Betting on Chinese Electronic Cars?
– Analysing BYD's Innovation Capability

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Extended Abstract

The development of the Chinese automobile industry is accompanied by increasing pollution and energy dependency on imported fuels (Wang 2008a). Therefore, both foreign and local automakers and suppliers are venturing into the of new energy cars in aims of taking bigger shares of world's fastest-growing auto market – China.

BYD Company, Ltd. is the local leader in the production of hybrid and electronic cars. In a turbulent year 2008, the company received investment valued at $230 million from American tycoon Warren Buffett. On December 15, 2008, the company launched the first plug-in hybrid vehicle (PHEV), one year ahead of GM and Toyota. The prototype of pure electric car E6 was exhibited at the Shanghai International Auto Show in April 2009, and is expected to be sold in Europe in two or three years.

BYD has experienced three great leaps forward in less than fifteen years. Founded in 1995, the company quickly became the world second largest battery company in 2002, by producing 65% of the global nickel-cadmium batteries and 30% of the lithium-ion mobile phone batteries. After creating the affiliate BYD Auto in 2003, this Hong Kong Stock Exchange listed company started its production of conventional gasoline cars through the acquisition of a bankrupt state-owned automaker in China. The volume of sales was more than 193,000 units in 2008 despite the fact that most of its cars appear to have been based on imitations of best-selling Japanese cars. Also in 2008, BYD announced the commercialisation of the F3DM, a PHEV that was not dependent on a professional charging station. By pricing the F3DM at ¥149,800 ($21,700), this car was nearly half the price of the Toyota Prius (sold in China for about ¥280,000) with the similar battery technology. Thus, F3DM became the milestone of BYD's third stage of development – producing hybrid and electronic cars.

How can BYD achieve such significant results? This case study focuses on the company's innovation capabilities. BYD's success is based, first of all, on the breakthrough strategies by

the reinvention of its business model. After presenting the three stages of company's development, we then focus on three aspects of innovation capabilities: technology, organization and HR management. From the aspect of technology innovation, BYD managed to combine imitation and innovation for the design and production of batteries, conventional cars and electronic cars. Similarly to some other Chinese carmakers, innovation in product architecture is the clue to understanding the company's quick development (Wang, 2008b). From the aspect of organisational innovation, two of BYD's distinguishing features are high integration of its value chain (from R&D to component production to assembling) and its labour-intensive manufacturing organisation. The paternalism HR Management practices and intensive trainings demonstrate the unique capability of managerial innovation in BYD. This paper concludes with future perspectives and challenges of BYD vis-à-vis its global competitors, customers and governmental regulations linking with electronic cars. BYD's audacious corporate strategy is questioned as well.

Key words

Chinese automobile industry, hybrid car, electronic car, BYD, innovation capability

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1. Introduction

The world's first mass-produced plug-in hybrid (PHEV) was launched in December 2008 by BYD Auto, at least one year ahead of comparable offerings by GM and Toyota. BYD Auto also exhibited the prototype of its pure electric car, E6, in April 2009, and announced its anticipated commercialisation in Europe two or three hence. This carmaker is the affiliate of BYD Company Ltd, one of the global battery makers from China. Having embarked upon car production in 2003, the company has become the fifth carmakers to produce Chinese branded cars, producing 192,971 units in 2008, a year on year growth rate of 92.25%. It was also during the global financial crisis that American tycoon Warren Buffett announced his intention to invest $230 million in BYD in the autumn of 2008.

During 2008, the declining automobile giants contrasted markedly with the soaring of BYD. American carmakers experienced the greatest turmoil, and the U.S. government's emergency loan of $21 billion approved in 2008 could only partially relieve the deep-rooted problems of industrial development. European and Japanese carmakers, except for a few like Audi, also announced pessimistic forecasts in the coming years. Facing dramatic societal and economic impacts on scarce resources (such as petrol) and environmental protection, the "Big 6" are planning to shift from traditional gasoline cars to hybrids and electric cars, as a new way to revitalise and compete (Sachs, 2009). But why did Warren Buffett bet on newly emerged BYD for its future commercial success of hybrid and electric cars, vis-à-vis the giants at the edge of the abyss?

How can BYD achieve such significant results? This case study focuses on the company's innovation capabilities. BYD's success is based, first of all, on the breakthrough strategies by the reinvention of its business model. After presenting the three stages of company's development, we then focus on three aspects of innovation capabilities: technology, organization and HR management. From the aspect of technology innovation, BYD managed to combine imitation and innovation for the design and production of batteries, conventional cars and electronic cars. Similarly to some other Chinese carmakers, innovation in product architecture is the clue to understanding the company's quick development (Wang, 2008b). From the aspect of organisational innovation, two of BYD's distinguishing features are high integration of its value chain (from R&D to component production to assembling) and its labour-intensive manufacturing organisation. The *paternalism* HR Management practices and intensive trainings demonstrate the unique capability of managerial innovation in BYD. This paper concludes with future perspectives and challenges of BYD vis-à-vis its global competitors, customers and governmental regulations linking with electronic cars. BYD's audacious corporate strategy is questioned as well.

2 The BYD group – a great leap forward to the automobile industry

BYD has experienced three great leaps forward in less than fifteen years. Founded in 1995, the company quickly became the world second largest battery company in 2002, by producing 65% of the global nickel-cadmium batteries and 30% of the lithium-ion mobile phone batteries. After creating the affiliate BYD Auto in 2003, this Hong Kong Stock Exchange listed company started its production of conventional gasoline cars through the acquisition of a bankrupt state-owned automaker in China. The volume of sales was more than 193,000 units in 2008 despite the fact that most of its cars appear to have been based on imitations of best-selling Japanese cars. Also in 2008, BYD announced the commercialisation of the F3DM, a PHEV that was not dependent on a professional charging station. By pricing the F3DM at ¥149,800 ($21,700), this car was nearly half the price of the Toyota Prius (sold in China for about ¥280,000, or $40,580) with the similar battery technology.[1] Thus, F3DM became the milestone of BYD's third stage of development – producing hybrid and electronic cars.

Became giant in the world battery industry in seven years (1995-2002)

The BYD Company Ltd. was founded in 1995 for the production of rechargeable nickel-based (nickel-cadmium, NiCd) batteries. By July 2002, the company has become the world largest manufacturer in this business, by producing 65% of the global nickel-cadmium batteries. Its market shares in the NiCd business in several key industries were as follows: 75% in wireless phone (for fix phone line), 38% in toys, 30% in electronic hand tools, and 28% in the mobile phones. In seven years, the company also quickly became the world's number two maker of nickel metal hydride batteries (NiMH) and the number three maker of lithium ion (Li-ion) batteries (Kang and Ke, 2008).

The remarkable success in such a short time was greatly attributed to BYD's founder, M. Wang Chuanfu. Having started academic work in the Beijing Non-Ferrous Research Institute after completing a Master's thesis on battery technology in 1990, Wang captured the signal of business opportunity in 1993. He read an industrial report announcing Japanese companies' strategic shift from nickel-based rechargeable batteries to high value added NiMH and Li-ion batteries. According to Wang, the manufacturing base of NiCd battery could move out from Japan to somewhere else, for example China. After working as General Manager of Shenzhen Bi Ge Battery Co., Ltd between 1993 and 1994, Mr. Wang founded the Shenzhen BYD Battery Company Limited in 1995 with two partners by borrowing 250 thousand yuan (around US$36,200). It was under Wang's leadership and breakthrough innovation that the company achieved significant development. We will explain in details in the following sections.

For all three types of batteries, BYD was duplicating its key successful factor formulated by Mr. Wang: inventing a new manufacturing process so as to achieve significant low costs while maintaining quality. The capital intensive and highly automated manufacturing process of Japan was completely redesigned by Mr. Wang. Machines were replaced with manpower wherever feasible. To further reduce the price, BYD even produced some key machinery

[1] The exchange rate between Chinese RMB and the US Dollar is subject to fluctuation. To simplify the calculation, our convert rate is based on 1 USD = 6.9 RMB in 2008.

itself, rather than importing it from other countries. In the research and development (R&D) centre in 2005, two-thirds of total 20 engineers were dedicated on process design and the remaining one-third focused on battery chemistry (Huckman and Maccormack, 2007). Thus, the first assembly line of BYD for the production of 3000 to 4000 NiCd batteries a day only cost around one million yuan (US$144,930), while a similar line in Japan cost at least ten times as much. Furthermore, BYD's investment in equipment for the production of Li-ion batteries is 12 times less than that of its Japanese counterpart (Table 1). For example, the fully automated production line in the dry-room in Japan was converted into a highly labour intensive production line with partial dry room facilities on the manufacturing line. Even though the nominal productivity of BYD is 10 times less than that of a Japanese company (due to BYD's high number of employees), the unit cost of one battery is about 4 RMB less -- a big cost advantage compared to Japanese companies.

Table 1: Cost advantage of BYD at Li-ion battery

	BYD	**Japanese company**
Production capacity	100,000 units/day	100,000 units/day
Cost structure		
1. Salary		
N° of employees	2000	200
Monthly Salary	1500 RMB	23,600 RMB (328990 JPY)[2]
2. Equipment investment	50 million RMB	690 million RMB (100 million USD)
Annual Equipment Depreciation (in 5 years)	10 million RMB	138 million RMB (20 million USD)
3. Raw material	Similar	Similar
4. Overhead	N.A.	N.A.
Estimated unit cost of one battery	1 RMB	5-6 RMB

Source: based on Kang and Ke (2008).

BYD also find solutions to maintain quality consistency which had been affected by the increasing usage of manpower. Its first solution was to decompose the production process into numerous simple-skill labour operations. R&D people constantly revised the allocation of activities so as to further reduce the quality fluctuation educed by labour intensity. The second key solution was to use simple assisting devices like jigs. According to BYD, "labour plus jigs equals automation" (Huckman and Maccormack, 2007, p. 6).

This joint effort on cost and quality control contributed to the skyroking growth in two critical periods. During the Asian financial crisis in 1997, leading Japanese companies were in the red because the global market price of batteries decreased 20% to 40%. On the contrary, the sales of BYD increased 90% in that year. The same scenario happened in the internet bubble of 2001. Again the global price of Li-ion batteries was reduced 20-50%, but the sales revenue of BYD increased 50%, from 873 million yuan (US$ 127 million) in 2000 to 1305 million yuan (US$ 189 million) in 2001, thanks to its significant cost and price advantages.

[2] Based on the average monthly basic salary of Japanese workers in the manufacturing industries in 2008. From: http://www.chinahrd.net/zhi_sk/jt_page.asp?articleid=159899.

Table 2: BYD's Global Battery Market shares, 2002

NiCd		NiMH		Li-ion	
Manufacturer	Market share	Manufacturer	Market share	Manufacturer	Market share
Sanyo (JP)	36	Sanyo (JP)	49	Sanyo (JP)	28
BYD (CN)	31	Matsushita (JP)	17	Sony (JP)	19
Matsushita (JP)	17	BYD (CN)	8	Matsushita (JP)	16
Others	16	Others	26	BYD (CN)	9
				Others	28

Note: JP: Japan; CN: China. JP and CN represent the contry of origin of the company.
According to latest data, BYD has 65% global market share of NiCd batteries, and 30% of global market share of Li-ion cell phone batteries in 2008 (www.greencarcongress.com).
Source: Adapted from Huckman and Maccormack (2007).

The extraordinary success in the battery industry during this seven year period pushed Mr. Wang to contemplate his next strategic move. At this time, the world battery industry was still led by several Japanese giants. In the segment of NiCd battery, a mature technology, BYD had become the number two in 2002. However, the market power of Japanese counterparts in NiMH and Li-ion batteries was still overwhelming (Table 2). The technology gap between BYD and Japanese companies in these two segments was still wide. At this time, BYD also raised a fundemental question regarding its core competency. Did the core competency reside in the product (which is battery) or the capability of process engineering? Different answers would drive the company to different directions. The fact that BYD expanded its business to the passenger car production in 2003 points to their answer to this question.

Entering the automobile industry in 2002

The "sudden" idea on the expansion to the automobile industry was taken by Wang Chuanfu in January 2003, following the company's IPO (initial public offering) on the Hong Kong Stock Exchange in July 2002. In the IPO prospectus report published in June 2002, BYD only mentioned its intention to become the world second biggest battery firm, but nothing was disclosed about its intentions in the automobile industry. When Wang decided to acquire a Chinese automobile company, investors threatened to sell BYD's shares. Firstly, investors worried about the strategic change of the company that had not been disclosed before. Secondly, fund managers afraid of the dilution of competencies and a cash drain away from the company's battery business. Consequently, this affected the value of the shares. Nevertheless, Wang's entrepreneurial spirit drove him to expand the company's business into the automobile industry.

BYD acquired Shaanxi Qinchuan Auto Company Limited (Qinchuan Auto) on January 2003 as a way to get a licence for auto manufacturing. By 2001 and 2002, a total of 28 carmakers, including foreign and local companies were producing passenger cars in China. In order to rationalize this highly fragmented industry, the government made it impossible to enter this industry except through the acquisition of an existing mismanged player. BYD invested 250 million yuan (US$ 36.2 million) in Qinchuan Auto as its entrance fees into the China automobile industry.[3] Because of the obsolete technology and equipment, as well as limited capacity of expansion in Qinchuan Auto, BYD built a new manufacturing plant in the Xi'an Hi-tech Development Zone, located in the same province.

3 Qinchuan Auto, a state-owned enterprise, started small car production in 1989. The ALTO was produced under the licence of Japanese Suzuki, but ended in 2000. A new model FLYER, essentially the copy of ALTO continued its production with small quantities.

After two years of hard work, a brand new car, the F3 (C-class), made its successful debut. The F3 rolled of the assembly line on April 16, 2005. The 100,000th unit was produced on June 18, 2007, 20 months after production began. From April 2005 to February 2006, the company received numerous awards by different Chinese organisations. Meanwhile, a mid-size sedan, the F6 (D-class) entered production in August 2007. In 2008, the company also announced the commercialisation of the F0, a subcompact car (A0 class). In 2009, five new models are planned to be launched, including a subcompact F4, a MPV version of the M6, the F6DM, and the e6.

Before the financial crisis, Mr. Wang announced an audacious objective: to become the number one carmaker in China by 2015 and number one in the world by 2025, an unrealistic plan in the eyes of most current carmakers. Despite the financial crisis, the BYD group realised sales revenue of 28 billion RMB (US$ 4.1 billion) in 2008, a year-on-year increase of 32%, and paid 2.5 billion taxes (US$ 362 million). The growth rate of BYD's auto sales in the first three months of 2009 was 181%, an astounding success (Table 2). The company expects its 2009 sales to be double that of 2008, approaching the threshold of 400,000 units.

Table 2 BYD's car sales 2005-2009

	Vol. of production	Growth rate	Vol. of sales	Growth rate
2005	11236		11171	
2006	60135	435.20%	60116	438.14%
2007	100376	66.92%	100126	66.55%
2008	192971	92.25%	170882	70.67%
2009 (Jan.-March)	64895	123.34%	77821	180.55%

Source: BYD company.

The era of electric cars since 2008

BYD started the sales of F3DM, the first commercialised plug-in hybrid electric vehicle (PHEV) that does not need a professional charging station on December 15 2008. The sales of this type of hybrid vehicle were at least one year ahead of two automobile giants General Motors and Toyota. Priced at 149,800 yuan ($21,700), the model costs more than twice the basic gasoline model F3 (sold at 60,000 yuan, or $8,780), but still half the price of the Toyota Prius, sold in China for about 280,000 RMB (US$ 40,580). BYD foresees a price cut to 100,000 yuan ($14,636) when the volume sales take off and Chinese governments begin to offer consumer subsidies. The only current customers are institutions such as the Shenzhen municipal government and the China Construction Bank.

In addition to its pricing advantage over the big carmakers, the F3DM had also demonstrated some technical advantages. With a maximum speed of 160 kilometres per hour (99 miles/h), this "dual mode" car travels for 100 kilometres (62 miles) powered by battery, and then an additional 300 kilometres (267 miles) powered by BYD's own 1.0-liter gasoline engine (BYD371QA). Thanks to its breakthrough battery technology, the newly developed ferrous-based battery (FePO4) has the advantage on cost, capacity, and safety compared to the Lithium-ion battery. The battery pack can be fully recharged by an ordinary electricity outlet in nine hours. Using industrial charging equipment, it takes only 15 minutes to bring the capacity up to 80 percent. The company claims the of battery pack life 2,000 charge cycles and a range of over 600,000 km, or up to 10 years.

For these and other reasons, Warren Buffet demonstrated a vote of confidence in BYD's commercialisation of next-generation, environment-friendly electric vehicles, and battery technology in general. The American tycoon proposed to invest 1.8 billion HK dollars ($230 million) to acquire a 10 percent stake of BYD in September 2008. This would be Buffet's second China-based investment after PetroChina.[4] This transaction will take place via MidAmerican Energy Holdings Co., a subsidiary of Mr. Buffett's Berkshire Hathaway, Inc. Mr. Buffett commented in a press release (Ouyang, 2008):

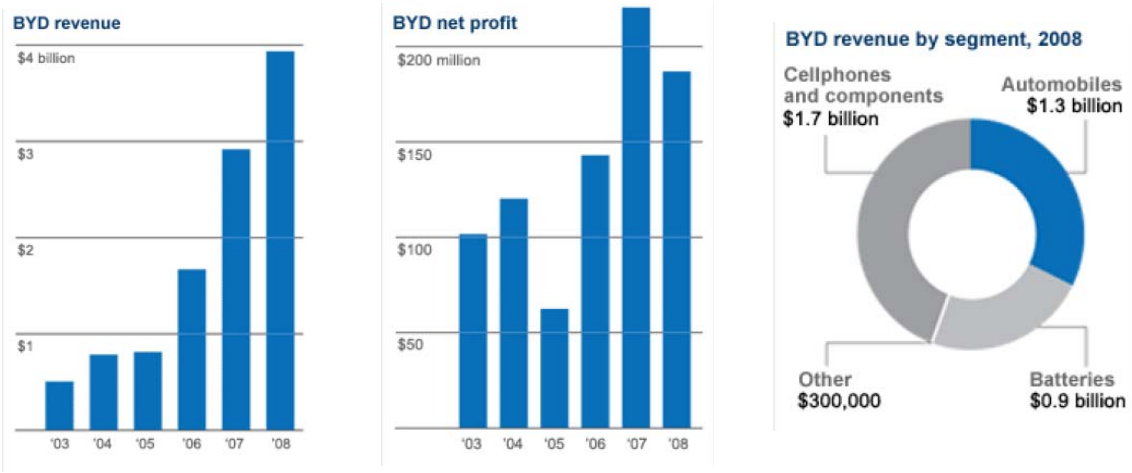
> "We are thrilled to be partners with BYD and the people of China. Mr. Wang Chuanfu has an extraordinary managerial record, and we welcome the opportunity to work with him,"

This investment signal is confirmed by David Sokol, chairman of MidAmerican (ibid).

> "As worldwide discussions relating to global climate change and environmental respect continue, the technologies being developed by BYD will be an integral part of the future."

BYD's breakthrough growth and technology advantage have led Buffet to bed on the future of the company.

Figure 1 BYD's business growth, 2003-2008



Source: Gunther (2009).

The essential: low price and fair quality as a clear customer value proposition

The success of BYD is based on a clear customer value proposition: low price and fair quality. This has helped BYD to win customers from its competitors. Taking BYD's car as an example, I will explain the details of its customer value proposition.

BYD's cars have answered three critical needs of one category of Chinese consumers. This category of consumers has a combination of three distinguished features on the acquisition of

[4] PetroChina (HK，0857) is the largest domestic oil company listed in Hong Kong market. Buffet totally invested 1 billion HK dollar in 2003 (US$ 128 million) for holding 6.7% of shares.

a car: as the Chinese middle class, they admire western sophisticated cars, they use the car as a symbol of their career success, but at the same time, they are highly price sensitive due to their lower purchasing power.

Accordingly, BYD has taken the following solutions. First, BYD's takes Japanese cars as a benchmark due to their commercial success in China; therefore, the "me too" strategy was less risky. Secondly, more attention has been paid to the design of the car. Not only did BYD simply imitate the Japanese models, but it also modified the perceived drawbacks of them so as to further increase the level of customer satisfaction. Thirdly, BYD cars are priced significantly lower than Japanese cars. For example, the F3 of BYD is benchmarked on Corolla model of Toyota (one of the best selling B class cars in China) but priced at 59.8 thousand RMB (US$ 8,667), 66% cheaper than the Corolla (EX 1.6G), priced at 114.8 thousand RMB (US$ 16,638). BYD used a similar pricing strategy for its F6 model, with a combined benchmarking of from the Toyota Camry and the Honda Accord. In 2008 BYD also benchmarked its F0 against the Toyota Aygo. As for quality, BYD also sweetened their offerings with a warranty good for five years or 100,000 kilometres. Surveys demonstrate that the costs of after sales repair of BYD car is also at least half of that foreign cars.

To fulfil its customer value proposition, BYD developed significant innovations in terms of technology, organization and HR management. In the following section, we will further study the details.

3. Technology innovation

Imitation through reverse engineering

From a technological point of view, BYD heavily relies on reverse engineering to produce its cars. The benchmarked cars are decomposed into components, then scanned and digitised by devices such as three dimensional scanning and related software. If the focal components are patented, BYD will make modifications, otherwise, components will be directly copied. Compare to the development of a brand new car which costs 2-3 billion USD, the advantage of reverse engineering is the low cost of R&D and short time to the market. The imitation of the best selling foreign models can also reduce the risks of market uncerstainty.

In fact, the choice of reverse engineering by BYD is also based on the failure of its experience in forward engineering. When BYD acquired Qinchuan Automobile, the company had designed a new car named F2 (internal code: 316) but it failed, due to its weak technology (WBR, 2007). This experience further confirmed the strategy of imitation by BYD. The president, Mr. Wang Chuanfu openly discussed the issue of imitation to the media: "I will not build a car starting from zero. We must produce the car based on the most advanced automobile platform in the world" (Zhu, 2008).

Creative imitation and heavy investment on R&D

At the same time, BYD's imitation is creative. As defined by Drucker (1985), the creative imitator also has the ambition of market or industry dominance but in a less risky way. Since the product and market has been accepted by consumers, the creative imitator only need

further improve some major problems made by existing leaders, and offer better products or services. For example, even though BYD's F0 is a based on Toyota Aygo, some designs such as the lighting system have been modified so as to make the car more appealing to Chinese consumers.

BYD's most significant technological innovation is in architectural change. Because BYD is not yet capable of producing its own engine, the F3 can be equipped with several Mitsubishi engines (4G18 model of 1.6L and 4G15 model of 1.5L, for example). This is an example of quasi-open product architecture in which the components of two close integral cars from different carmakers (Toyota Corolla and Mitsubishi engine) are combined, following the logic of mix-and-match. This creates a more open, modular design. The "quasi" refers to a transitional phase between close integration and open modular architecture design. While the mix-and-match method is common in the PC industry, it yet to be widely embraced at the automobile industry (Wang, 2008b). The general manager of BYD automobile sales company, Mr. Xia Zhibin foresaw the future competitiveness of BYD:

> "under the context of homogenisation of key modules like engine and transmission, the competition of new cars will probably only be on appearance and design. The highest stage of BYD's car production is to make the car body as easily changed as that for cell phones". (Zhu 2008)

From this point of view, BYD is contributing to the architectural transformation of passenger cars in China. The future trajectory of car architecture also partially depends on the evolution of leading Chinese carmakers like BYD, Chery and Geely, among others. For example, since BYD has the intention of high vertical integration, if BYD massively internalises the production of those key modules, then the product architecture will re-orient to closed modularity. But if BYD continues to count on external suppliers such as Mitsubishi and Delphi, the quasi-open product architecture will be emerge and crystallize in China. In this process, leading tier-one foreign component suppliers can also play critical roles in the architectural change.

This type of innovation is beyond "creative imitation", and it can even be identified as the "breakthrough innovation", since it can have a significant impact on carmakers, suppliers, and eventually the whole automobile industry. The carmakers can achieve considerably lower costs. Component suppliers can explore bigger economies of scale supplying the same components to different carmakers. In return, the number of players in the industry will also increase because of lower barriers to entry. If the quasi-open architecture becomes crystallized, we can foresee a Chinese automobile industry with much bigger number of players in the forthcoming ten (or even twenty) years. The path of consolidation will be much longer than that of automobile industries in western countries in the early 20th century.

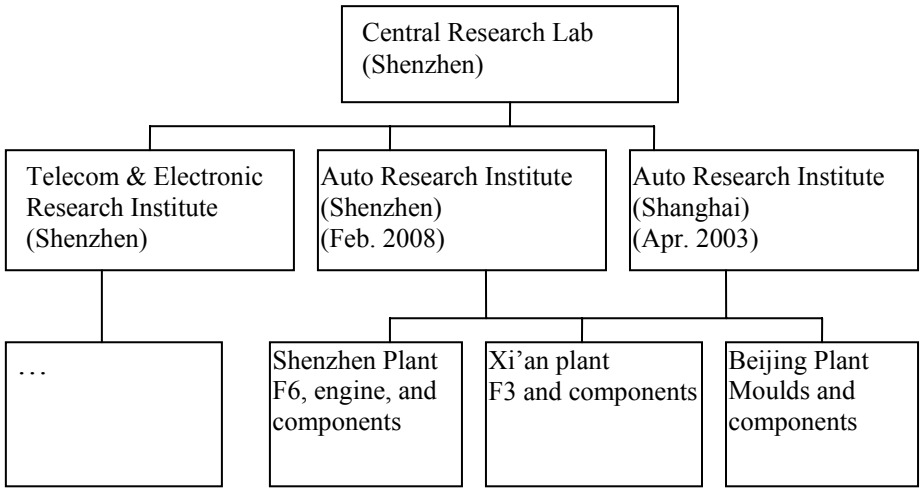
To realise both the imitation and innovation, BYD has heavily invested in R&D. Its R&D system is composed of three levels (Figure 2).

The central research lab (CRB), positioned at the highest level, is located in Shenzhen, and is responsible for basic and comprehensive research. There are three industrial research institutes under the management of the CRB. One is in the field of the Telecom & Electronic Industry, another two are in the automobile industry.

The automobile R&D centre in Shanghai was established in April 2003 with 3000 employees. The newly established Shenzhen Auto Research Institute was inaugurated in February 2008 with 5000 employees. This institute has the capacity to host 13,000 employees, among which 2,800 will be R&D people in the future. This institute has several centres, including automobile engineering, auto and component testing, electronic vehicle, etc. BYD has the ambition to build the biggest automobile R&D centre in China. These two institutes at the second level of R&D are more focused on product development, and in particular, volume production and industrialisation of new products.

The third level of R&D is positioned at the manufacturing plant level. Each workshop has a division of R&D, focusing on detailed technical issues on the manufacturing line. This three-layer R&D organisation has highly integrated basic research, applied research and on site application. In addition, each level of R&D institute has its objective of patent application, which incentivizes constant innovation.

Figure 2: BYD's R&D centres



Source: Yu (2008)

BYD has not only defensive but also offensive actions on the intellectual property rights (IPR). Each project of new car development has the participation of several legal persons specialized in IPR. Based on the database of patents, these specialists will inform the status of patent registration of those technologies being investigated. If the technology is patented, solutions of technology modification should be worked out for avoiding the risks of IPR infringements. If the technology is non-patented, it will be applied directly. Wang Chuanfu also clearly stated in an interview:

> "For a development of new (car) product, in fact 60 percent (of technology) comes from public literature (without patents), 30 percent comes from samples, 5 percent comes from raw materials, etc., the own research only rests on around 5 percent. We widely use non-patented technology, and the integration of non-patented technology becomes our own innovation. We should respect intellectual property rights, but we can also avoid the usage of patented technology." (Xing, 2009)

The patent team, composed of more than one hundred researchers, also actively helps BYD apply its own patents. In 2006, there were around 200 design patents, including both car design and important parts, such as lighting systems, making the cumulated number of patents applied for by BYD reach more than 1100. In 2007, the number of patents in BYD increased by 30 percent, and the expenditure on patents application and maintenance doubled that of 2006, which was RMB 10 million (US$ 1.45 million). Patent applications in the field of electric and hybrid cars in Europe, the USA, Korea and Japan have reached more than 700 by the end of 2007. In the following section on HR management, we will explain how the generation of patents is stimulated.

4. Organizational innovation

It is still too early to define the "BYD production system (BPS)", but it is worth an investigation into its innovation in process engineering so as to understand the achievement of its breakthrough strategy. In the battery business, BYD successfully converted this capital intensive industry into labour intensive industry by re-inventing the manufacturing process. BYD tried to optimize the inputs and combination of inputs (labour, machine, capital) in the Chinese context. This production system innovation has given BYD a significant cost advantage over incumbents, and an enduring competitive advantage. This is what Johnson et al. (2008) described as one important step of formulating a successful business model: identifying key resources. -. When BYD entered the automobile industry, the company applied the same model of production system.

Optimizing the combination of inputs

BYD has modified the four main operations of manufacturing process – pressing, welding, painting, and assembling so as to reduce the costs. In the assembly line, BYD uses a labour-intensive approach. Specific machinery is replaced by standardized machines to avoid the technology dependence on suppliers. This is a way to avoid high transaction costs entailed by "specific assets". Highly automated machines are replaced by semi-automated machines. In addition, imported machines are replaced by machines produced in-house. For example, the painting line from German company Dürr costs more than RMB 100 million (US$ 14.5 million). The in-house line with the similar function costs only RMB 30-50 million (US$ 4.35-7.25 million). The above changes rely on an increased usage of labour.

This kind of optimization on the process engineering is based on the deep understanding of BYD's strength (low labour costs) and weakness (shortage of capital) in the Chinese social and economic context. BYD has also demonstrated its strong capacity to convert its constraints into new business solutions and enduring competitive advantages. The company

does not take the western model of production as a given condition, but proactively thinks about the optimal usage of human resources in China, and reduction of the usage of capital intensive equipment. However, BYD is also aware of the impact of quality after the modification of input between labour and machinery. To keep the consistency of quality, the company provides a lot of training for workers and invents special tools such as jigs.

High level of backward integration

Another significant difference between BYD and the mainstream carmakers is BYD's strong tendency of backward integration of component and mould production. At least 70percent of components are produced by BYD's different business units. Taking the example of F3, F6 and F0, except for tyres, windscreens, and those standardized components, around six types of components (with 42 varieties) are produced by different business units located in different cities (internally coded as the 11th, 13th, 15th and 16th business units, respectively). The following list is not exhaustive: steering system, shock absorber system, lighting system, fuel tank, interior parts, harness, radiator, condenser, seat, breaking system, door, chair and headrest, wiper, indicator mirror even CD and DVD player (CBU 2009).

In the Pingshan plant located in Shenzhen, some components traditionally outsourced by other carmakers are produced internally (Table 3). Even a power generation station was constructed to ensure a stable supply of electricity. Mr. Lin Hongye, Director of the Integrated Business Office, Central Research Institute, explained:

> "The costs of in house small volume production are equivalent to the price of external purchasing. But the significant advantage is the speed of reaction. If we buy from the outside, the coordination costs will be higher, and we may miss some market opportunity (WBR, 2007).

Table 3 High degree of backward integration – example of Pingshan Plant

Function	Total M²	Description
Assembling	West part	
Pressing	44100	5 pressing lines, for F series cars.
Welding	53424	Using in-house designed welding fixture
Painting	N.A.	The same layout as that of Shanghai Volkswagen
Assembling		Two assembly lines of 500 meters long, Current annual capacity: 100,000 units/year; future capacity: doubled.
Components	East and Middle	
Plant N°	Total M²	Products
Plant N°1	34,000	Interior and exterior decoration, front and rear bumper
Plant N°3	N.A.	East zone: painting of bumper. Middle zone: plastic components of interior and exterior decoration, West zone: assembling of door sheet and dash board, production of trunk, inner panel, rear deck, luggage compartment, and floor mat.
Plant N°5	23,000	Plastics for auto electronics, fittings and hardware
Plant N°19	40,000	Airbag, air conditioning, electronic components
N.A.	38,000	Engine of BYD (371 model for example)
R&D and management	North West	
"hexagon building"	120,000	Composed of three auto R&D centres: Auto Engineering Research Institute , Auto and Component Testing Centre , Electric Car Research Institute » and administrative function. Total capacity of hosting: 13,000 employees, among which 2,800 R&D personnel.

Logistic	East and West	
Power station	N.A.	Power generation station, 12,000 KW/ hour.
Living area for staff	N.A.	Total host capacity: 50,000 employees. Including: dormitories, canteens, shopping etc.

Source: Introduction on BYD Auto at Pingshan, Shenzhen.
http://auto.tom.com/2007-08-09/0D57/11104949.html, in Chinese, viewed March 15th 2009.

In addition to these components, engines and transmission systems, BYD has further expanded into mould design and production. According to a local automobile expert, the cost of the mould represents one third of the car. Counting the units of inspection, technical equipment, and jigs related to mould, the total value would be more than half of the complete car. Therefore, BYD acquired one mould company in Beijing right after its acquisition of Xi'an Qinchuan automobile in 2003. In less than five years, this business unit (labelled as N°12 business unit) has become one of the biggest auto mould companies in China. Its cost for producing the mould is 70 percent less than that of imported moulds.

BYD has also stressed the importance of establishing its own manufacturing facilities for the production of components and car assembling. For example, all the manufacturing equipments for the hybrid car F3DM were internally produced by BYD.

This production model of high vertical integration is similar to that of BYD's battery business. BYD believes this model can contribute to cost savings, quality control, and a reduced time to market. By comparison, in the Japanese battery industry, the manufacturing facilities are outsourced. The time span between delivering the technical requirements to the delivery of manufacturing facilities is 2 to 3 years. If the life cycle of the product is short, then advanced technology may become obsolete before manufacturing equipment is delivered. Based on this observation of the Japanse battery industry, BYD decided to take an approach of high vertical integration. In this manner, the costs can be significantly lower and time to market can be much faster. Details of the "BYD Production System" have not yet been disclosed by the company, but BYD has expressed full confidence in the advantages of its cutting-edge production system (CBU, 2009).

In my opinion, BYD has duplicated this pattern of high vertical integration from its battery business to the automobile business because of the current technical constrains. For traditional cars, BYD has changed the product architecture to a quasi-open modular type. Due to the nature of imitation but also modification on the design of components, small quantities of those "particular" components are too expensive for suppliers to produce. Therefore, BYD was obliged to internalize its production. For electronic cars, the industrial standards have not yet established. A high level of vertical integration can ensure the quality of breakthrough products and help BYD to maintain its competitive advantage. In the middle and long run, if those technical conditions evolve, the high vertical integration of production will subject to modification.

5. HR management innovation

By the end of 2007, BYD employed more than 120,000 persons, among whom 100,000 were workers and 10,000 were engineers. The labour costs represented around 12.5% of total revenue. BYD's long-term plan is is to have 300,000 to 400,000 workers and 30,000 engineers.

BYD has also taken full advantage of its labour cost advantage in China to launch R&D and technology innovation. For example, the salaries of R&D people in China are at least 5 to 8 times less than that in western countries. In addition, a high labour usage in China entails higher flexibility to the company.

When it begins production on a new model, rather than buying completely new manufacturing equipment, BYD relies on retraining workers and partial modification of existing production lines (Luo, 2008). This decreases the cost of new model introduction and allows for a faster time to market.

Systematic training

To guarantee the productivity and quality of production, BYD has implemented a system of training. During the last several years, around 5,000-8,000 graduates were recruited each year by BYD's different business units. The first training module is a two-week orientation, including the introduction of company's mission, development and planning, basic skills like business communication, and career planning. After new employees join their intended business units, the second module is more specifically oriented to the particular skills requested by each business unit. The third module is compulsory annual training. Each course is composed of 1 or 2 credits, and each employee is required to complete a minimum of 48 credits annually. The choice of courses is based on each individual's job function. In addition to these three modules, each business unit also proposes its own training courses which are free of charge to the employees. Employees are free to decide whether to participate.

Engineer: The culture of risk taking, new games

To achieve the breakthrough technology, Mr. Wang Chuanfu deliberately employs fresh graduates. He believes that the "blank slates" are more easily trained according to the needs of company. Corporate culture is comparatively easy to be adopted. After several years' stay in the company, junior talents may be channelled toward higher level positions. For example, among 3,000 automobile engineers in BYD's Shanghai Automobile Research Institute, 90 percent graduated after 2004. Without a deep background in automobile production, these young engineers are not constrained by the "mainstream", and are thought by the company to be more open to breakthrough ideas. Young talents are encouraged to take risks, participate in projects, and access core technologies from the beginning of their employment with BYD. As for senior management, among the seven vice presidents directly under the supervision of Mr. Wang, the majority started the careers at BYD after their graduation from university (Fan, 2009). As commented by Mr. Wang Chuanfu:

> "BYD not only builds products, but it is also good at building people, converting university gradutates into engineering teams. BYD recuruits several thousands of granduates, because we know the manufacturing of cars starts with manufacturing of talent, then equipment, then cars. We need not only ten talents, but ten thousand, so we must have the capacity to convert graduates into talent" (CBU, 2009).

Worker: from single skill to multiple skills by job rotation

In line with the production process, tasks are decomposed in such a way that each worker only uses simple skills to accomplish it. This is to ensure the minimization of quality variability. At the same time, to compensate for the monotony production work, and to reduce the turnover rate, the company offers the opportunity of job rotation. Workers who are making progress and demonstrate their capacity of team management can be promoted to the role of production supervisor.

According to observation, there is not yet a unified corporate culture for workers and engineers. For the workers, BYD stresses discipline. Some training is similar to a military approach. For example, workers are required to walk in line while being on or off duty and when entering the canteen. The company is also aware that this management style can not be applied to engineers and managers. They should be motivated and driven by the vision of the company (Fan, 2009).

A complete welfare system

To retain talent, BYD has heavily invested in its own welfare system, including certain activities that are normally the responsibility of the government. According to the staff hierarchy, employees have access to dormitories or apartments at prices significantly below market. Since most of employees were recruited all over the country, BYD has built education systems from kinder garden, to middle schools and vocational colleges, so as to retain employees by solving their family concerns.

Furthermore, the company has invested in canteens, convenience stores, and sports and recreation complexes for employees. All of these facilities have constructed by BYD at locations within close proximity to the company. Employees are able to access these facilities by walking or by bicycle. Since the company is located in an industrial park, far away from downtown, these services are able to greatly reduced the logistic concerns of employees and thus keep them focused on their work.

In addition to the above benefits, the salary range for young graduates and scientists is between 3,000 and 6,000 RMB. For example, the average salary for young graduates after their internships was about 3,500 RMB/month in 2008. There are opportunities for (merit-based?) salary increases every half year. Compared to foreign competitors, this salary package, including the benefits, is still much less expensive. It explains how BYD is able to achieve significant cost saving from recruiting talent with the similar competencies.

The above measures of intensive training, with differing focus on engineers and workers, and a high level of social welfare, demonstrate a “people centred” value creation by BYD. However, some workers have complained about heavy workloads. Though their absolute salaries are higher than those of other companies in the same region, employees worked 12 hours a day, and only had 2 days off per month until late 2008. The extra working hours were not compensated according to the company’s policy. This working load is higher than the average of industry level.

6. Impact of financial crisis

Even though BYD has continued to grow during the period of financial crisis, its profitability has not escaped impact. For example, the 2008 revenues of BYD Electronics, a Hong Kong listed affiliate, (0285，HK; http://www.byd-electronic.com), and the origin and foundation of the company's business, increased by 48 percent over that of 2007, reaching 8.56 billion RMB (US$ 1.24 billion). However, its net profit was decreased by 30 percent to RMB 765 million (US$ 110.87 million). This was still a remarkable result, compared to that of its competitors. It was the fruit of strategic shifts in the following fields:

- In the business of cell phones, the company increased the production of complete cell phones, to compensate for the slow growth of cell phone components. In 2007, the divisional revenue of cell phone components was 67 percent of total revenue, and complete cell phone was 33 percent. In 2008, the proportion changed to 55 percent and 45 percent, respectively. Key customers like Nokia, Motorola and Samsung reduced their contracted amounts, but BYD managed to identify new local customers from China.
- BYD further expanded its business scope from batteries and cell phones to "3C" (computer, communication and consumer) products. To compensate for the slow down of the global cell phone market, BYD decided to penetrate into the fast growing netbook segment (competing with the lies of Asus Ecc PC, Acer Aspire One ; Lenovo S10. etc.). BYD has the ambition to become one of the leading producers of 3C products.
- The company also expanded its manufacturing facilities from China to overseas. BYD Electronics started production in Chennai, India after completion of phase I construction in 2008. In Feburary 2008, one Korean invested factory located in Hungary was acquired by BYD for 15.5 million euros. The production restarted in the second half of year of 2008. BYD aims to build a global supply network for leading and emerging cell phone companies coming from India, China, and Eastern Europe.

Despite the strategic shift, employees of BYD in China still experienced negative impacts of financial crisis.

- First, the working hours were cut. Compared to the extra work during weekends, and only two days off per month that were common before late 2008, employees were obliged to start taking Saturdays and Sundays off 12 December 2008. This measure could help BYD save at least 10 million RMB (US$ 1.45 million) per month (based on the calculation of 500 RMB extra pay/person/ month (US$ 72.5), and 20 thousand employees).
- Second, the salaries have been cut by an average of 6 percent.
- Third, a non-paid one-month holiday at some business units such as batteries, cell phones, micro electronics, and automobiles, has been implemented. According to one employee of N° 1 business unit (NiMH recharging battery, print circuit board, and cell phone charger), about 30% of staff from the plant, or more than one thousand people, were asked to take the compulsory holiday.
- Fourth, newly recruited employees and employees of below G grade (BYD classifies employees from the top to bottom in grades from A to I), will have a higher possibility of being laid off.
- Fifth, new recruitment of low skill employees was stopped.

Mr. Wang Chuanfu has been proud of BYD's labour intensive model of production, and has identified it as one of the company's core competencies. In the Asian financial crisis in the late 1990s and the IT bubbles in the 2001, it was this strategy that helped the company achieved significant low costs and thereby surpassing their Japanese competitors. However, during the current unprecedented economic downturn, this BYD model has been much less effective than before. If the whole industry is unable to quickly recover from financial crisis, a massive restructuring of BYD production model may be required. Therefore, the macro-economic environment can also be one important factor that determines BYD's production model.

7. Future perspective and challenge

In less than 15 years, BYD has achieved marvellous results both in the battery industry and the automobile industry, among other businesses. There are at least three attributes to the unique innovation capability of BYD: (1) innovation in the production model by optimising the combination of technology, labour and machinery in the context of the Chinese economy; (2) innovation in the boundary of the firm, by highly vertically integrating the value chain; (3) innovation in HR management, including the intensive training, complete welfare, and also challenges offered to young management and engineering teams.

The ability of BYD to catch up to many of its competitors, both in the battery industry, and in producing both gasoline and emerging electric cars, has important implications for the "mainstream" carmakers in developed countries. Companies should constantly innovate, not only at the incremental level, but also at the radical level. BYD's innovation is not only at the product level, but it is also accompanied by breakthrough innovation in its production model, its manufacturing process, and its highly integrated value chain. BYD demonstrates that carmakers should not wait until a crisis to launch radical changes.

However, BYD is also confronting various challenges in the automobile industry. Main competitors of electric cars like Toyota and GM have much bigger sales volumes, and their technologies are also more mature. Local Chinese carmakers such as Chang'an, Chery, Lifan, and Hafei, are speeding up production of hybrid or electric models by purchasing batteries from local or foreign suppliers. New arrivals like Valeo and Michelin are jointly working on electric power train systems. Despite economic and social benefits of electric cars to China, the Chinese government has not yet established clear incentives for car manufacturers and consumers. The battery charging station is far away from widespread construction. This pushes BYD's electric car to western countries, where the preferential policies for green cars are more advanced. However, BYD plans to meet strict norms and standards of European and North American countries, but efforts to meet these standards have delayed the introduction of BYD's product to those markets.

At the corporate strategy level, BYD is facing the delicate balancing act between diversification and concentration. Behind the current success of BYD's automobile business, there is potential risk to its sustainable growth. By the end of 2008, more than 70 percent of BYD's auto sales relied on a single model, the F3. The newly commercialised F6 and F0, which both debuted in 2008, have not yet achieved market success. Market shares of hybrid

and electric cars are still marginal both in China and in overseas markets. BYD is still a small player compared to the giants. In the IT business, BYD also has ambitious plans of expansion, from a supplier of batteries and cell phones to one of computers, communication and consumer products. BYD's manufacturing sites are also expanding from China to India and Eastern Europe. Such a wide expansion of business, as well as a significantly high level of vertical integration in each business may dilute its precious capital and core competency.

In the period of global financial crisis, BYD's previous expansion strategy probably needs to be revised because of the significant market change. Can BYD's production model be sustainable in the long run? Even gigantic companies like Microsoft and Dell in the IT industry, and General Motors and Toyota in the automobile industry have not successfully achieved high vertical integration. Mr. Wang Shufu clearly has audacious ambition and will not easily give up "Building Your Dream" (BYD). There is a question as to whether BYD is fully aware of the potential risks and pitfalls due to the current economic turmoil, and whether it can re-identify its core competency of future growth. However, I do not believe that American tycoon Warren Buffett's investment to BYD is a blind bet.

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