance indicators. One EV policy researcher (R1) told us:

In the next few years, the government will keep playing a big role in the EV industry, and I believe the emerging EV forces like Nio will get the financial and policy support

as usual. On the one hand, automotive manufacturing has significant social and economic value; on the other, carbon neutrality is an inevitable trend… The local government will benefit from the increased taxation and jobs generated by the thriving business. Making a larger share of the EV market benefits both Nio and local governments.

According to Li et al. (2016), with the extensive investment from government industrial funding, the technical patents, manufacturing and sales volume, and business models of new energy vehicles have shown rapid growth. B2C BSM is also flourishing under the shelter of the government. Although local governments have been extensively involved in EV projects, they will also sign the Valuation Adjustment Mechanism and other similar agreements with EV manufacturers to mitigate certain risks (Li et al., 2016).

Finally, several financial institutions support B2C BSM. BAMC concluded an RMB 531 million Series B fundraising in August 2021, increasing the total funding to approximately 2 billion RMB (Sina, 2021). When asked about the investment's purpose, the financial institution that assisted Nio in issuing $2 billion ADSs (American Depository Shares) cited two reasons: one was to respond proactively to the central government's policy of ‘supporting the real economy with finance,' and the other was to provide a more diverse portfolio of investment products to its clients (Sina, 2021). One of our interviewees SP1 claimed that:

We invested in Nio's BAMC because we are convinced that: just do it for something worthy. We can forgive a temporary loss for the short term as long as it can guarantee the expected annualized return in the long term…… BSM has a large room to exert itself.

Investments in B2C BSM have been preliminarily becoming financial instruments that make consistent and predictable cash flows for financial institutions. This is analogous to renting a house where the tenant does not own the house (battery pack) but has the right to use it. However, the tenant must continue to pay rent as long as he or she lives in residence. If 10 million BSM vehicles are rolled out, the battery assets will be worth 600 billion RMB. A simple calculation can be done to measure the cost-benefit of a single battery:

- BAMC's initial investment in battery procurement is 70,000RMB.
- The annual battery leasing price is around 12,000RMB (Nio, 2021).
- The income tax (25%) and assuming the average life of the leased battery is eight years (15% residual value).

Finally, the internal rate of return (IRR) of BAMC is about 6.4%. Investors are already getting a good return on their money with this deal. However, it should be emphasised that the current research of B2C BSM in battery gradient utilisation has not yet developed a scale to feed the massive battery investment. Furthermore, although the hydrometallurgical process for cathode materials (a low-energy, low-cost, and low-pollution recycling technology) has started to be used industrially, more breakthroughs are still needed in the recycling efficiency of anode materials and electrolytes (Yao et al., 2018). Therefore, the current capital investment still has no excess return and still awaits further market testing.

In summary, unlike conventional charging EVs and B2B, B2C BSM is a game-changing innovation in supply chain structure, centring on BAMC that shares the cost of significant battery assets and builds an operational model for battery lifecycle management. In addition, the various stakeholders in the joint venture expect financial benefits from the collaboration and access to future options, opening new doors and unforeseen opportunities. As one interviewee (BAMC2) put it:

(BAMC) was set up for the short-term goal of lowering capital costs and increasing the value of each battery through battery lifecycle management…We are still exploring what BSM can become and how far it can go…

4.3.2 User Experience-First Business Model Innovation

After building the supply chain structure, the second critical component of B2C BSM is determining how to generate value for customers as well as for the company, partner networks, and relationship capital. In other words, SCI requires the construction of an acceptable, continually developing business model. Through semi-structured interviews and secondary information, this section attempts to map out Nio's business strategy and the business model to achieve it.

a) User Experience-First Strategy

Before the business model, it's worth discussing the business strategy at first; after all, it's the blueprint for value creation and serves as the foundation for this case study. As Ovans (2015) notes, business model is a story that explains how enterprises work, and when you start comparing business models, you enter the area of strategy. EV is Nio's primary product. As soon as speaking about EVs, it can't help but mention the pioneer Tesla. Both Nio and Tesla began with high-end electric sports cars, pursued autonomous driving, and used OTA (On the Air) software updates similar to those found on smartphones. Their vehicles no longer relied on car dealers, but instead sought to reach customers directly through online platforms and self-running stores. They have made significant strides in this revolutionary innovation. However, according to our study, their business models are fundamentally different because of their distinct strategy. Tesla's business strategy is "to accelerate the world's transition to sustainable energy". Nio, on the other hand, believes strongly in "shaping a joyful lifestyle by offering premium smart electric vehicles and being the best user enterprise." For Tesla, the fastest way to hasten the energy revolution is to lower the price of electric vehicles so that they are accessible to the general public. Tesla is on target to reduce the price of new energy cars down to $25,000 via a series of possible cost reductions, Musk said on battery day (Chokshi, 2021). Unlike Tesla, Nio will produce high-end EVs with exceptional customer service. Nio's thoughts on two different business strategies are also mentioned by NEST2 who is both a sales and consumer of Nio:

Our average sales price for a single EV is over 150,000 RMB higher than Tesla's, indicating that to some extent, our target consumer groups do not overlap……We will not be lowering our prices in the near future……We still want to rely on our products and services to satisfy, or even surpass, our users' expectations....... Our short-term goal is to make it easier to refill electricity than gas.

Prioritizing consumer experience has led Nio to consider an unconventional business model compared other B2C EV companies, and the first step is to identify the factors that influence the user experience. Back in 2014, when Nio was first established, it conducted a market survey with a sample size of more than 60,000, and the topic was " Why people are not interested in EVs". The results showed that 46.8% of users thought that charging was not guaranteed, followed by 30.9% who thought that the battery price was high, 10.7% who thought that maintenance was inconvenient, and 5.4% who were worried about safety (Nio, 2020). Accordingly, Nio is certain that fulfilling consumers' energy replenishment requirements in a variety of scenarios is the key to alleviating EV usage anxiety. The core of Nio's business model is hence the development of a comprehensive and systematic energy service system. One interviewee introduced Nio's thoughts in order to effectively explain the scenarios in which users use EVs (as shown in Figure 4.4). A grid-based mapping can be created by setting the driving area on the X-axis and the dwell duration on the Y-axis, and then analysing unique scenarios and demands. For example, urban areas may account for 60% of car usage and people are likely to stop for energy replenishment in places where spend an average of more than two hours (perhaps at work, home or hotel). As for individual customers, they can choose to install charging piles in their own parking spaces or use the Superchargers and BSS set up by Nio in city centers. Another example: intercity traffic accounts for 4% of vehicle usage and user may stay for about 1-2 hours (probably in a scenic spot greater than 100km away). BSS and supercharging piles put at high-speed nodes can perfectly match their needs at this scenario. It's clear that B2C BSM is an important part of Nio's energy service. Together with mobile charging vehicles, fast charging piles, and public charging networks, to form an energy services system for the whole community. This helps Nio achieve its purpose of providing the best user experience in energy replenishment.

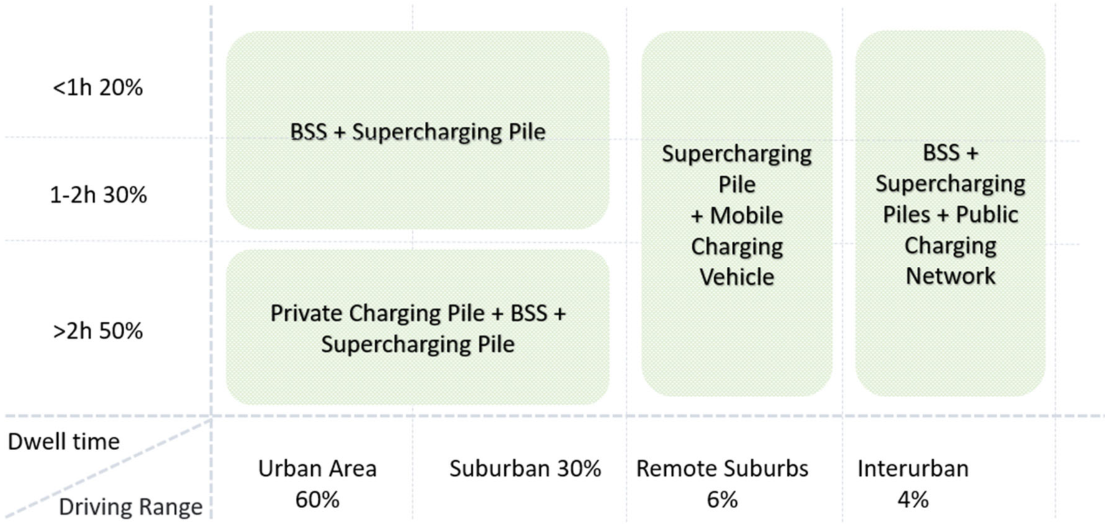


Figure 4.4 Full Scenario of Nio Energy Services (Source: Semi-structured Interview)

b) Flexible Battery Leasing Plan

Another core of Nio B2C BSM's business model innovation is the flexible battery leasing, or in more detail, an optional and upgradeable leasing plan for the chargeable and swappable EV. First, this study analyzes the basic leasing plan of B2C BSM that is optional for Nio users. Take the top-selling model, ES6 with a 70kwh battery pack, as an example, assuming an average monthly driving range of 2,000km (as shown in Table 4.3).

	Cash Purchase (Charging only)	Battery Leasing (BSM and Charging)
Whole EV Cost (Yuan)	343600	343600
Battery Deduction (Yuan)	0	70000
Customer Payment (Yuan)	343600	273600
Devaluation Rate in 5 years	38%	45%
Residual Value after 5 years	130568	123120
Battery Leasing Service Fees (yuan/month)	0	1060
Energy Consumption Per 100 Km (kwh/100km)	16.8	16.8

Energy Replenishment Price (yuan/km)	0.08	0.35
Monthly Mileage (km)	2000	2000
Monthly Energy Replenishment Cost (yuan/month)	168	0
Total Expenses - Static (yuan/5 years)	223100	214100
Total Expenses - Discount Rate 3% (yuan/5 years)	240200	225600

Table 4.3 Cost Comparison of Battery Leasing and Cash Purchase

*Users pay $1060 per month for a 70kwh battery pack and cut 70,000 yuan off the vehicle's price. For a 100kwh battery pack, users pay $1560 per month and cut 128,000 yuan from the car's cost. A Nio user can get six free BSM services a month, assuming that the home charging price is 0.5 RMB per kWh. Data source: semi-structured interviews and Nio (2021).

Looking at the cost structure, the difference between cash purchase and battery leasing is mainly reflected in four aspects: vehicle purchase expense, battery leasing fee, residual value rate and energy replenishment price. First, BSM can significantly reduce vehicle purchase expenses by eliminating the need to purchase the most expensive part--batteries, e.g., the NioES6 saving 70,000RMB in initial expenses. By then the short-term savings from BSM will have been wiped out by rising cumulative battery lease costs due to increased vehicle lifespan. Nio BSM prices are meant to give customers a variety of options. Customers who can afford to buy a vehicle and want to use it for a long amount of time are more likely to buy out, whereas those who are confident in the improvement of battery technology or plan to replace the vehicle in the near future are more likely to rent. In addition, there is a clear disparity in residual value between the two models. According to the interviewer's revelation, the BSM can theoretically create a residual value advantage over charging because it avoids the danger of battery depreciation. Or in other words, customers will not be charged for the depreciation of rental batteries. Although academic research has concentrated on EV residual values (e.g., Tan et al., 2018), the industry has not yet created a standardized assessment approach. The residual value rates in Table 4.3 are based on interviewer disclosures and do not necessarily represent the general situation. Finally, Nio gives six free BSM services per month, basically giving it as a value-added service to consumers for free; however, with the increase of users, Nio will bear a heavier burden on BSM service. It is not ruled out that the free policy will be abolished in the future, and the settlement will be based on "single swapping service fee + electricity cost difference between old and new batteries".

Additionally, the B2C BSM enables flexible upgrades, allowing users to rent batteries on demand, e.g., upgrading to 100kwh before a long trip. Consumers' preference for long-distance driving and the associated range anxiety are both evident in a study from McKinsey (2020), which finds that, by 2020, 45 percent of consumers expect an EV range of 600 kilometres or more, a significant increase from the previous year's study (26%). However, given the growing raw material costs of batteries, purchasing large capacity but pricey batteries may not be wise. The idea of leasing high-capacity battery packs on demand has become possible by the B2C BSM. Consumers can select the most appropriate (rather than the highest capacity) battery pack for their actual travel needs and avoid incurring high sunk costs to meet infrequent long-distance travel needs. At the same time, the interviewees NEST2 also revealed that there is room for further exploration of flexible upgrades:

Then, in 2022, we will broaden our flexible upgrades even more so that customers have more options. For example, week-long rentals will be supported in the near future (Users can only subscribe on a monthly or annual basis currently) … It will be easier for users to switch to a smaller battery next year, reducing their daily rental costs.

C) Value-Added Battery Lifecycle Management

Having ownership of the batteries allows BAMC and Nio more freedom to access battery data and excavate valuable information, which is difficult for other charging EV manufacturers to replicate. As mentioned earlier, extending the life of a battery pack is a priority over recycling for environmental and commercial reasons. BAMC1 told us:

We (BAMC) detect the battery health status through the EV Battery Management System (BMS) or BSS sensors. When the worst condition cell in the pack no longer meets the criteria for continued use, it becomes the shortest board in the barrel. Next the entire pack will be withdrawn from BSS inventory and flow. Please note that this is not the end, but the beginning, where the gradient utilization of the pack begins.

Another industry expert R2 also told us:

Nio has a lot of channels that can make money other than rentals. Retired batteries can be sold to telecom operators to make 5G base stations, or used for electric motorcycles, or solar energy storage stations. Interestingly, the recycling price of retired batteries has exceeded that of new goods this year due to insufficient battery supply. Previously acquired at a 60% discount, now the recycling price is even 20% higher. In addition, because BSM's old batteries are mostly in large quantities while in good condition, the economies of scale have also made Nio more competitive.

The irrationality of the market and distorted supply chain demand information (the "bullwhip effect") can both contribute to price fluctuations for retired batteries. However, the market has shown battery recycling and gradient utilization to increase the life cycles value. On the one hand, the standard recycling model has difficulty recovering batteries from dispersed customers, while the BSM model has the inherent advantage of efficiently boosting the recovery rate and introducing more and relatively high-quality old batteries. The variety of performance and specifications of non-BSM power batteries, on the other hand, will lead to the instability of the gradient utilization system and lower the value of reuse. For example, the difference between the voltage and internal resistance of individual battery cells reduces the actual capacity of the gradient utilization system, leading to current and voltage instability, which reduces the reliability and safety of long-term battery operation (Zhu et al., 2018). In contrast, BSM can manage a massive number of batteries in a balanced and scientific manner to ensure reliability and safety, thus maximizing the value.

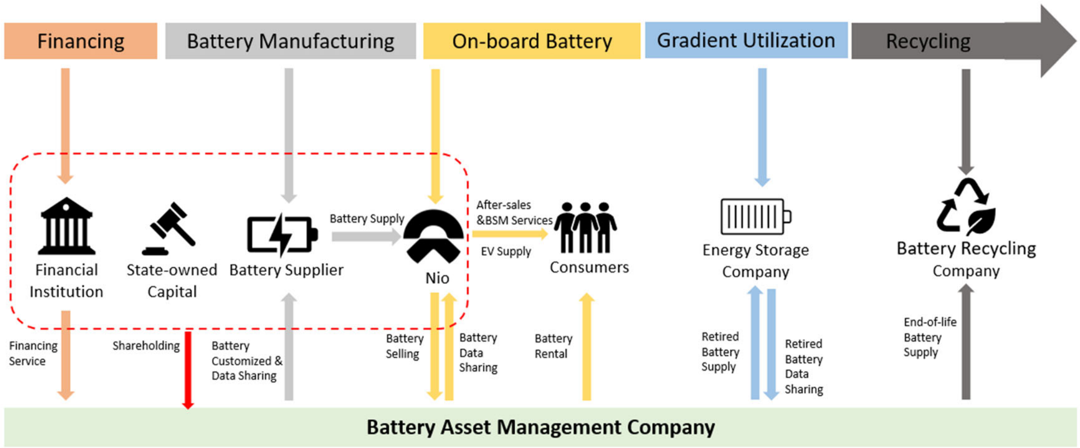


Figure 4.5 Business model of B2C BSM

Battery lifecycle management not only creates value for the upstream, but also profits the final consumer , which shows it is in line with user experience-first strategy. First, the residual value will no longer be a concern for consumers. EV depreciation is mainly caused by the rapid upgrade of battery technology and battery depreciation (Zheng et al., 2020). With the introduction of B2C BSM, battery packs will always be maintained and renewed by BAMC as long as the consumer can afford the additional battery rental price, saving the battery itself from wear and tear depreciation. To cater to the growing green consumption concept, Nio's sustainability report (Nio, 2021), which is constantly scrutinized by consumers and annually published, will also include its battery recycling and carbon reduction initiatives.

In general, the B2C BSM business model (shown in Figure 4.5) stems from the business strategy of putting user experience first. The flexible battery leasing plan supports both charging and BSM completes Nio's energy service system and covers almost all EV application scenarios. At the same time, when the battery no longer meets the minimum performance requirements, it can still maximize the value of the battery asset through large-scale gradient utilization and battery recycling. Also, consumers do not have to worry about battery depreciation and recycling, more in line with the concept of sustainable consumption

4.3.3 Technology Innovation in Battery, BSS, and Cloud Computing

To achieve lifecycle management of each battery pack, Nio and its supply chain partners have developed technology innovations including battery technology, BSS design and siting, to cloud computing data platforms. Combining secondary information and takeaways from interviews, here is a detailed discussion.

a) Upgradable, Swappable Battery Technology

Using BSM instead of recharging allows the battery to be "always new," but the battery's physical size must remain the same as the capacity of the battery increases (ensuring that it fits all Nio models). This requires the battery to increase its energy density continuously. Battery pack structure innovation maybe is a good idea to do that. The traditional battery structure was to wrap a group of cells into a "module" and then use the "module" to build the entire battery pack. Nio and its battery supplier have jointly developed CTP (Cell to Pack) technology that can skip the module to save more space. Applying this technology refinement, the 100kWh pack can increase energy density by 37% without changing the pack shell size and a minor weight increase (Wang et al., 2021). Along with structural improvements, next-generation solid-state batteries led by material innovations will also be introduced, according to BMR3.

We have been working tirelessly on battery innovation by working with leading battery suppliers…… There will be a 150kwh battery on the market next year, and it is expected to have amazing 350Wh/kg energy density. We have started making prototypes.

Simultaneously, BSM must handle the issue of preserving the stability of the battery's connection to the vehicle while it is unloaded and loaded. This is because a battery pack weighs 500kg and requires a solid connection as well as a certain amount of floating space. Bayobolt, a battery bolt invented by Nio, is the answer for this problem. With a sensor located at the very top, it can determine whether the battery has been connected well. While shackling and unshackling, other sensors evaluate the rotation angle to make sure that it doesn't become overly large or small and still maintains the necessary torque. In real time, the wear of the bolt can be also monitored. This bolt was highlighted by several interviewees(BMR1; BMR2; NEST3)

This is our self-developed patented part.... In BSM, 10 bolts can be tightened or loosened at the same time, and the battery can be completely taken off in 15 seconds.

As BSM becomes more widely used by users, technology research will progressively focus on swapping efficiency, component reliability and longevity, battery safety and their energy density. In these areas, Nio holds many patents, but there is still space for more advancements in the future.

b) Modular BSS Design and Demand Driven Site Selection

The BSS is the place where BSM is implemented and the physical facility where important assets - batteries - are stored and managed. By reviewing the patent information system of the National Intellectual Property Administration (CNIPA) and compiling interviews, this study found that Nio designed the BSS primarily using a modular concept, which played an important role in scale up and cost reduction. The Nio BSS just like a shipping container, and its interior consists of two main rooms, the operation room and the battery swapping room. The former includes the charging and swapping control module, the communication module and the human-machine interface. In this room engineers can work for BSM control. The battery status will be automatically uploaded to the cloud computing system. The battery swapping room mainly includes the swapping platform, swapping system and charging platform. The swapping platform is able to position and lift the vehicle. The trolley performs battery swapping. The charging platform is responsible for charging and storing batteries. The system composition of BSS is shown in Figure 4.6(Nio, 2016 and 2017).

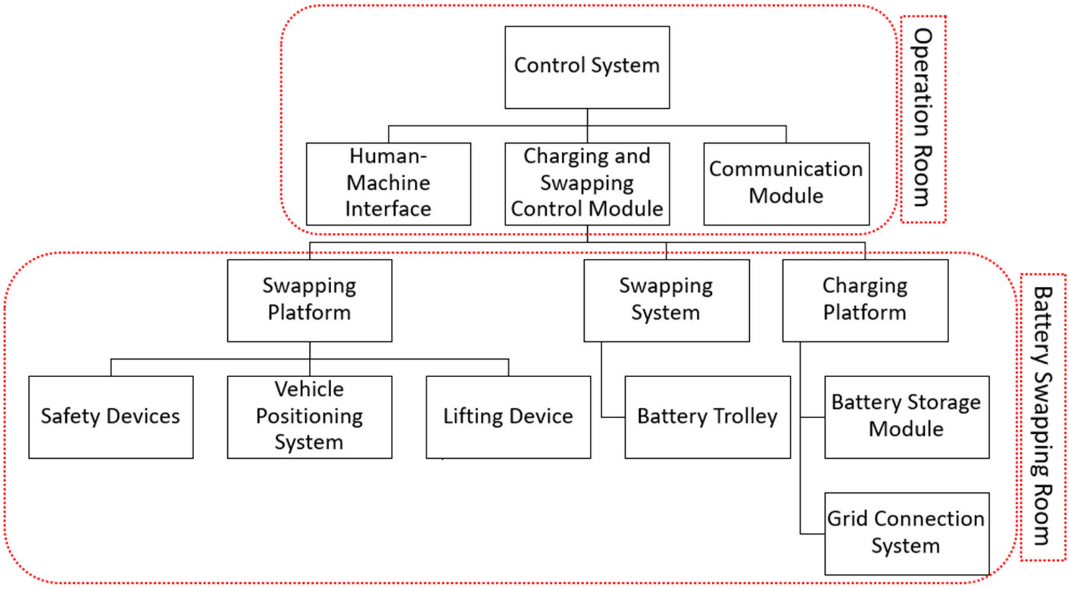


Figure 4.6 Nio BSS Modular Structure Diagram (Source: BSS Patent from CNIPA)

When asked about the efficiency and cost of BSS construction, NEST2 described:

***BSM cost must be controlled to accomplish rapid implementation. At first beginning, our goal is: costs 2 million yuan(nearly 400,000 CAD) to build one, three parking spaces, and roughly 60-70 swaps per day. After that, we worked with the BSS manufacturer to make the second generation of the BSS even better. We streamlined the internal modules and can finished the setup in about seven hours, with 4 parking spaces, 13 batteries, and a theoretical maximum of more than 300 swaps per day. That's huge. I can't say more about the cost, but I can seriously say that it is much more modest than outside estimates and also more affordable*.**

Nio's efforts to control the cost of the BSS can also be seen in a patent filing (Nio, 2016), where Nio's second-generation BSS eliminates the lifting device and adds autopilot so that the user does not need to get out of the vehicle during the swapping process, making uninterrupted BSS operation into a reality. The streamlined structure also allows for fewer mechanical breakdowns and maintenance costs while at the same time reducing the need for human resources. Nio has reduced labour costs by about 10% by reducing the size of the BSS operations team. Also, the second-generation BSS provides lounges for consumers, which reduces consumer dissatisfaction associated with waiting during peak periods (Nio, 2017). Notably, it also demonstrates that the second-generation BSS may also be expanded modularly in response to increasing demand, therefore doubling the battery storage capacity, making the BSS potentially more efficient. In addition, Nio holds 43.5% of the shares of the BSS manufacturer, which is like Toyota's vertical integration to keep manufacturing costs as low as possible while ensuring product quality and reducing barriers and distortions in information flow (Fane et al., 2003).

Apart from minimising the production cost of BSS, properly determining the location is also a rigorous challenge. The configuration of the Nio BSS network must be upgraded and optimised in order to reduce the overall operating costs of the energy service system. Nio's site selection team considers factors such as user density in the region, the accessibility to regional BSM resources, and the covering of critical routes. BSS usually supports two types of scenarios: 1. urban and suburban, and 2. intercity highways. One of interviewees NEST2 discussed the first type of scenarios:

We use the Vehicle Station Ratio (how many EVs are covered by a single BSS on average) to determine how many BSSs to build in a region, Besides that, we also set up a series of site evaluation systems to qualitatively and quantitatively analyze potential sites, such as their accessibility, hoisting capacity, load-bearing and drainage capacity; property ownership; fire protection; electricity supply; rental costs for five and eight years; and more. Occasionally, we listen to local users' voices because they are familiar with the area better than we do and vote via the app community to make final decisions…. Some strategic partners including PetroChina, Sinopec, and Shell have decided to support our BSS in their gas stations, providing us with the ideal position.

Nio ignored the high-speed scenario early on, but after listening to user feedback and doing market research, they changed their mind. According to one of our interviewees NEST3.

Only one-third of the efficiency of the urban BSSs could be found in the early highway BSSs…… As time went on, we began to get an increasing number of complaints from our users regarding the lengthy wait times associated with the highway swapping……Our data also showed that holiday highway BSS consumption was 3-5

times greater than urban BSS……. So, we changed our BSS site selection strategy to focus more on high-speed networks.

The siting of the Nio highway scenario focuses on trunk lines connecting densely populated areas and short-distance highways around metropolitan areas. Now Nio has basically formed a highway network that can be simply summarized as: five verticals, three horizontals, and four metropolitan areas (as shown in Figure 4.7). The five verticals mean 5 national highways linking important political and economic centers in a north-south direction, for example, Nio has completed layout in G1 Beijing-Harbin, G2 Beijing-Shanghai, G4 Beijing-Hong Kong-Macao, G5 Beijing-Kunming, and G15 Shenyang-Shanghai. Similarly, the three horizontals are the three national highways running east-west, namely G50 Shanghai-Chongqing, G30 Lianyungang-Horgos, G60 Shanghai-Kunming. The "four metropolitan areas" include Beijing-Tianjin-Hebei metropolitan area and Yangtze River Delta metropolitan area, which has been fully covered by Nio BSS. In addition, the Guangdong-Hong Kong-Macao Greater Bay Area and Chengdu-Chongqing metropolitan area will also be connected very soon (Nio, 2021). It is evident that Nio has basically formed a highway BSS network, which is very helpful for EV users to embark on inter-city grand tours. One interviewee indicated that Nio will continue to open more "capillary" sub-city segments in the next 2-3 years to extend the network to more cities and populations.

Figure 4.7 Nio BSM Highways Network Layout in China (Source: Nio)

c) Cloud-based Battery Data Platform

B2C BSM technological advancements are reflected in improved battery asset forecasting and scheduling via a cloud-based battery data platform. As a result of a mismatch between the user's real-time battery demand and the BSS supply capacity, Nio must find a way to decrease the user's waiting time. For example, if an EV owner selects the 100kwh lease plan, he or she will have a difficult time finding a BSS that can deliver a bigger battery since most batteries in circulation are 70kwh. A cloud-based battery deploying and scheduling strategy can help. To begin, Nio uses the Graph Convolutional model to constantly train the high-dimensional factors (holidays, weather, traffic, special events) that impact user demand to get the connection between them, thus getting more accurate prediction results. One interviewee BAMC2 explained:

We compose "Training Set, Cross Validation Set, And Test Set" of historical order in the ratio of 6:2:2 for training and validating the algorithm model. This process is like a primary school student learning mathematics, the Training Set provides textbook

knowledge to help students build their own knowledge structure. The Validation Set ensures that the student's problem-solving skills are exercised through homework assignments, and the Test Set is used as the final exam to test the overall competence.

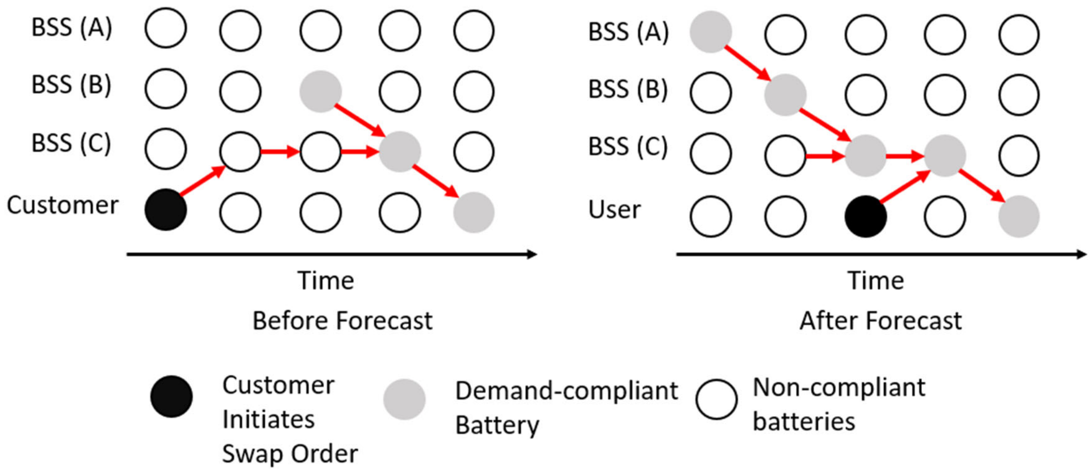


Figure 4.8 Consumer Swapping Demand Forecasting Performance

With such forecasting algorithm, the cloud-based battery data platform can make battery scheduling in time before users placing orders (as shown in Figure 4.8). For example, dispatch more 100kwh batteries to the highway BSS before the Golden Week holiday.

Additionally, the Cloud enables Nio to extend battery sharing among users by assessing battery inventory and demand in each BSS. If demand exceeds supply, Nio will send a peer-to-peer message to 100kWh battery pack users who living near by and inviting them to join in battery sharing. In other words, users with 100 kWh batteries can rent batteries at leisure with Nio points (which can be redeemed for products or services in the Nio APP).

Another function of the cloud computing platform is to provide lifecycle management for the huge battery assets. When the battery is loaded on the EV, data such as temperature, voltage and current are measured by the vehicle monitoring system and transmitted to the cloud computing platform. This highly sensitive monitoring system operates 24/7 in real time and can accurately detect and intercept irregularities in their infancy. Other supply chain partners are also given access to the data in order to conduct batch recalls of batteries that pose safety risks or to facilitate further engineering and materials science enhancement. According to the data provided by the interviewees, Nio is now able to achieve a world-leading 95% pre-recognition rate and accuracy rate for faults. In addition, the BSS is equipped with a wealth of sensor devices, including temperature, humidity, smoke, flooding, and vision sensors, allowing for more careful and frequent battery checking, which is not available in charging EVs. Also, BSS detects scratches, bumps and visible mechanical damages on the underside of batteries using image recognition technology and gradually accumulates samples to increase identification accuracy. BAMC removes the substandard batteries from circulation and places them in the gradient utilization or recycling process.

Overall, with the cloud-based battery data platform, Nio enables smarter and more efficient battery forecasting, scheduling, and more comprehensive battery safety management.

4.4 How to Promotes SCI

The previous section demonstrated Nio's innovations in supply chain structure, business model, and technology. This section will explore the supply chain learning and collaboration implemented by Nio and its supply chain partner from a process perspective, and analyze how these have impacted SCI.

4.4.1 Supply Chain Learning for B2C BSM

Bessant et al. (2003) first formally introduced the concept of "supply chain learning" (SCL) and identified three phases of SCL, namely, set-up, running and sustaining. Combining the information collected from the interviews, this study borrowed this framework to delineate Nio's SCL.

To begin, Nio and his supplier partners teamed up throughout the setup phase to achieve the B2C BSM business model. SCL was mostly driven by Nio during this period and was primarily focused on organization's internal learning, while knowledge acquisition was primarily based on case studies and market analysis reports from overseas BSM experimenters. Internal R&D team plus outsourced manufacturing have mainly contributed to Nio's BSM knowledge base, which separates the company from its competitors and offers primary competitive advantage. At the same time, the supply chain partners are not proactively involved in SCL, but rather in a simple manufacturing OEM relationship. According to BAMC1&2:

Indeed, the BSM cases of BP and Tesla used to be our learning material that was very inspiring for us…… We certainly worked with some consulting companies to validate the rationality of the B2C BSM strategy…… We started to assemble a team for a series of R&D such as BSS and battery and outsource to manufacturers for production.

In the running phase, Nio started to pilot test, construct, and operate BSS on a small scale in major cities like Beijing and Shenzhen. This enables a modest expenditure to be made to fulfill some customers' energy replenishment needs while also gathering their feedback on BSM. At this period, SCL's knowledge sources gradually expanded outside the organization, with a particular emphasis on the voice of consumers. The first BSM users began contributing to the Nio APP community by sharing insights on battery leasing models, BSS site selection, and operational optimization. Users could communicate directly with Nio's executives via this channel. As consumer C2 put it:

If you want to talk bad about Nio on the internet, you're likely to use the Nio APP, which is also the easiest place to find critical voices. For example, in early BSM experience, people didn't know how many people were in line for swapping and couldn't figure out how long it would take. The complaining post soon received response from the CEO, and very soon the APP added queuing information and a reservation function.

The external source of knowledge drives faster continuous improvement of B2C BSM. In addition to this, Nio has also offered an internal SCL online learning platform for all employees, including 1000+ courses in automotive, finance, internet, manufacturing, and management. The platform also access Nio branches and suppliers, sharing their work experiences and improvement practices and incorporating them into the supplier relationship management (SRM) evaluation process.

Finally, in the sustaining stage, along with the development of national BSM business, the scope of SCL knowledge sources also extends to the outside of the supply chain, such as the government-led BSM standard-setting association, where policy information, industry development dynamics, and the interests of all parties can be obtained. By joining forces with other BSM supportive automakers, Nio spearheaded the participation and development of five standards related to BSS safety and structure (Xinhua, 2021). At the same time, the sustaining phase is the most challenging since it needs supply chain partners to retain long-term enthusiasm and constantly seek new interests to replace the initial motivation (Bessant et al., 2003). For example, some customers stated:

Currently, more users have clogged Nio's service, resulting in lengthy wait times for some of the older BSSs(C3)…… Instead of working to keep the community in harmony, a small minority of members engage in personal attacks on one another over the mere fact that they hold differing viewpoints(C4)……

As can be seen, the challenge is constantly present. If service resources are unable to keep pace with the expansion of core users, a reduction in service quality is unavoidable. Simultaneously, as the planner of general coordination, Nio must evaluate the viewpoints from individual users in order to avoid the dilemma of focusing exclusively on the local optimal and overlooking system-wide optimization. Despite these obstacles, ongoing SCL is critical for promoting SCI.

This study also found that in addition to expanding the breadth of SCL knowledge sources, SCL should continue to examine the depth of knowledge, that is, continue to explore the potential value of data in hand. One interviewer BAMC1 mentioned that:

One of our (BAMC) strengths is that we have a lot of data on EVs and batteries, so we may also use machine learning to solve the BSM's order priority problem. This is a great way to figure out which queuing method has the lowest overall cost (e.g. minimum average wait time, average number of people in queue). It is also possible to continuously improve the user experience by collecting more data and continuously changing the algorithm parameters.

However, the innovations resulting from SCL can in turn create new problems. For example, machine learning for planning BSM order prioritization suffers from an overall high complexity, and the algorithm's learning rules are a black-box process for users. Users who do not understand its principles are likely to misunderstand and thus become dissatisfied, which in turn requires SCL to continuously collect information in breadth and depth and make improved decisions. Thus, SCL facilitates SCI while evolving dynamically; it is a journey rather than a destination.

4.4.2 Supply Chain Collaboration for B2C BSM

Supply chain collaboration is generally a cooperative strategy in which one or more businesses or business units work to achieve mutual benefits (Simatupang and Sridharan, 2008). This study finds two distinct kinds of Nio supply chain collaboration for the B2C BSM depending on the different partners. One is collaboration with internal supply chain partners; BAMC is unquestionably the best example of this type of collaboration, which is explored in-depth in 4.3.1. Another is collaboration with external supply chain stakeholders, which refers to groups not directly business affiliated with Nio, such as government and regulatory agencies, industry associations, and local communities. Nio's instance demonstrates an intriguing expansion of engagement with external supply chain partners.

First, Nio starts strategic collaboration with petroleum companies such as Sinopec, PetroChina, Shell, etc. in the BSS deployment, which is the opposite of the inherent perception that new energy and petroleum industry are incompatible. Nio can obtain BSS site selection and operational convenience through the oil giant, such as gas stations with a suitable construction area, clear property ownership, and standardised supporting service facilities, which can significantly reduce the cost of the BSS network's construction and accelerate its completion. And what do petroleum companies want to gain from the collaboration? The interviewer SP1 answers our questions:

As we see it, the full-scale electrification of the automotive industry is indeed going to happen. We (Sinopec) have more than 30,000 gas stations nationwide. If new energy vehicles gradually replace fuel vehicles in the future, will these 30,000 gas stations become a burden? However, if we use this vast network to build BSS and actively introduce new technologies, will it (gas stations) become a valuable core resource to help us transform and improve?

Petroleum companies reconsider their strategies in light of carbon neutrality. By partnering with Nio, BSM can gradually increase the proportion of sustainable newborn business and gradually reduce the carbon emissions from its traditional operations. Thus, BSM may be an attractive cake for oil giants. It also inspired a new reflection that if petroleum companies enter the B2C BSM sector as well, will there be a fierce competition with Nio? For instance, Battery asset management looks like a perfect emerging business for the well-funded oil giant. Also, there are potential collaborations with other BSM operators. How to choose a strategic partner and how to maximize their gas station resources will be the next thing to address.

Another interesting external stakeholder in the B2C BSM supply chain is the large wholesale stores represented by Red Star Macalline (Chinese homewares merchant), Metro (B2B wholesaler), and IKEA (world-renowned furniture merchant). They all have established stores in major cities around the country and sufficient parking lots to assist Nio with BSS site selection. A discussion with SP2 clarified their motive for these collaborations:

People like Nio, they make fancy EVs…… In some ways, Nio's customers overlap with our target customers, the growing Chinese middle class who care about sustainability and healthy living…… Nio is also a great match for our values: user experience comes first…… and we strongly believe that BSS can really help some of our customers who have EV……and very likely to bring in new customers.

Although Nio and these large wholesalers do not have a direct business relationship, they are well aware of the value proposition of each other's target users. A shared marketing strategy has also become the direction of supply chain collaboration. It also proves that individual enterprises have limited resources and capabilities, and supply chain collaboration can achieve the accumulation of potential users, customer responsiveness improvement, and better access to target market segments.

The last category of external stakeholders is the advanced clean energy solution provider represented by Lian Sheng New Energy, which is dedicated to the promotion of photovoltaic energy storage technology. Their supply chain collaboration focuses on technology innovation, with the goal of installing photovoltaic panels for Nio BSS as a way to achieve electricity savings and even self-sufficiency. As a result, the supply chain collaboration has achieved complementary strengths and enhanced knowledge sharing and innovation performance.

Overall, in addition to the coordination within the supply chain, B2C BSM can be divided into three categories externally: 1. traditional energy giants for strategic realignment purposes; 2. large wholesalers for brand marketing purposes; and 3. clean energy solution providers for technology innovation purposes. Companies in different industries have different but complementary capabilities to Nio, uniting their capabilities to create value for end users. In this process, supply chain collaboration is also integrated into the overall context of SCI.

4.5 Problems and Challenges

While building a new supply chain structure and innovating business models and technologies, Nio also faces external turbulence such as restrictions on standards rollout, technology competition, and changing consumer preferences. In addition, the underlying meaning of B2C BSM is being challenged by how to promote the BSS network and operation better and how to explore the battery data continuously.

The most immediate threat comes from technological advancements, which are narrowing the time gap between rapid charging and BSM. Tesla's latest generation of V3 superchargers takes only 20 minutes for mid-range charging (from 20% to 80%) (Tesla, 2021). Meanwhile, for the research community, battery technology is not constrained by bottlenecks; for example, next-generation solid-state batteries may attain a mind-boggling 500Wh/Kg weight energy density, a 4C charge multiplier, and improved cycle longevity and safety (Reisch, 2017). The value of BSM will be re-examed when the speed of chargers catches up with the speed of the gas pump.

Second, it is challenging to standardize battery packs across EV and brands, and it is also difficult to ensure compatibility with BSM technology; for example, some companies use side-mounted BSM rather than Nio's chassis-mounted BSM. The fight over BSM standards essentially determines the supply chain voice. It is not difficult to imagine that advancing the battery or BSS standard will be extremely tough, as it involves multi-party interests. On the one hand, EV manufacturers are reluctant to open their battery patents to outsiders for fear of being degraded to a body manufacturer. On the other hand, standardized battery packs compress design flexibility because sometimes designers have to compromise chassis structure for the standardized battery pack, thus dramatically affecting EV driving ability. To some extent, standardized battery packs are not conducive to competition in the EV market and undermine consumers' quest for diversity. As R1 critiqued:

If BSM only serves one brand, it makes no sense. ……Other EV manufacturers are not likely to use its battery standard, which requires paying royalties and limits the competitiveness of their own EVs…… Consumers will benefit from BSM, but the investment value needs to be well thought out.

Finally, there is also a question in the industry: Will the improved user experience brought by Nio B2C BSM be worth its investment? BSS is an asset-heavy project, and its costs can be roughly analyzed by land rent, battery cost, BSM equipment, labor costs, and daily operations. The total cost of a single BSS is estimated to be between 1 and 2 million RMB, where land rent is still on the rise, just like NEST3 stated:

A good location attracts many competitors, charging stations, B2B BSM operators are involved in bidding……. Yes, our land rents are rising.

In addition to the financial investment, finding a right BSS location remains challenging. Firstly, land approval is one of the long-standing confusions for Nio. Unlike charging stations, BSS has particularly high requirements for environmental compliance. For example, a large number of battery packs are not allowed to be placed around residential areas and hospitals. Residents in the community have also resisted the noise and electro-magnetic pollution caused by BSS. At the same time, the power infrastructure in some areas is outdated, making capacity expansion difficult. Finally, some BSSs also have queueing problems caused by excessive BSM orders over battery supply during peak periods.

In conclusion, this study finds that B2C BSM is still in its infancy and that the challenges it faces should not be underestimated. The main barriers include the following: 1. the development of rapid charging and battery technology; 2. the difficulties in promoting battery and BSM standards; and 3. the enormous investment and BSS network location issues.

5 Discussion

5.1 Dynamic Technology Innovation and SCI

B2C BSM is unfeasible without technology improvement in batteries, BSS, and cloud computing platforms, as previously indicated. On the other hand, it may become outdated as charging technologies advance. The paradox of dynamic technology innovations is mirrored in the instance of Nio and is examined in a few SCI literatures (Answer et al., 2020; Sabahi and Parast, 2020), however this thesis considers it inadequate. This is because latecomer technology developments, such as B2C BSM, act as competitors to the prevailing technology route, necessitating time-consuming and sustained attention from academics (Sheremata, 2004). Previous SCI literature has focused more on top supply chain operation, for example, the SCI practices of well-known companies, such as Apple and its suppliers' CPFR (Collaborative Planning, Forecasting and Replenishment) (Wang and Shin, 2015) and ignored the SCI development of emerging technology competition. Therefore, this thesis recommends that dynamic capability theory be further integrated into SCI theoretical discussions (Chowdhury and Quaddus, 2017), as it may give strategic and tactical decision-making inspiration for SCI practice.

Dynamic capability theory explains how organizations use dynamic capabilities to gain and maintain a competitive advantage in responding to and creating the external environment (Chowdhury and Quaddus, 2017). Dynamic capabilities, according to Helfat et al. (2007), are an organization's ability to proactively generate, extend, and adapt resources such as material, human resource, and available assets, as well as technology. Supply chains are similar to organizations in that their technology innovations are never foolproof and unchanging, therefore the inclusion of Dynamic capability theory in SCI theoretical discussion can broaden its connotation.

Dynamic capability theory can offer Nio's SCI with useful practical guidance. Nio and its supply chain partners can immediately reorganize and optimize resources to dynamically acquire long-term competitiveness, or at least not be phased out, if revolutionary advances in charging technology occur. For instance, they can implement 1. selective scale-down of BSS based on available data; 2. business improvement by converting existing B2C models to B2B for increased turnover; and 3. rapid conversion of BSS to

Supercharging Station based on BSS modularity and existing power infrastructure resources, which could increase long-term competitiveness.

5.2 Knowledge Stocks, Knowledge Flows and SCI

As indicated in section 4.5, the size of the entire B2C BSM market will be drastically reduced if Nio does not promote its BSM standard. However, if Nio's standards are promoted, their implementation will be challenging and meet opposition from numerous stakeholders (e.g. charging EV manufacturers). Patents are the carriers of the knowledge stock, and maximizing the value of the knowledge stock is contingent on the manner and efficacy of knowledge flow (Roper and Hewitt-Dundas, 2015). In fact, despite the fact that supply chain learning has been frequently highlighted and underlined in the SCI literature (Mandal and Scholar, 2011; Yoon et al., 2016), there is scant work tying the knowledge stock and knowledge flow to SCI.

Roper and Hewitt-Dundas (2015) critique the ambiguity relationship between knowledge stock and innovation performance based on a resource-based view, arguing that the existing knowledge stock, as measured by patents, negatively affects the firm's innovation output. In other words, the view that more patents are better is false. Inspired by this, this thesis argues that devoting too many resources to developing, protecting or defending patents rather than effectively commercializing them can be a dangerous practice. In contrast, the promotion of open innovation aimed at facilitating knowledge flow may be more important for SCI (Gianiodis et al., 2010). In addition, this thesis also explores how to find the appropriate way of knowledge flow from stakeholder theory (Wayne, 2012). Supply chains, similar to organizations, should balance the interest claims of various stakeholders in an integrated manner and not only focus on the increase of its own interest. Therefore, a win-win commercialization model may have a positive impact on SCI in terms of knowledge flow. In other words, the effective and efficient knowledge flow needs to be based on mutual benefits, and the exploration of appropriate commercialization strategies needs to be jointly explored by all stakeholders.

This discussion may also provide empirical insights for the promotion of the B2C BSM standard by Nio. Nio must first evaluate how to commercialize and maximize the value of its pricey BSM patents which are primarily the result of internal research and development. Nio can therefore engage in continuous and active external supply chain learning and coordination, as well as actively participate in the process of defining BSM standards and become a significant stakeholder with leadership responsibilities. Alternatively, based on stakeholder theory, Nio might share its battery and BSS patents with other EV manufacturers in order to cooperatively explore commercial operation solutions that are mutually advantageous. BAMC, a consortium of numerous stakeholders, can serve as coordinator and organizer during this process. Lastly, standardizing BSM is likely to be a time-consuming endeavor; therefore, it is recommending a phased, incremental improvement. Battery pack sharing can be adopted in stages, with commercial vehicle research taking precedence (cabs, logistics vehicles, heavy trucks, etc.). BSS sharing can also be implemented in the B2B sector first, and the B2C sector can be modified in response to changes in market dynamics.

5.3 Cost and SCI

Although SCI may bring many benefits, such as optimized operational efficiency, improved service quality, economic prosperity, environmental protection, and increased social responsibility (Belanger and Crossler, 2011), cost consideration is neglected in the SCI literature. This may be because more of the SCI literature is more conceptual and theoretical rather than empirical discussions biased towards business operations (Wong and Ngai, 2019). Or perhaps cost reduction is seen as the purpose of SCI and the impact of cost in the SCI process is overlooked (Wong and Ngai, 2022). Or perhaps cost is a financial perspective on supply chain operations, which may involve business privacy and is difficult for academics to fully capture (Li et al., 2014). But in cases such as Nio's, this thesis finds that the cost perspective of SCI is worth examining because it is highly likely to be the root cause of SCI failure (e.g., the BP failure (Christensen et al., 2012)).

This thesis recommends that costs be incorporated into the SCI discussion by, first, incorporating Listed Companies as research subjects, given that they regularly make public financial disclosures, and so do stakeholders upstream and downstream in the supply chain. In addition, long-term and continuous research is required to provide a more thorough and objective perspective of the cost's effect on SCI. In the instance of Nio, there are doubts concerning the high cost of B2C BSM deployments, and this research use a dialectical perspective to explain. However, this is merely an argument based on existing knowledge, and not a quantitative analysis that is long-lasting or comprehensive.

On the one hand, unlike the traditional automobile industry, the EV's investment logic is similar to Internet investment in that it prioritizes sales volume over profit: when User experience is enhanced, Nio sells more cars, investors will be optimistic, the stock price will rise, and Nio will be able to finance more money through the capital market. And when the market share is sufficiently large, the BSM titans who control the core resources may become the final harvesters. Prior to then, it is expected that government subsidies such as BSM vehicle, BSS construction, and subsidized electricity will continue. Lastly, the added value in battery life cycle management is expected to be the largest source of revenue for B2C BSM, which provides ample room for expansion.

On the other hand, the preceding reasoning chain contains numerous uncertain assumptions. In a competitive EV market, for example, will customers gravitate toward BSM, and will cash flow from stock market financing support an ambitious BSS deployment? Will policy incentives continue to encourage B2C BSM development, and will Nio ultimately be able to trade its BSS resources for market dominance? Finally, cost is still determined by market share, which is influenced indirectly not only by the product itself, but also by policy subsidies and standard promotion. Furthermore, the stability of the supply chain's money flow, information flow, and logistics, as well as the continuous improvement of internal processes, will have an impact. As a result, the information gathered in this study so far is insufficient to provide a solid answer, but it is hoped that future studies will continue to investigate the development of B2C BSM from a dialectical standpoint.

5.4 Hidden Competition and SCI

In the SCI literature, supply chain collaboration has been discussed (Yunus, 2018), but the underlying competitiveness has been overlooked. As pointed out by Ingram and Yue (2008), interorganizational collaboration may reduce rivalry in the near term, but may increase competitiveness in the long term. In light of this, this research suggests that it is worthwhile to investigate the hidden competition in SCI literature. It can be explained by the cooperation-competition theory (Bengtsson and Kock, 1999 and 2000); Walley (2007), who argues that business activity is a unique form of a non-zero-sum game that can achieve a win-win situation, in which firms, from the perspective of their own development and the optimal allocation of social resources, induce new adjustments in inter-firm relations, either from cooperation to competition, or vice versa. This thesis, inspired by this idea, contends that there is also a relationship between competition and collaboration in supply chain innovation. In such a unique connection, supply chain stakeholders eliminate resource duplication and waste while benefiting from each other's core strengths. Concurrently, new business opportunities are formed.

In fact, the case of Nio partially supports this viewpoint. Despite being potential competitors to each other, Nio does not have to struggle to find a suitable BSS site because the gas station provides the ideal power facility and land; the Tier-1 battery supplier gains BSS operation experience and knowledge stock from Nio BSM, which laid the foundation for developing B2B BSM; and the oil company cooperates and compete with Nio to gain new business transformation opportunities.

5.5 Government Role and SCI

In the case of Nio, this thesis discovers that the government plays a critical and decisive role, and that such a crucial stakeholder is underappreciated in the SCI literature. This might be because the majority of SCI work (Munksgaard et al., 2014) focuses on the US scenario, where value-add is a greater driver of SCI than policy pressures. It's also likely that governments, as external stakeholder, is difficult to control and influence by decision makers within the supply chain (Hahn, 2020). The absence of regulation also hampers the effectiveness of sustainable supply chains, causing serious corruption and judicial abuse (Silvestre et al., 2020).

In conclusion, future SCI literature should explore including the visible hand – the government – into the theoretical discussion. According to Liefner and Losacker (2020), present theories of innovation in developing economies should avoid emphasizing one-way transitions. Instead, the process of innovation will be selective (beginning with a few enterprises first) and multidirectional (different firms explore different approaches). As a result, in the Nio case, this thesis contends that, in addition to fostering B2C BSM development through subsidies, the government should focus more on SCI process in terms of supply chain learning and supply chain coordination. For example, the government led BSM standard committee should collect information on Nio's operation experience and standards as a knowledge base, and on the other, encourage and involve more BSM operators or EV manufacturers in the standard committee to promote supply chain collaboration and create more innovation knowledge. Finally, the government should establish an efficient evaluation method for the subsidies to minimize subsidy misuse.

In order to provide a more explicit and conceptual framework of the themes, this thesis will use Table 5.1 to summarize the Chapter 4 case study and Chapter 5 discussion.

Why Nio chooses B2C BSM?	External Motivators	Policy Incentives
		BEV Market Growth
	Internal Motivators	Enhance User Experience
		Enhance Battery Asset Lifecycle Value
		Improve Energy Replenishment Efficiency
What Nio has done for SCI?	Supply Chain Structure Innovation	Battery Asset Management Company(BAMC)
	Business Model Innovation	User Experience-First
		Flexible Battery Leasing Plan
		(Battery) Gradient Utilization and Scaled Recycling
	Technology Innovation	(Battery) Structural/Material Innovation
		(Battery) Fast & Reliable EV-Battery Interlock
		(BSS) Modular Design
		(BSS) Continuous Streamlining of Internal Structure
		(BSS) Demand-Driven Network Planning
		(Cloud Computing) Graphical Convolution Algorithm Forecasting

		(Cloud Computing) Peer-to-Peer Delivery for Battery Leasing
		(Cloud Computing) Diversified Sensors
How to Promotes SCI	Supply Chain Learning	Set-up Phase: Internal R&D + Case Study
		Running Phase: Pilot Test + Consumer Voice + Internal Learing Platform for Employees & Suppliers
		Sustaining Phase: BSM Standards Association + Compliance
	Supply Chain Collaboration	Collaboration within the Supply Chain (BAMC)
		Collaboration outside the Supply Chain(Petroleum Companies;Wholesalers; Photovoltaic Manufacturer)
Problems and Challenges	The Rapid development of charging and battery technology	Dynamic Technology Innovation and SCI: Dynamic capabilities to integrate resources and proactively face technology competition
	Difficult to form a unified BSM standard	Knowledge Stocks, Knowledge Flows and SCI:Instead of Protecting the patents, Nio should promote.
	Enormous Investment	SCI Literature Should Add Quantitative Costing
More Theoretical Discussions	Hidden Competition and SCI	SCI Literature Can Be Combined with Cooperation-Competition Theory
	Government Role and SCI	SCI Literature Should Discuss the Role of Government

Table 5.1 Conceptualized Theme Summary

6 Conclusion

6.1 Summary

This thesis finds that B2C BSM's SCI benefits from external macro environment, such as policy incentives and rapid expansion of the EV market. Within the supply chain, SCI is inseparable from the pursuit of user experience, value-added battery assets, and energy replenishment efficiency. Two components comprise the SCI research framework: innovation content and innovation process.

In terms of innovation content, BAMC, the battery asset management company, is the core of supply chain structure innovation. As a unique organization of joint venture of various stakeholders, it reduces the capital pressure caused by the enormous battery assets, while also serving as the information hub of collaboration within the supply chain and enhancing its accessibility and interconnectivity. B2C BSM is rooted in Nio's user-first business strategy, and tactically tends to optimize the scenario of energy replenishment for the final consumers. Specifically, in addition to lowering the purchase price and eliminating the hassle of battery depreciation, Nio also offers a more flexible and continuously improved battery leasing solution. Maximizing the value of battery assets through gradient utilization and high-volume recycling is another manifestation of business model innovation. The B2C BSM technology innovation covers three areas. First, the battery pack material and structural innovation ensures higher energy density and safety in a limited volume. Secondly, the BSS adopts a modular design concept to pursue rapid deployment, cost savings and sustainable expansion, and the BSS site selection strategy is dynamically changing with the voice of consumers, i.e., focusing more on important high-speed networks and metropolitan areas in the future. Finally, the cloud-based battery data platform also enables more accurate swapping order forecasting, smarter battery scheduling, and more accurate and frequent battery safety checks through artificial intelligence algorithms, richer sensors, and IoT technology that cannot be achieved by conventional charging models.

The case of Nio also demonstrates how, as SCI evolves, the supply chain learning and collaboration's breadth and depth change dynamically. First, the sources of knowledge for supply chain learning show an inside-out trend, beginning with internal R&D and progressing to consumer voice and supplier feedback from outside the organization, and finally SCL expands to industry associations outside the supply chain (this includes other BSM operators and governments). Simultaneously, continued exploration of existing battery data and operational experience will place increased demands on the next SCL. Similar to SCL, inside-out supply chain collaboration has become prevalent. Early collaboration within the supply chain enabled BAMC to incorporate the interests of various supply chain stakeholders, which became a significant structural innovation within the supply chain. Outside of the supply chain, collaboration with gasoline companies, large retailers, and emerging technology companies has enriched the content and played a role to the SCI's sustainable development.

6.2 Theoretical Contribution

Like the views expressed in the reviewed SCI literature, this study contends that supply chain learning and supply chain collaboration play a positive role in supply chain innovation. Meanwhile, this thesis also finds that more perspectives and theories can be incorporated into the theoretical discussion of SCI, which enriches the theoretical boundaries of SCI.

To begin, this thesis discovers that dynamic technology innovation is frequently overlooked in the SCI literature, and it is proposed that dynamic capability theory be more fully integrated into the theoretical discussion, emphasizing the need to reorganize and optimize technological resources in a more flexible and dynamic manner in order to cope with the dynamic technology competition. Second, this study challenges the notion that more patents are better, arguing that SCI should place a greater emphasis on the added value of knowledge stock (patents) and the efficacy and efficiency of knowledge flow. Simultaneously, according to the stakeholder theory, determining the best strategy to promote and commercialize knowledge should take into account the interests of other stakeholders. Third, there is often a lack of a process perspective and a financial perspective in the SCI literature when calculating the cost of implementation. So, a long-term and dialectical assessment of cost's influence on SCI is required. In addition, this thesis also encourages attention to the importance of competition hidden under supply chain collaboration and the role of government to the SCI literature.

6.3 Limitation

The thesis is actually a case study based on exploratory qualitative research, is more qualitative than quantitative. The majority of the information provided by the interviewers was also subjective and qualitative, which may have distorted comprehension. For instance, one interviewee mentioned the increase in land prices in BSS, but the researcher was unaware of the exact magnitude and exact numbers. In addition, since the interviewees for this paper focused primarily on B2C BSM within supply chain stakeholder organizations, a subjective bias is unavoidable. Respondents have a natural tendency to highlight the positive aspects of what they are doing while ignoring the negative aspects (Rook, 1984). Naturally, quantitative analysis is also challenging for reasons of commercial confidentiality. For future research, it may be possible to narrow the scope of the study and develop quantitative analysis by focusing on the public disclosure of BSM companies.

6.4 Future Research and Recommendations

This study answered the Why, What, and How questions, but not the 'How does it perform' question. Therefore, future research could consider combining SCI with sustainable performance to evaluate whether B2C BSM is more sustainable relative to B2B BSM or Charging. For example, to quantify one battery's carbon emissions over the whole B2C BSM life cycle and compare it to other models.

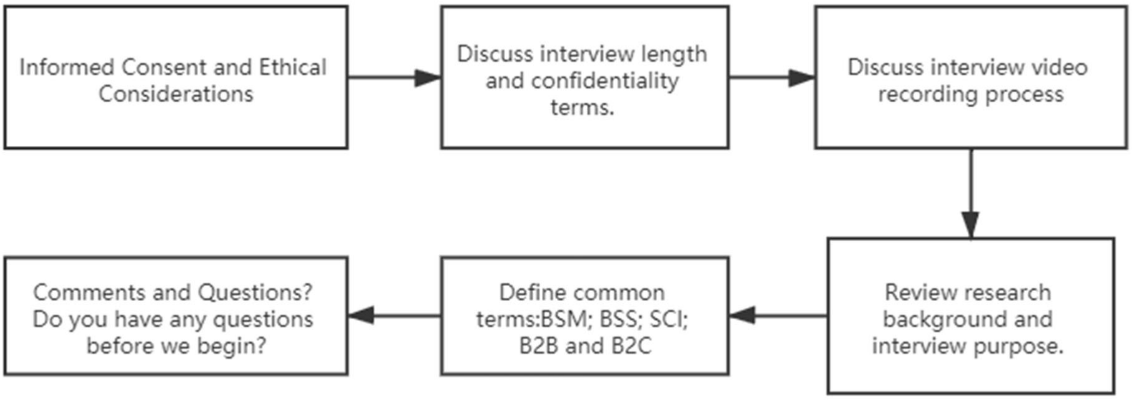
Secondly this study focuses horizontally on the upstream and downstream supply chains around the focal company (Nio). Although the supply chain innovation linkages among stakeholders and between them and Nio are considered at a macro level, an intra-organizational perspective is lacking. This means that business process innovation, organizational structure innovation, and technology innovation within a specific organization are not explored in depth. Therefore, future researchers may be able to vertically explore the details of a specific company in the B2C BSM supply chain, such as battery suppliers, battery recycling companies, and BAMCs.

Finally, as discussed in Part 5. The development of B2C BSM can continue to be reviewed from a dialectical perspective, and the costs of B2C BSM deployment, including economical, environmental and social costs, can be objectively and quantitatively analyzed. In addition, the government role and the competition hidden in supply chain collaboration could be added to the theoretical discussion of SCI literature in more cases.

Appendix

Interview Questions

Part 1: Pre-Interview Protocol



Part 2: Interview

General topics:

(About Nio BSM SCI process, same for all stakeholders, except consumer.)

Q1: Please tell me about your role in the company? What role does your company play in the B2C BSM supply chain.

Q2: We all know that BSM is a new thing, how did you increase your understanding of it before you approached it? did your company or other stakeholders provide any training and guidance?

Q3: Which supply chain stakeholders have you done business with and were you satisfied with this kind of collaboration with them?

Q4: In your opinion, what are the successes or challenging for Nio in achieving B2C BSM? Can you give some examples?

Q5: Do you have any other ideas to share with me about Nio's supply chain innovation?

Specific- Topics: (topics related to SCI contents appropriate to the stakeholders)

Battery Asset Management Company

Q1: How do you see Battery Asset Management's role in Nio's supply chain?

Q2: Do you think your joint venture background has an impact on the BSM supply chain, and how would you comment on such an impact?

Q3 What role does Battery Asset Management play in enabling Nio's battery leasing business?

Q4: How do you see your business evolving in the next 5 years in this area (i.e., BSS and with Nio)?

Nio Energy Services Operations Team

Q1: Could you please introduce the structure and functions of Nio BSS? Or any technology you find attractive and interesting.

Q2: For the current BSS design, do you think it can meet customers' needs for battery swapping? Why?

Q3: I found the new BSS design in your patent documents. What is your collaboration with other Nio supply chain stakeholders in this area? Is this process going well?

Q4: We know that Nio was the first company to offer BSM services to individual consumers. How do you see this pioneering role?

Q5: How do you think about BSS's service and operation process, and do you have any interesting experience or challenges that you would like to share?

Q6: How do you see your business evolving in the next 5 years in this area?

Battery Manufacturer

Q1: Can you give us a brief overview of your daily work, especially those business related to other Nio supply chain partners?

Q2: In your company's perspective, how do you see Nio's BSM and BaaS battery leasing model. How do you feel about the cooperation with Nio?

Q3: We know that you have formed a battery management company with State Capital and Nio, what is your role in it and how do you see this supply chain collaboration?

Q4: When the batteries are worn out or even scrapped, how will the battery recycler, which is also your subsidiary, handle them and how will it ensure their economic, social and environmental performance?

Q5: How do you see Nio's business evolving in the next 5 years in this area?

BSM Researchers

Q1: How do you see the battery leasing model and the application and supply chain development prospects of new players like Nio in this area of car manufacturing?

Q2: What is the impact of state-owned capital on B2C BSM? How do you see the phenomenon of Nio forming supply chain sub-joint ventures with companies in different sectors?

Q3: We know that Nio is involved in the drafting process of several national standards for BSM. How do you see the impact of these standards on China's electric vehicle industry?

Q4: What are the differences in supply chain innovation between an electric vehicle manufacturer like Nio and a traditional car manufacturer?

Q5: How do you see Nio's business (and this area) evolving in the next 5 years?

Consumers

Q1: Are you satisfied with the service of Nio BSM? Why?

Q2: Would you recommend Nio's electric vehicles to others because of the B2C BSM and Why?

Q3: Did you own an ICV before you bought Nio, and if so, which one did you prefer? Why?

Q4: How often do you go to BSS and which do you use more often, charging or swapping?

Q5: If there will be an improvement in Nio's BSM, which aspect would you most prefer to improve?

Informed Consent Form for Interviews

Research Project Title:

B2C Battery Swapping Model: A Supply Chain Innovation Perspective

Principal Investigator and contact information:
Lei Yi (MSc Student); Email: [redacted]

Research Supervisor and contact information:
Dr. Bruno S. Silvestre (Advisor); Email: [redacted]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Purpose of this Study

This research focuses on the Battery Swapping Model (BSM), a promising method for recharging electric vehicles (EV). Nio, an emerging EV producer, is one of the few companies working with B2C BSM. From the standpoint of supply chain innovation (SCI) theory, we'd want to learn why Nio selected B2C BSM and how such SCI has evolved. What are each supply chain member's innovation strategies and tactics, and how do they interact and work with each other?

The goal of this research is to learn more about B2C BSM's evolution and present state, as well as to improve industry and academic understanding of its supply chain innovation approach. Also, we hope to refine and conclude the SCI theory model suitable for BSM from a theoretical perspective, which also broadens the application boundary of SCI theory.

Interviews
In this qualitative study, one-on-one semi-structured interviews will be conducted (about 60 mins) via Zoom. You can choose any preferred time windows. A second interview may be arranged if needed. You are encouraged to stop the discussion for a break and have absolute freedom to terminate the meeting when you feel any discomfort. Please note that Interviews will be recorded by Zoom and transcribed for research purposes only. All videos will be deleted at the end of the data analysis (Around March 2022).

You will receive a de-identifiable document that PI summarize, transcribe, and encode via WeChat or email within a week after the interview. You will review the following: whether the transcribed information is accurate, whether existing any omissions or misunderstandings, whether there is information that could identify who you are, and any other comments you may have. You will

have one week to respond. If there is no response by the deadline, you may be contacted again. Your data will not be accepted by this study until given your permission. Please note that you have complete flexibility to withdrawal the study as long as it's before March 15, 2022, because after that, your personal participation data cannot be destroyed separately. However, if the decision to withdraw is made before this date, the research team will work with you to delete any data you produced, ensuring that you are not negatively impacted.

If you want, you will be provided a summary of research results via WeChat or email one month after data analysis, around April 2022. This summary will be brief, comprehensive, and written in simple, plain language for better understanding.

Benefits and Risks
This research has the potential to enhance your professional growth by enhancing your thoughts about BSM and EV supply chain innovation. Simultaneously, the progress of information brought forth by this study would broaden BSM expertise in academia and industry, thus boosting its market development. Please note that this research will not have compensation for your participation.

This study may also come with risks, such as negative consequences if you mistakenly share sensitive information about your company or business partner. We will warn you not to reveal any information that you deem sensitive before/during/after the interview to avoid such risks. Additionally, your identifying information will be coded in future research, ensuring your privacy.

Confidentiality
Only de-identified/coded information will be displayed in the final published publication, ensuring a better level of confidentiality and privacy. Also, your insight will be directly quoted by this exclusive code (like BAMC1, BM1, C1, NESOP1, R1). A list will be kept, which connects the coded name to your real name so that data may be re-linked if necessary. All de-identified and identified files will be deleted in May 2027. Before that, they will be stored in a secure UM OneDrive, with access only to the research team.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Research Ethics Board at the University of Manitoba, Fort Garry campus. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Officer at 204-474-7122 or HumanEthics@umanitoba.ca. **A copy of this consent form has been given to you to keep for your records and reference.**

(Participant) consent to video recording during the interview. [Tick required]

☐ Yes ☐ No

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