ISCTE Business School
Instituto Universitário de Lisboa

The Choice of Technological Innovation Modes:
A Multiple Case Study in the Green Lighting Industry in China

TAN Guoyi

Thesis submitted as partial requirement for the conferral of

Doctor of Management

Supervisor:

Professor Virginia Trigo, Associate Professor, ISCTE University Institute of Lisbon

Co-supervisor:

Professor LI Shiming, Professor, University of Electronic Science and Technology of China, School of Management and Economics

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Declaration

I declare that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university and that to the best of my knowledge it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed Tan guo yi Date April 30. 2013

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作者签名： 日期： 2013年4月30号

姓名(拼音) Tan guo yi

Abstract

Since the beginning of the 21st century, the human living environment has been increasingly facing serious challenges. Energy-saving and environmental protection has become the theme of the era. Worldwide governments and enterprises work on the effective policies and measures that are jointly committed to the use and development of clean energy. In the 12th "Five-Year Plan" (i.e. The National Economic and Social Development Plan between 2011 and 2015) the Chinese government makes it clear that the energy saving and environmental protection industries will be the priority for its development.

The green lighting industry is the new wave of energy saving and environmental protection industry. Due to its long industrial chain and comparatively less capital investment, the industry has attracted a large number of start-ups. According to statistics, the majority of enterprises in the industry were established less than ten years. The emerging entrepreneurial enterprises play an important role in the green lighting industry. However, the technology of green lighting is not mature yet. The competition of the industry is highly strong due to the fast changing market and demanding performance of the products. Against this backdrop, it is an inevitable requirement to strengthen and emphasize technological innovation.

Based on the reality of green lighting industry, this thesis aims to develop models of technological innovation for entrepreneurial enterprises facing resource and capability constraints. Taking Grand Technology Co. Ltd, Kingsun Optoelectronic Co. Ltd and Sanan Photoelectrical Co. Ltd as the cases for the study, we focus our research on the competition environment of green lighting industry and identify the characteristics of entrepreneurial enterprises and technological innovation models. We then construct a theoretical framework for the selection of technological innovation of entrepreneurial enterprises with resource and capability constraints. The research adopts a multiple case study method to study representative companies of green lighting industry and finds the differences in the innovative selection under different resource and capability constraints.

Key words: entrepreneurial enterprise, resource, capability, technological innovation, China

JEL: M1，O3

Resumo

Desde o início do século XXI que o meio ambiente tem vindo a enfrentar desafios cada vez mais difíceis e que a necessidade de proteção ambiental se tornou no tema da época designadamente através da poupança de energia. Os governos e as empresas de todo o mundo trabalham no sentido da promoção de políticas e medidas destinadas à utilização e desenvolvimento de energias limpas e, no seu 12º Plano Quinquenal (i.e. o Plano Nacional de Desenvolvimento Económico e Social para o quinquénio 2011 - 2015), o governo chinês torna bem claro que será dada prioridade ao desenvolvimento de indústrias no ramo da poupança de energia e proteção ambiental.

Neste âmbito insere-se a indústria da iluminação verde pelo seu impacto na poupança de energia. Nos últimos dez anos esta indústria tem atraído um número elevado de empresas nascentes devido à extensão da sua cadeia industrial e às necessidades de investimento relativamente reduzidas pelo que são empresas no seu estádio empreendedor que desempenham um papel importante na indústria da iluminação verde. Contudo, a tecnologia não está ainda suficientemente madura e a concorrência é muito intensa devido à elevada dinâmica do mercado e às crescentes exigências quanto ao desempenho dos produtos sendo inevitável reforçar e enfatizar a necessidade de inovação tecnológica.

Baseando-se na realidade que a indústria da iluminação verde apresenta, esta tese pretende analisar e propor modelos de inovação tecnológica para empresas empreendedoras que se confrontam com escassez de recursos e de competências. Para tal foram estudados os casos das empresas Grand Technology Co. Ltd, Kingsun Optoelectronic Co. Ltd e Sanan Photoelectrical Co. Ltd procurando-se identificar e analisar as características destas empresas e os seus modelos de inovação. Através desse estudo procurou-se depois apresentar um modelo teórico para a seleção de inovação tecnológica por parte de empresas que se debatem com restrições de recursos e competências. Esta tese adopta o método do estudo de caso múltiplo e, focalizando-se em empresas representativas do fenómeno a analisar, foi possível encontrar diferenças no modo de seleção da inovação tecnológica em função das restrições de recursos e competências de cada empresa.

Palavras chave: empresa empreendedora, recursos, competências, inovação tecnológica, China

Classificação JEL: M1，O3

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Chapter 1: Introduction

This chapter deals with the background of the study, which explains the necessity to promote innovation in Chinese lighting industry. As China's economy has been developing very fast in the past three decades and will be expected to grow in a fast pace, a sustainable energy supply will be a great challenge to the economic development and wellbeing of the people in China. Energy-saving technology application in terms of lighting industry has drawn more and more attention from the government, academics and industry. Seeking appropriate models for different types of innovation in the green lighting industry appears to be more strategic than ever before. Chapter One introduces the current situation of China's energy consumption and analyzes the importance of taking strategies to save the energy. Among the important strategies, developing energy-saving lighting technology becomes the vital solution to the energy problem of China.

1.1 Research background

1.1.1 The significance of saving energy and protecting the environment

(1) The energy crisis and environmental protection has become a worldwide problem.

The development and progress of human society depends on the energy consumption. In particular, since industrialization began, the global demand for energy is growing. To date, the energy that human beings can utilize is mainly oil and coal-based fossil resources. As non-renewable resources, these energies will be depleted sooner or later. According to the analysis of International Energy Agency, despite the emergence of a variety of alternative energy technologies to meet the global demand, countries have used the energies in a more efficient way. However, in the next decade, global demand for fossil fuels will continue to grow and occupy a major position in the global energy structure in a long run.

The global energy consumption grew by 2.5% in 2011, among which China accounted for 71% of incremental global energy consumption. Global energy growth was on a par with the historical average but much lower than the 5.1% growth in 2010. All net growth was from emerging economies and the growth rate reached 5.3%. However, the energy demand by

Organization of Economics, Cooperation and Development OECD（The organization for economic cooperation and development) countries declined by 0.8% for the third time in the past four years, among which Japan decreased sharply. Oil is still the main source of energy, accounting for 33% of the global energy consumption. Oil, gas, coal and other conventional energy sources dominate. According to the analysis report of BP, it is predicted that the world's oil is only enough for 54 years of exploration, natural gas for about 64 years, nearly 112 years of coal at the present energy consumption level[1]. In a long term, human beings must seek new sources of energy. So the new energy industry will be vigorously developed.

In the context of high energy consumption, the environment has been faced with great challenges: environmental pollution, unbalanced ecology, global warming. Due to global warming, the sea level has risen 10 – 20 centimeters. If the sea level rises two meters, Los Angeles would disappear in the sea; if it rises six meters, Shanghai would disappear[2]. Global warming has seriously affected the sustainable development of human society.

Global warming can be mainly attributed to the greenhouse effect caused by the emission of CO_2 during industrialization process. At present, the energy resources are mainly chemical energy resources, such as coal, petroleum and natural gas. According to the statistics released by international energy institution, the carbon emission in 2011 has reached 31.6 billion tons with an increase of 3.2% over 2010. The carbon emission has increased quickly in China, India and other emerging economies.

Greenhouse emissions have caused global warming, which has drawn widespread concern in the international community. Addressing global climate change, saving energy, reducing consumption has become an imperative. In December 1997, the Third Conference of the Parties of the United Nations Framework Convention on Climate Change (hereinafter referred to as "the Convention") was held in Kyoto, Japan. Representatives from 149 countries and regions agreed on the Kyoto Protocol designed to limit emissions of greenhouse gases from developed countries to curb global warming. On December 7th, 2009, the conference themed “Can climate change save the earth, and how to save the earth?" was held in Copenhagen where the countries present have reached consensus that by 2050 the worldwide emission will be reduced to half of that in 1990. A decision to start the second phase of "Kyoto Protocol" and to launch the project of the Green Climate Fund was made at

[1] BP Statistical Review of World Energy June 2012

[2] Yang Xuexiang, Correct Understanding of the Consequenc of Sea Level Rising, Guangming Website, on June,9 2010

the Global Climate Change Conference held in Durban, South Africa, form November 28 to December 9, 2011.

The negotiations on World Climate Conference have been very difficult, and all countries, especially the developed countries and the developing countries, criticize each other and the conflicts between them have been constant, which is in fact the fight for the social and economic interests of their own countries. For a long time, the economic development and energy conservation can not be balanced worldwide.

(2) Difficulties in balancing the energy crisis and the economic and consumption growth in China.

China has become the world's second-largest economy and is also the second largest energy consumer. Though it is enjoying rapid economic growth and great achievements in the construction of its process of reforms, it has also paid a big price in resources and environment. The conflicts between economic development and resource consumption and environmental protection have been intensified and people complain severely about the environmental pollution, which could be the consequence of unreasonable economic structure and extensive mode of growth. Therefore, if we do not accelerate restructuring the economy and modifying the growth mode, the resources will soon run out and the environment will break down; hence the economic development can not be sustained.

In fact, during the period of the eleventh "Five-Year Plan"3, due to the energy crisis 10% -12% of the enterprises could not operate normally for the insufficient electricity supply. Every year, at the peak time of electricity consumption, in a number of regions, electricity limit is imposed on both residents and enterprises. In the future, Chinese economy still needs to develop; however, under the enormous pressure of energy saving and emission reduction, we must modify the current mode to seek for a more scientific way to development.

As a developing country, China is at an important stage during which industrialization and urbanization are speeding up. As a result, China is faced with a larger population, resource and environmental pressures, and higher energy consumption. In 2011, the total energy consumption in China reached 3.48 billion tons of standard coal, which has become

[3] The “Five-Year Plan” is a part of China national economic plan which is mainly about the key national construction projects, production force distribution and important proportional relations of the national economy. It sets the goal and direction of the national economic development. The first “Five-year Plan” was started from 1953 and eleven “Five-year Plans” have been made so far. The eleventh one was implemented between 2006 and 2010. At present the tweleveth “Five-Year Plan” (2011-2015) is being implemented.

the world's first largest energy consumer. In recent years, the energy consumption growth has kept about 5%, higher than the world average and the OECD countries4. China's energy consumption has increased every year in the world's total energy consumption. With China's economic growth, the shortage of China's energy is growing. With the current economic development mode, the conflict between economic development and energy consumption will become increasingly prominent. Changes must be made to the economic development mode, industrial structure and the use of energy.

As the world's second largest economy, China faces huge challenges in terms of energy consumption, climate change, green house gas emissions. At present, China depends on coal as its main energy, which results in large amounts of greenhouse gas emissions. It also restricts its industrialization and modernization process. China promised a decrease of 40% --45% of carbon dioxide emissions per unit of GDP by 2020 over 2005 at the World Climate Conference in Durban5. In early 2012, the Chinese government introduced the "controlling greenhouse gas emissions during the 12th five-year-plan, which proposed a significant reduction in carbon dioxide per unit of GDP and targeted at a decrease of carbon dioxide emissions by 17% per unit of GDP by 2015 over 2010.6

(3) China's priority to the development of energy-saving industry so as to solve the energy crisis

China is aware of the tremendous impact of climate change from the scientific and social development and starts a positive response.7 On the basis of the first "Renewable Energy Law" passed in 2005, China put forward "China National Pan for Addressing Climate Change" in 2007, which highlights specific measures in key areas.8 To reduce the carbon dioxide emissions in the atmosphere, on the one hand it is necessary to optimize the energy structure to develop the new clean energy such as wind power, solar energy and tidal energy, on the other hand new products shall be introduced through the technological progress to develop the energy saving and environmental protection in order to reduce the energy consumption.

In the 11th "Five-year Plan", namely 2006 to 2010, China clearly stated that the energy,

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4 Conference proceedings of the Fourth China (Taiyuan) International Energy Industry Exhibition

5 China Securities Website: Durban Climate Conference

6 " The 12th Five-year Woking Plan for Controlling Emission of Greenhouse Gas" China State Concil

7 The first in the raw energy law

8 China National Plan for Addessing Climate Change, China State Concil

raw materials, real estate, transportation industry, energy-saving and environmental protection were the key industries for development and support. To develop the economy, the State Council attached great importance to energy saving and emission reduction which was regards as an important means to restructure the economy, change the development mode and promote scientific development. The objectives included about 20% reduction in energy consumption per unit of GDP and the binding target of 10% reduction of total emissions.

China's 12th “Five-Year Plan” (namely, from 2011 to 2015) aims to promote development in key areas with focusing on developing energy conservation and environmental protection as well as strategic emerging industry. Chinese government, in the program of energy conservation issued by the State Council, requires the governments at all levels to fully understand the importance and significance of energy conservation and emission reduction. In addition, work of energy saving is assigned to the specific principal leaders of local government.

The Chinese government urges to develop the emerging industries of energy saving and environmental protection, of information technology, biotechnology, high-end equipment manufacturing, new energy, new materials and new energy automobile. To relieve energy crisis, the main task of these industries is to provide equipment, product and services involving energy-efficiency, environmental protection and resource recycling.

The industry of energy saving and environmental protection includes six areas, namely the energy-saving technologies and equipment, energy-efficient products, energy services industry, advanced environmental protection technology and equipment, environmental products and services. The energy efficient lighting is an important part in the energy saving and environmental protection industry. According to "the decision by the State Council on accelerating the development of strategic emerging industries" (National Development and Reform Committee [2010] No. 32) and the “ Notice of comprehensive energy conservation program during the 12th five-year-plan” issued by the State Council (National Development and Reform Committee [2011]No. 26), to promote rapid and healthy development of energy saving and environmental protection industry, the State Council, issued "a plan of developing energy saving and environmental protection industry", and pinned green lighting as the second most important industry in the area of energy-saving.

1.1.2 Green lighting is an important industry practicing energy saving.

（1） Lighting has become the world's second largest industry of energy consumption.

Electricity for lighting accounts for 20% of world electricity consumption and Chinese lighting counts for 13% of the total electricity consumption. Many countries and regions in the world are vigorously promoting the development of green lighting. Green lighting means saving energy and reducing air pollutants and greenhouse gas from power generation emissions through improving the efficiency of electrical lighting system, so as to achieve the environmental protection. LED energy-saving lights are the representatives of the green lighting and developing green lighting can save energy and money, and can ensure the national energy security and reduce air pollution and protect the environment. The Chinese government attaches great importance to energy-saving lighting, and has included green lighting as the main energy saving projects in the Ninth Five-Year Plan and the Tenth Five-Year Plan and in the "Eleventh Five-Year Plan" and the "Twelfth Five-Year Plan" as the focus of energy-saving projects. The Chinese government launched China's green lighting projects in 1996, and carried out three-phased green lighting international cooperative projects with the United Nations Development Program (UNDP) and the Global Environment Facility (GEF).

（2） The global influence of the application of green lighting technology.

In the whole world, the overall lighting market in 2010 reached 130.207 billion US dollars[9]. While the tradition lighting market has gradually declined LED lighting will increasingly penetrate into the area of tradition lighting market. It is expected that the market share of the LED products will reach 19.9% of the world lighting market. The global lighting market will see a rapid growth in the next few years. The global LED lighting in 2013 is expected to grow to 31.6156 billion US dollars[10]. Table 1-1 shows the global LED lighting market penetration forecast data in the year 2009-2013.

Table 1- 1 Global LED lighting market penetration forecast data 2009-2013

Year	2008	2009	2010	2011	2012	2013
Global LED lighting market penetration rate	1.5%	1.9%	3.2%	10.6%	14.6%	19.9%

Source: Digitimes, 2010/2

From the development of China’s semiconductor lighting market, the semiconductor innovation and industrialization expansion has become an important condition for the rapid growth of China’s semiconductor lighting market since lighting projects launched in 2003. In

[9] A survey and investment strategy report of China semiconductor LED industry between 2010-2015

[10] A survey and investment strategy report of China semiconductor LED industry between 2010-2015

particular, with the government support on the demonstration lighting engineering and subsidies for purchase of semiconductor lighting products, China has become one of the fastest growing semiconductor lighting markets. In 2010, China's LED chip output value reached 50 billion RMB. The LED packing production value got 250 billion RMB and the application LED value reached 90 billion RMB[11].

At present, China's energy is mainly generated by thermal power, which consumes oil and coal. Constantly soaring oil prices have caused the increase of the cost of power generation. In addition, large amounts of carbon dioxide from firing coal caused greenhouse effect. Today, when the energy crisis and the greenhouse effect are getting more and more serious, energy saving and environmental protection has become an imperative, as the low efficiency of traditional source of energy resulted in the fact that only 3% -12% of the electricity is transformed into light and a large amount of energy is wasted[12]. Therefore, it is an imperative to prohibit the use of lighting with traditional energy source and to promote green energy-efficient lighting.[13] At the EU spring Summit in 2008, the European Union countries reached a consensus on gradually replacing incandescent lamps with new energy-saving light source to reduce greenhouse gas emissions. Many countries legislate against the production of energy consumption light, and traditional energy-consumption light source suffered a constant global ban.

Currently, among many energy-efficient lighting products in the market, LED lights are the product of advanced technology. LED lights are semiconductor lighting, and LED is an abbreviation for light emitting diode. Because it is cold and solid light source, it is featured by low operating voltage, low power consumption, high luminous efficiency and endurance, and has become the mainstream in the field of energy-efficient lighting. In fact, LED lamps can save 80% energy over incandescent lights and 50% over fluorescent energy-saving lights.[14] Since green lighting can greatly save energy, the power generation can be cut off and thereby energy consumption and carbon emissions will be reduced as well. If all the incandescent lamps are replaced by the energy-saving lighting, over 60 billion kwh would be saved annually, which is close to the generation capacity of the Three Gorges Power Station per year, or is equivalent to saving 22 million tons of standard coal and this can help to reduce the

[11] Date statistics by Gaogong LED Industry Insitute (GLII)

[12] LED Lighting, Baidu Website

[13] LED Lighting, Baidu Website

[14] http://www.alighting.cn/News/2008324/V14701.htm

emission of over 6000 tons of carbon dioxide and 59 million tons of sulfur dioxide.[15]

According to the "11th Five-Year Plan" and the "12th Five-Year Plan", China will carry out 10 major energy conservation projects, among which green lighting and the promotion of efficient energy-saving lighting system will be the main task. Therefore, as a fourth lighting revolution after fire, incandescent and fluorescent, semiconductor lighting (LED) will become the technology trend in the next few years. The development of the green LED lighting industry will greatly influence the global environment, as well as the economic and cultural areas and will bring the whole world great enjoyment of art and beautiful light.

1.1.3 Technology innovation is the drive of the development of green lighting industry.

Semiconductor (LED) lighting industry is an important part of the green lighting which is divided into "upstream" and "downstream" and is composed of four parts: epitaxial wafers, chip, package, application (the whole lamp manufacturing). The intellectual property rights of epitaxial wafer and chip technology are controlled by Japanese, European and American companies, and most major processing equipment is mainly owned by European and American countries. Because there are some problems with sealing, and application, and there is a lack of major companies, talents, funds, and skills, and the customers are not confident enough in LED industries, this is affecting the upstream development.

According to a survey of Chinese Association of Lighting in 2010, 70% of companies in lighting industry in China are losing money, 20% are breaking even, and only 10% of the companies are making profits[16]. The statistics of the national semiconductor lighting industrial engineering R & D and Industry Alliance showed that in the first three quarters of 2011, more than 90% of the enterprises of the LED lighting industry are losing money and less than 100 enterprises have their own intellectual property rights, which means that the green LED lighting industry lack technological innovation and hence lack core competitiveness. To win customers' recognition, they must achieve technological innovation, to advance their technology in a more mature and more economical way. But now more than 95% of LED lighting companies are small and medium-sized enterprises; in addition, their technological innovation is constrained by resources and capacity.

From the general development of industry, technology has played a key role in the

[15] China Industry Daily, June 25, 2008

[16] Development Report of China Lighting Industry in Twenty Years, China Lighting Appliance Association, 2010

industry transition from infancy to growth. Technical progress and technological innovation is the driving force of industrial development. Technological innovation improves product performance, cost structure and market acceptance. For the whole industrial chain of green lighting and the related technologies, there is currently lack of collaborative innovation. The innovation environment of the industry is poor and insufficient technological innovation becomes the bottleneck which restricts the industry from the development.

1.1.4 Technological innovation in enterprises is driven by the enterprise resources and capacity.

Though technological innovation is the key of developing green lighting industry, and of enhancing the competitiveness of enterprises, technological innovation has been constrained by the fact that the majority of enterprises in China are entrepreneurial SMEs.

（1） Enterprise technology innovation is restrained by limited resources.

Technological innovation in enterprises is guaranteed by the supply of strategic resources, general resources and market factor resources. The three kinds of resources, especially internal resources, are very scarce for start-up enterprises, where there are serious shortages of funds, qualified human resources and there are the problems of poor management, lacking ability to adapt to the changes in the market and lacking competitiveness, poor corporate credit status, low level of marketing management, inadequate government support for the enterprises and immature social service system.

（2） Technological innovation of the enterprises is constrained by its capacity.

The technology innovation of the start-up enterprise is constrained by management, investment, R & D capability, production capacity and marketing capabilities. For the majority of the manufacturing enterprises in China, especially SMEs, the management level is low, they do not have enough funds, lack scientific and technological personnel, their R & D ability is poor, the overall quality of the production equipment is poor, and they lack marketing network. They are facing many difficulties and problems when it comes to technological innovation (Cai, 2008; Jia et al., 2006). The practical measures should be taken to change the unfavorable situation of technological innovation.

（3） The plight of entrepreneurial enterprises in technological innovation

Chinese entrepreneurial enterprises are faced by many difficulties in technological innovation due to the constraints of resources, and their own inadequacies, such as:

The first one is the shortage of innovative talents and high quality employees (Zhang, 2011).

Conservative ideology of the planned economy period makes most of the high-quality talents to select relatively stable, relatively leisurely universities and research institutes, instead of joining the wave of the market economy and fierce challenges. Only 38% of the R & D personnel selected enterprises are concentrated in large enterprises [17]. This makes it difficult for enterprises to get much-needed high-quality talent scarcity of researchers, the lack of a driving force of innovation of the pioneering period.

The second problem is the lack of funds that make it hard to finance enterprises (Xi, 2012).

Technological innovation means the transformation of scientific and technological achievement into productive activities, which needs substantial investment. For start-up enterprises, they do not have sufficient funds to support innovation activities and therefore financing for SMEs is very difficult.

Third, technology intermediary institutions need to be improved.

Technological innovation is a highly social activity. Individual companies generally do not have all the capacities and resources for technological innovation. So they need to co-work with other enterprises on innovation. It takes a large amount of energy and financial resources to collect information to find the right partner. Hence, the intermediaries can play a key role in connecting the small and medium-sized enterprises to promote cooperation between them and achieve optimal allocation of resources. However, in China, the intermediaries are not mature and face many problems, for instance, the number of intermediaries is small and the professional level is comparatively low, there is a lack of cooperation, and the service is not standardized and not multi-oriented. They fail to build a strong information network system and fail to promote technical information exchange among SMEs (Gao, et al., 2003)

Fourth: the lack of legal protection.

The government has not attached enough importance to the start-up enterprise and cannot provide complete legal system to support technology innovation of entrepreneurial

17 Discuss about the plight of small and medium-sized enterprise technology innovation in our country and the countermeasures, Science and technology economic market，Xuliya,2007,02,28

enterprise. Moreover, there are some problems with the enacted laws and regulations for the entrepreneurial ventures.

In summary, in the era of energy conservation and environmental protection, green lighting industry is an important emerging industry. Technological innovation and technological progress is important to the development and popularization of green lighting industry. The key to technological innovation is to reduce costs and increase production, and to enhance the core competitiveness of the enterprises. However, the deficiencies of innovative enterprises, which are subject to a number of constraints, affect their technological innovation. Under the constraints of resources and capabilities, the selection of appropriate technology innovation modes, is a key issue that most entrepreneurial enterprises need to face and it is also worthy of in-depth study by the academia.

1.2 Research questions

The background introduced above indicates that the green lighting industry has a huge development potential in China and in the world as a whole. However, technological innovation has become the obstacle to the development of the industry and how technological innovation is selected has become key to the development of business and industry.

This thesis is aimed to study the following questions: for green lighting industry, what are the features in terms of resources and capabilities of entrepreneurial enterprises? How can start-ups select appropriate technological innovation under the constraint of resources and capabilities? The thesis attempts to establish technology innovation selection mode in the context of constraints of resource and capability, and to explain the modes relevant through multiple case studies of green lighting industry.

The thesis is composed of five chapters. Chapter one is the introduction describing the research background, the main research questions, theoretical values and the arrangement of the chapters.

Chapter two deals with literature review. This chapter summarizes the development of corporate resource theories and then provides a detailed discussion of resources and capacity. The basic model of technological innovation, entrepreneurial enterprise features are also discussed in the chapter. Literature review will provide literature support to the theoretical model.

The third chapter deals with the research design. This part, based on the requirements of

the research, proposes practical design. Through a multiple case study method, this part is written up following the procedures of case studies. This chapter gives a full description of data collection, data analysis and the selection of specific cases.

Chapter 4 mainly discusses technology innovation selection in green lighting enterprises. It is composed of multiple case studies and is based on the studies of Sichuan Grand, Kingsun in Guangdong and Sanan in Xiamen. This thesis discusses the corporate background of these three companies, their development history, current status, the challenges they are facing and their status quo of resources and capacity. To conclude, the technological innovation selection model under the constraint of resources and capacity is proposed in this chapter.

Chapter 5 deals with conclusions and implications of the study. This chapter summarizes the conclusions of this study, identifying its inadequacies, and expecting to improve the conclusions in the follow-up studies.

1.3 Research outline

First, based on the above background we propose the research questions. Then the literature review is conducted with regards to the relevant theories and the understanding that the selection of technology innovation by entrepreneurial enterprises depends on its resource and capability. The study takes a static view to analyze the resources of enterprises such as human resources, technology resources, capital resources and market resources. It also takes a dynamic view to analyze the capabilities such as input capability, research and development, and marketing capability. On the basis of this, we propose the selection framework of technological innovation. The main body of the thesis is composed of three case studies. We analyze the resources and capability of three companies and their technological innovation selections. The final section summarizes the study and presents the outlook.

The research outline is as demonstrated in Figure 1-1.

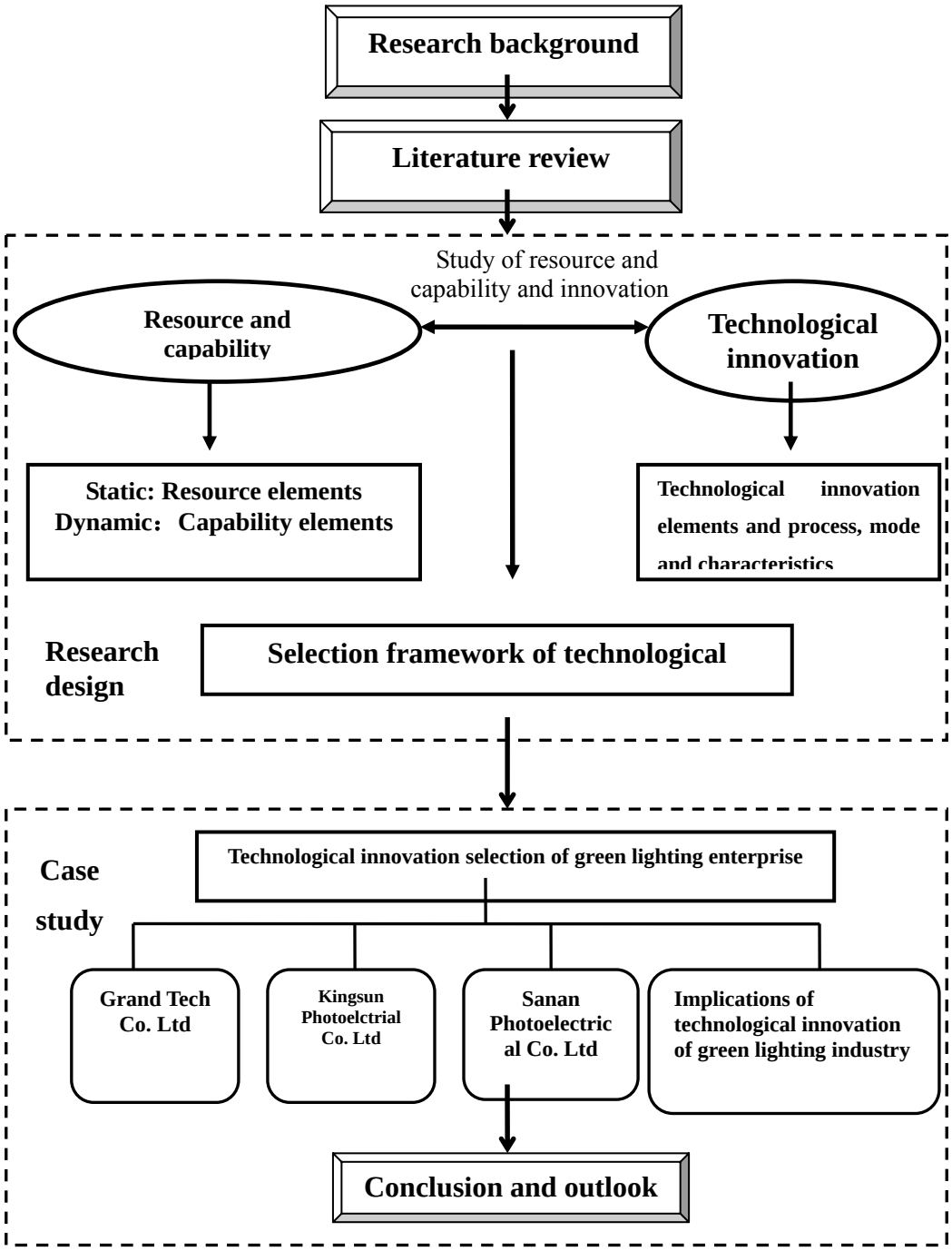


Figure 1- 1 The outline of the study

1.4 Research significance

Today，China is facing the enormous pressure of energy saving. The development of green industries is the focus of the economic development of the country in the long run. But China’s green lighting industry has yet to establish clear industry standards and achieve synergy and integration between the middle and downstream of the industrial chain. There are

also some problems in terms of applications and to solve such problems technology innovation is needed.

Technological innovation plays a key role in green lighting industry and how to choose the technology innovation mode to promote the development of green lighting and to enhance the competitiveness of enterprises is the main issue. This thesis focuses on the green lighting industry through multiple case studies, and proposes the theoretical framework of the entrepreneurial enterprise technology innovation selection, which is both theoretically and practically significant.

Chapter 2: Literature Review and Theoretical basis

This research is aimed at studying technological innovation selection by start-up ventures under resource and capability constraints in the context of China. The key words involve “start-up venture”, “technological innovation” and “resource and capability”. The chapter is outlined as follows: first, the related theories, such as resource-based theory, enterprise capability theory and social network theory, are reviewed; second, entrepreneurship and entrepreneurial opportunities are presented; Finally, the innovation theory as well as technological innovation modality are reviewed. Reviewing these theories will help to lay a theoretical basis for the research.

2.1 Theory of enterprise resource and capability

2.1.1 Resource-based theory

Resource-based theory (RBT) was developed from the study of competitive advantage in the field of economics and strategic management. On the source of enterprise competitive advantage, there have been two main viewpoints: industrial organization view (Porter, 1980, 1985) and resource-based view (Wernerfelt, 1984; Barney, 1991). With the influence of the traditional economics and industrial organizational economics, earlier scholars studied the competitive advantages from the perspective of external competitive environment of the enterprise. It was not until the birth of the resource-based view that an increasing number of scholars started to focus on the resources of the enterprise and its influence on strategies and competitive advantages.

The resource-based theory was mainly originated from Penrose's (1959) enterprise growth theory and Nelson and Winter's (1982) evolutionary theory. Followed by the development by Wernerfelt (1984), Barney (1986, 1991) and Peteraf (1993), the theory has now become an essentially economic accredited school of business theory. Penrose (1959) argued that firms were composed of a bundle of resources. Wernerfelt (1984) pointed out that the internal resources of firms were of great significance for making profits and maintaining their competitive advantages, which played a decisive role in creating market advantages. His contribution promoted the academic field to turn to the resource-based and capability view

from the theory of industrial organization. Grant (1991) further studied the roles of four resource endowments on the sustainable competitive advantages, namely, durability, transparency, transferability and reliability.

With the development and maturity of the resource-based view, RBV theory has gradually become one of the main theories in strategic management. According to RBV, the strategic success of firms is based on its resource structure and the internal resources vary from one firm to another. So, firms can utilize heterogeneous resources to provide unique products or services, which are different from those of their competitors. By acquiring, owning and exploiting these resources, firms can take the advantage and specialty of the resource to obtain their competitive advantages (Prahalad and Hamel, 1990).

Although most scholars take different perspectives to formulate their own views on the competitive advantages of firms based on the resource view, which to a great extent enriched the theory, their studies are of difficult operationalization on the whole. For this reason, Barney (1991) and Peteraf (1993), based on those previous studies, constructed an analysis framework of competitive advantage of firms from the resource-based view.

Barney (1991) argued that different firms possessed or controlled different resources hence their resources are heterogeneous. When firms have resources that are valuable, rare, inimitable and non-substitutable, they are likely to attain sustainable competitive advantages and enjoy better performance. The value and rarity of resources is a necessary condition to generate competitive advantage, but in order to obtain a sustainable competitive advantage, firms must have resources that are difficult to imitate and substitute. Limitability directly concerns the ability of competitors to purchase or accumulate the target resource with the same endowment to generate competitive advantages. Non-substitutability directly concerns the ability of competitors to acquire other resources. Therefore, the attributes of being inimitable and non-substitutable focus more on the barriers impeding the imitability and substitutability, and a large amount of studies on RBV have been conducted to recognize and classify these barriers (e.g., Rommel, 1987；Dierickx&Cool, 1989；Grant, 1991).

Peteraf (1993) took a different perspective to explain the formulation of firm's competitive advantages based on the resource view. Her analysis is more focused on the basic price theory, especially in the economic analysis of different types of rent. According to Peteraf, only when the resources controlled by firms meet four requirements at the same time can they generate the sustainable competitive advantages: a) the firm can rely on the heterogeneous resources to obtain rent; b) by virtue of prior restrictions on competition, the

firm can obtain quality resources which are lower than the cost of rent; c) the firm can rely on the immobility of resources to keep rents within it; d) finally, the firm can hold the rents by virtue of afterwards restrictions on competing for the resources.

As Barney and Peteraf systematically integrated the various theories of competitive advantages based on the resource view, the frameworks developed by both of them have been widely accepted by the academic field. As they put forward the thesis on this analytical framework: "the resource-based view: the cornerstone of technological innovation", Barney and Peteraf 's analytical framework laid a solid foundation for the following studies which are relevant to the resource-based view. William et al. (2011) suggested that the resource-based view provides the conditions for diversity of the enterprise and presented an outlook for the future studies in this field.

In recent decades, more attention has been given to the knowledge-based view (KBV) by the academia, which has become a branch of the resource-based view. According to the knowledge-based view, firms have heterogeneous knowledge. The competitive advantages of firms come from the creation, storage, and application of knowledge (Zander and Kogut, 1995; Conner and Prahalad, 1996: Spender and Grant, 1996). In spite of the special attribute of knowledge, it can be categorized as a kind of resource detained by firms. Therefore, as a branch of the resource-based view, the knowledge-based view (KBV), which focuses on the knowledge of firms, has extended and perfected the theoretical framework of the resource-based view.

According to the previous literature, various resources of firms are summarized as illustrated in Table 2-1.

Table 2- 1 Main resources of enterprises

Types of resource	Main contents
Financial resource	Cash and financial capability of firm, the ability to generate cash profit
Physical resource	Manufacturing equipment and its layout, raw materials and procurement
Technological resource	Various intellectual property and the relevant technical knowledge
Innovation resource	Technicians and equipment for research and development
Goodwill resource	Brand recognized by customers and suppliers, goodwill, and partnership
Human resource	Employees' training, adaptation and judgment
Organizational resource	Organizational structure and its planning, control and coordination

Source: "Strategic Management: Competition and Globalization" by M.A Hitt, R. Duane Ireland, R.E. Hoskisson. Translated by Lv Wei, et al (2012), Mechanical Industry Press.

Generally the resources of firms can be categorized into two kinds: tangible and intangible. Resources such as plant facilities, production equipment, raw materials and other resources of physical form, that is tangible resources, often enable firms to have a basic production or ability to provide services, but they are easier to obtain through market transactions, thus making it difficult to use them as a source for gaining access to the advantages of technological innovation. Intangible resources include knowledge, trust and communication between managers and staff, thinking of all staff, innovation capability, management capacity, management practices, goodwill of enterprise products and services, the way of communicating with people and business reputation. The intangible resources are usually rooted in the history of firms and accumulated through long-term development. It is usually difficult to mobilize, hence the main source of technological innovation advantage of firms.

By summarizing the relevant studies on the resources of firms by a large number of scholars, Barney (1991) classified the resources of firms into three types: physical capital resources, human capital resources and organizational capital resources. Physical capital resources include the application of hard technology by the firms, plants and equipment, the geographic location of firms and access to raw materials and so on. Human capital resources include training, experience, judgment, intelligence, relationship and insights of mangers and staff. Organizational capital resources include the formal chain of command structure, formal and informal plan, control and coordination of the system as well as the informal links between internal groups or the firm and its surrounding environment.

On the basis of the resource-based theory, the theory of technology innovation advantage further explains the mechanism of obtaining rent through firm resources. In accordance with the ownership of resources and the two dimensions of heterogeneity and incomplete mobility of resources, the resources for obtaining the technology innovation advantage can be divided into three types: the first type is the heterogeneous and incomplete mobile resources that firms own; the second type is the homogeneous and incomplete resources that firms possess; the third type is the homogeneous and incomplete mobile resources that firms do not own.

Based on the theory of technological innovation advantage of the resources and taking the resource ownership and the heterogeneity and incomplete mobility of resources into consideration, the resources used to acquire the technological innovation advantage can be divided into (i) enterprise strategic resources, (ii) ordinary resources and (iii) market factor resources. The strategic resources of firms are the direct source of technological innovation

advantage of firms while the ordinary resources, together with market factor resources, constitute the important source of enterprise to enhance and strengthen the strategic resources, which indirectly affect the performance of enterprises to obtain sustainable technological innovation advantages.

Among the various resources of firms, the strategic resources are the source of firms to gain technological innovation advantage. The characteristics of strategic resources are embodied in a way that they are controlled by firms, enable firms to create and execute value creation strategies, and enhance the operational efficiency and effectiveness of resources (Daft and Weich, 1984). In addition, the complementary resources have a positive impact on the strategic alliance between enterprises. It can improve the level of partnership and further strengthen the competitive advantage (Liu, 2004).

The resource-based strategic view took a further study on the strategic resource of firms, which reveals the mechanism by which the strategic resources of firms acquire the continuous technological innovation advantage. It also demonstrates the heterogeneity and incomplete mobility of corporate strategic resources, which endows the strategic resource with the four attributes mentioned before, namely, valuable, rare, inimitable and non-substitutable.

However, not all the physical, human and organizational capital resources are corporate strategic resources. Enterprises also have considerable ordinary resources that are not heterogeneous and immobile, such as, the company’s plant, machinery and equipment, raw materials, and the front line of skilled workers. These ordinary resources do not simultaneously have the attributes of value, rarity, inimitability and non-substitutability. Although ordinary resources belong to the same specific enterprise, they can not become direct sources of advantage to gaining access to technological innovation because the competitors of the enterprise have similar resources due to the homogeneous and mobile attributes of those resources. Operation activities of firms are inseparable from the support of the ordinary resources; however, ordinary resources can only ensure the production and operation of enterprises to gain the breakeven point in the same industry. They can not directly create above average profits before they are integrated and transformed into strategic resources.

In addition to the internal resources, the impact of the external mobile market factor resources on the ability of enterprises to obtain the advantages of technological innovation can not be ignored, because the resources of market factors are the major source to upgrade and enhance the strategic resources of an enterprise. The market factor resources exist outside

the enterprises, and are not owned by any particular firms. Before they enter a specific enterprise, the external resources have the same homogeneity and mobility to all the enterprises, hence the equal opportunity for all in accessing market factor resources. This type of resources include all the factors pending for transaction, such as land, machinery and equipment, raw materials and semi-finished products, as well as college graduates and job seekers at the job market. Although these resources cannot make any contribution to enterprises when they are free outside the company, the huge potential of the enterprise to obtain the advantages of technological innovation will be displayed once they are integrated into the internal strategic resources with heterogeneity and imperfect mobility.

In summary, the resource-based view initially illustrates the importance of the internal conditions of firms for competitive advantage. In addition, it gradually formed a relatively complete theoretical system "from the inside out" strategic management, which has laid a solid foundation for the subsequent development of enterprise capacity management. However, the resource-based view has some imperfections, too. It overemphasizes the utilization of the existing resources of firms to obtain the rents without considering how to integrate the current resources and nurture the new resources. As time goes by, the resource-based view has matured and is facing new developments. Barney et al (2011) proposed the future research directions on the theory from a combination of the resource view with other views, including the resource acquisition process, the micro-foundation of the resource theory, continuity of the resource theory, and measurement methods.

2.1.2 Capability theory of firms

Competitive strategy emphasizes that the industrial structure is a key part of the competitive environment. However, the characteristics and evolution of industrial structure is only one of the main basis of formulating competitive strategy rather than a whole. The capability theory is a continuation of the analysis logic of the resource theory and emphasizes the unique capability in the process of enterprise production and management as a starting point to formulate and implement the competitive strategy of firms.

The school of capacity theory shifts the focus to the internal resource of firms and is closely related to total quality management, re-engineering and core competences, capacity competition, and the rise of the learning organization. It explains how the resource of a firm can be effectively combined in a dynamic competitive environment and promotes the generation of performance. If the capability of firms can be deemed as their resource, the

school of capability should fall into a broader resource school.

The capability theory of firms can be traced back to as early as 1920 and 1925. The economist Marshall argued that the evolution of the enterprise is decided by the increasing skills, knowledge and coordination. Enterprises must accumulate special abilities through "self-construction" and "self-building". This special capability is a core competency and the most central and fundamental part of an enterprise capability. Nelson and Winter (1982) proposed that enterprises are teams of capabilities and the development of enterprises is the result of the accumulation and expansion of core competences. Lippman and Rumelt (1982) put forward the theory of winning capability. Based on the study of excellent experiences of world top companies, Prahalad and Hamel (1990) pointed out that the true source of competitive advantage lies in the capability of the management of firms to combine the technology and production skills within the company, which enables the whole business to quickly adapt to changing opportunities. In addition, they put forward the concept of core competencies and pointed out that the formulation and expansion of the business advantage is closely related to the formulation and protection of the core competitiveness of firms.

Foss (1993) published a paper titled "Core competence theory" where he defends that it is the core competence focus on the individual key advantage in the enterprise value chain and the overall capability that stress the overall advantage in the value chain. In 1994, Hamel and Heene proposed a view of enterprise capability based competition stating that core competence is the basis on which a corporation draws up its strategy and is also a source of competitive advantage as it determines the business and products which the enterprise can make. Teece and Thomas (1997) put forward the dynamic capability of enterprises by which the dynamic capability refers to the capability to integrate, build and reconfigure the resource inside and outside of enterprises in order to adapt to a rapid changing environment. The concept of "dynamic capability" means that enterprises need to reshape their competitiveness to keep up with the changing business environment. When time effects and the speed of the market become critical, technology changes faster, and the future competition and the essence of market uncertainty require that enterprises have specific capabilities to respond to innovations.

Grant (1991) makes a distinction between resources and capabilities. He pointed out that the resources can be divided into tangible resources, intangible resources, and personnel-based resources. Capabilities can enable enterprises to combine the resources working together, and ultimately create a competitive advantage for enterprises. The

resource-based view adopts a static equilibrium analysis while the capability view takes the method of dynamic analysis by which various resources are put into interaction and coordination. The workflow and norms of enterprises are also put into the theoretical system. Although RBV has always considered unique resources and capabilities as the joint source of creating competitive advantages, scholars who are in favor of the capabilities highlight the role of capabilities in obtaining the competitive advantages based on the resource-based theory framework (Hamel and Prahalad, 1994; Prahalad & Hamel, 1990).

The school of competence turned their attention to the internal enterprise, closely related to which was the emergence of the total quality management, reengineering and core competence, capability competition and lean organization. The new strategic method is still rooted in the economics, which explains how the enterprise resource drives the performance in the dynamic context. If the capability of the enterprise is seen as its resource, then it belongs to the resource school in a broad sense.

According to the capability-based view, capability refers to the ability of enterprises to configure their controlled resources. They are information-based, tangible or intangible firm-specific processes and are produced by the interaction of the long-term enterprise resource and development (Amit and Schoemaker, 1993). These capabilities demonstrate the heterogeneity among firms within an industry and own the attributes of inimitability and non-substitutability (Barney, 1986; Mahoney and Pandian, 1992; Mit and Schoemaker, 1993: Peteraf, 1993). Therefore, capabilities have strategic potential to utilize opportunities or avoid threats, enabling the enterprise to obtain a near-monopoly in the market and create competitive advantages (Rumelt, 1984; Prahalad and Hamel, 1990).

Campbell, Goold and Alexander (1995) argue that the concept of capability is broader than the concept of core competencies, which include the entire value chain (core competencies are only reflected in one link or several links of value chain. The top companies should be able to make their strategic business units to create more values than their competitors. From the analysis and views above on the capabilities, it can be seen that the core competences are embedded in the production and operation of firms, constituting a combination of individual technologies and production skills with obvious advantages. They are accumulated knowledge in the organization, especially with regard to how to coordinate the different production skills and combine the knowledge of multiple technological flows.

With the increase in the theoretical study of enterprise capabilities, the view of dynamic capability emerged. Dynamic capabilities refer to the abilities of enterprise to respond quickly

to the external environment, integrate the competencies within and outside the enterprise, construct and rebuilt. Therefore, dynamic capabilities reflect the new and innovative competitive advantages that enterprises obtain.

Developed from the resource-based view, the dynamic capability theory was constructed upon Nelson and Winter's (1982) evolutionary economics. The theory holds that the competitive advantage of an enterprise comes from the excellent management and organization of the enterprise itself, the constitution of specific assets, and the path dependency of enterprise evolution (Teece et al, 1997). On the analysis of the four main strategic models (competition model, strategic confrontation model, the resource-based view model and dynamic capability model) formed in 1990s, Teece, Pisano, and Shuen (1997) first proposed the dynamic capability strategic model.

As the dynamic capability theory is based on the dynamic market environment, which is more consistent with the rapid changes in today's globalized market competition environment, the theory has recently attracted considerable attention from the field of strategic management and has gradually been adopted, studied and developed by many scholars.

Although some studies, based on the division of resources and capabilities of firms, attempt to separate the dynamic capability theory from the RBV theoretical framework, essentially the views, whether they are capability-based, knowledge-based or dynamic capability, have all been developed from the RBV theoretical framework. It is no doubt that knowledge is a kind of resource and belongs to the RBV theory. Therefore it would be better to improve and expand the RBV theoretical framework, which provides a rich, powerful theoretical and methodological support for the follow-up study of this research project.

Helfat and Peteraf (2003) put forward the life-cycle model of capability of firms, which divides the development of firm capability into three stages: formulation, development and maturity. By reviewing the relevant literature, parts of firm capabilities are illustrated as follows (Table 2-2).

Table 2- 2 Summary of the Enterprise capabilities and their performances

Capabilities	Main performance
Distribution capabilities	Effective use of logistics management technology
Human resource	Stimulate, delegate and promote employees
Marketing capability	Effectively promote products and serve customers
Management capability	Planning, effective organizational structure and management workflow

Production capability	Necessary design and production skills, perfection of product and components
Research and development	Storage of technological knowledge, technology conceptualization and commercialization

Source: Strategic Management: competition and globalization, (2012) written by M.A. Hitt, R. Duane Ireland, R.E. Hoskisson, and translated by Lu Wei, et al. Mechanical Industrial Press. (The appropriate adjustments have been made)

2.1.3 Enterprise social capital and social network

Bourdieu (1985) regards social capital as a network structure. Burt (1992) argues that social capital is a network structure that can produce resources and control them. Coleman (1988) further defined social capital, claiming it is not only a component of the social structure but also a personal resource. Chinese scholars who early studied social capital were Bian and Qiu (2000) who argued that social capital is the link between the action taker and society and the ability to obtain the rare resources through this link. In essence, social capital is a resource. Zhang (2004) divided social capital into horizontal relationship capital, vertical relationship capital and social relationship capital. He defined all the aspects of social capital (Table 2-3)

Table 2- 3 Components and classification of enterprise social capital

Social capital	Contents
Horizontal relationship capital	Relationship between enterprise and customers
	Relationship between enterprise and suppliers
Vertical relationship capital	Relationship between enterprise and alliance
	Relationship between enterprise and competitors
	Relationship between enterprise and other companies
Social relationship capital	Relationship between enterprise and higher education and research institutions
	Relationship between enterprise and intermediaries
	Relationship between enterprise and government
	Relationship between enterprise and industrial associations
	Relationship between enterprise and financial institutions
	Relationship between enterprise and venture investment institutions

Source: Zhang Fanghua (2004) The study of social capital and technological innovation performance of knowledge-based enterprises

Regarding the measurement dimensions of social capital, some scholars take “trust” as an indicator (Luo, 2009), others employ “intensity of relationship” (Granovetter, 1973) as an indicator, while others use network structure to reflect the dimension of social capital (Burt, 1992). The most classic one is the social capital structure dimension that includes cognitive

and relational dimension proposed by Nahapiet and Ghoshal (1998).

From the study on social capital, attention has naturally extended to social networks. Attention on enterprise network shifts the perspective of the strategic study from Porter's value chain to the value network featured in cooperation and competition. The so-called "social network" refers to the collection of the relationship between specific groups of people. This collection has a comprehensive feature, which can explain the behavior of the people in the group (Mitchell, 1969).

The challenging responsibility of entrepreneurs is to acquire the economic, human and technological resources controlled by others, which requires the use of their personal relation networks. An entrepreneur's social network is a network formed by entrepreneurs in their growth due to blood or geo-relations which are inborn or a result from interaction with other individual members. The social network of entrepreneurs is an important way for enterprises to obtain external resources and information.

Anderson and Miller (2003) argue that social capital and characteristics of social networks are resources of a person and influence the entrepreneur's ability to identify and track the opportunities that can provide profitability and potential growth to a business. The research in the field of entrepreneurship indicates that the success of a business depends on many conditions. In essence, entrepreneurship is viewed as a process by which entrepreneurs identify, acquire and accumulate resources to create business value. These resources include the entrepreneur's own human capital, physical capital and social capital. Entrepreneurs play an important role in the process of the creation of new enterprises and are those who obtain, identify and preserve entrepreneurial opportunities. For start-up firms, the social network of entrepreneurs is also the network of the enterprise, which has a significant impact on its survival. In the process of enterprise development, the social network of entrepreneurs can also bring information benefits.

The accumulation of external relations in a network is conducive to enterprise innovation. The creative sources of enterprises can be external and internal. External sources of innovation include new inventions in the industry and new technologies that promote the entire industry, thus promoting the development of the value chain. Internal innovation comes from the internal creative change, which can be of two types: simulated innovation and radical innovation. The external social capital of enterprise plays an important "glue" role in promoting cooperation. It can make the cooperation within the network run smoothly and

be beneficial to all the parties. Therefore, in the economy, social capital has become a key factor in technological innovation.

Chinese scholars generally believe that trust is the core element of the entrepreneurial social network. In the case of China, the transaction model is mainly built on the social network, and mutual trust is developed by building special personal relationships, because the more mature the relationship is, the more trust in each other, and the greater is the possibility of a deal.

The entrepreneur’s social network also helps to promote the innovation of enterprises as it is the entrepreneur who organizes and promotes innovation activities. In the process of promoting innovation, entrepreneurs are certainly influenced by their personal network and social network in which they are embedded (He and Qin, 2005; Zhou, 2005; Wu, Wang and Tang, 2007). Entrepreneurs’ network and its constitution to a large extent determine their ability to obtain information and resources. In addition, with respect to the entrepreneur’s personal network, the social network of entrepreneurs will have a more important impact on their innovation behavior because, by the social network, entrepreneurs can acquire and mobilize a higher degree of heterogeneous information and resources. In general, within a social network environment, the most important role of entrepreneurs is mainly reflected in two aspects: 1) to provide other members of the network with a new program and model for the future game; 2) in case of an incentive incompatibility problem between the entrepreneurs and other members, entrepreneurs will take advantage of their special status in the network and the special nature of the network exchange to solve this problem.

Social network of entrepreneurs is particularly important for small-medium enterprises. Entrepreneur’s network is conducive to entrepreneurial start-ups, the generation of the family business and family business network. Entrepreneurship with innovation as a core can further promote the transformation of family businesses into a modern enterprise system and network growth. The social capitals of entrepreneurs include the government social capital, technological social capital, financial social capital as well as market social capital of entrepreneurs. In addition, entrepreneurs’ social capital plays roles of access to critical resources, reduction of transaction costs and promotion of innovation. It is therefore an important activity for the entrepreneur to embed himself in a social network and realize the integration of network resources, which affects the success of entrepreneurial practice (Chen, 2009). The social network resources of entrepreneurs include institutional resources, market

resources, intellectual resources, empirical resources, all of which can help entrepreneurs to gain important resources to support economic development, so as to obtain the relative information advantages, which will help the enterprise technological innovation, reduce risks and save on transaction costs (Na, 2006).

In summary, due to the relative lack of institutional resources, the social relationship must replace to some extent the institutional factors in terms of enterprise resource configuration. In Chinese society where the rational level is not high, the social relationship of the enterprise plays a more important role in resource allocation. Emphasis on interpersonal relationships in Chinese society provides a favourable help for people to look for rare resources.

2.2 Entrepreneurial Theory

2.2.1 Entrepreneurship and entrepreneurial opportunities

Regarding the definition of entrepreneurship, some scholars simply define it as the creation of new enterprises (Low and Macmillan, 1988) or define it as new products, new processes, new organizations and new market combinations (Schumpeter, 1934). Cole (1968) and Stevenson (1985) have further elaborated on the meaning of entrepreneurship, i.e., including the creation of new enterprises and entrepreneurship in existing firms (intrapreneurship).

Entrepreneurship is a process by which entrepreneurs discover and identify business opportunities, organize various resources, offer products and services and create business value. The core of this process lies in integrating various necessary resources, utilizing resources and creating value. The definition involves the following elements: entrepreneurs, business opportunities, organizations and resources.

The entrepreneur is the individual or team being in the heart of the entrepreneurial process, hence the subject of entrepreneurship. Business opportunity is the entrepreneurial opportunity, which is the main driving force of entrepreneurship. The process of entrepreneurship is to utilize business opportunity and transform it into value. Organization is the organic system to coordinate entrepreneurial activities and also a vehicle for entrepreneurship. Entrepreneurial activities are conducted within organizations, so without organizational guarantee entrepreneurial resources can be integrated and the leadership of entrepreneur is groundless. Entrepreneurs need to organize the internal and external resources

of enterprise, including the determination, collection and configuration of resources. In summary, the entrepreneurial process is an interaction of entrepreneurs, opportunities, organizations and resources. It is a dynamic process by which value is created.

Entrepreneurship is not only about the creation of new businesses but also takes place in the existing firms. Miller (1983) argues that "entrepreneurship is the business activities relating to products, market and technological innovation". The entrepreneur is able to identify opportunities, promote competitiveness and ensure the sustainable growth of existing firms. Miller and Friesen (1982) claimed that entrepreneurial firms generally have a high degree of innovation, adventure and the characteristic of first-mover.

The process of entrepreneurship normally includes the following steps:

- To identify and evaluate the entrepreneurial opportunities
- To propose entrepreneurial plan
- To determine and obtain entrepreneurial resources
- To manage the growth of enterprise through the integration of resources
- To harvest entrepreneurial value

Entrepreneurship also has the following characteristics:

First, entrepreneurship means creation and innovation;

Second, entrepreneurship can break through the existing systems or orders to provide the entrepreneurs with development opportunities for miracles;

Third, entrepreneurship means the entrepreneurs can ignore the constraints of structure or order,

Finally, entrepreneur is forcing societies to be "societies of enterprising spirits" full of passion and vigor. Integrating the innovation spirit with entrepreneurship can pave the way for the implementation of entrepreneurial activities, which in turn changes the results into value. Entrepreneurship research is based on the behavioral process conducive to entrepreneurial activity and has a wide range of theoretical basis.

Entrepreneurship is important to both large and small businesses. By entrepreneurial behavior companies can create new businesses, improve productivity and obtain a competitive advantage to promote industrial development. It should be noted that entrepreneurship does not necessarily create new ventures but also creates new businesses within existing organizations. Entrepreneurship exists in a variety of forms, such as industrial innovation, investment in new business and process innovation. The entrepreneurial enterprise, which is

the subject of this study, includes not only a newly established enterprise but also new businesses created by the existing company.

Entrepreneurial opportunity refers to the introduction of new products, new services, new materials and new organizational ways and the possibility of having sales higher than costs (Scott Shane and S.Venkataraman, 2000). Broadly speaking, an opportunity refers to the possibility of obtaining above average value through a creative integration of resources to meet the market demand. The definition of opportunity is that it is "not precisely defined by market demand, or it is unused or underutilized resources or capabilities". This so-called capability refers to the basic technology or invention that has not yet entered the market and to some ideas for new products and services.

Kirzner (1973) regards entrepreneurial opportunities as the possibilities of integrating resources, meeting market demand and realizing market value. Zahra and Dess (2001) define entrepreneurial opportunities as "viable, profit-seeking potential business activities, which provide new products and services to the market". Whether in the study of resource theory or entrepreneurship theory, the resource heterogeneity is the common characteristic. So, the resource theory can well explain entrepreneurial behavior (Sharon and Lowell, 2001).

Entrepreneurial opportunities come in different forms. Regarding the entrepreneurial force in the product market, Drucker (2006) described three different opportunities: 1) the creation of new information enabling the opportunity to emerge with the invention of a new technology; 2) due to the invalid market development caused by the asymmetry of information, the opportunity occurs with the change of time and place; 3) in response to the cost of using other resources and changes of benefits, the opportunity occurs with changes in terms of politics, laws or demographic statistics. Chandler and Hanks argued "Although opportunities exist in a specific environment, the quality of the selection and development of opportunities can vary depending on the recognition and forecast ability of entrepreneurs". In addition, changes in technology, politics, society, laws and others also provide different approaches to utilize resources and increase wealth.

Though the opportunity of obtaining entrepreneurial profits could exist, the profit can only be obtained when the opportunity can be identified and be of value. It is one of the important competences of entrepreneurs to identify and select the right opportunities for a new business (Stevenson et al.1985). Therefore, the discovery and development of opportunities are key elements of entrepreneurship. Shane and Venkataraman (2000) argue that the identification and development of opportunities are the foundation of

entrepreneurship and should be the focus of this field of research.

The identification of innovation opportunities can be based on two perspectives: the discovery perspective and the creation perspective. The discovery perspective holds that opportunity is independent of the environment and is waiting to be recognized (Kirzner, 1997). Another one is the creation perspective. Saravathy (2001) holds that the opportunity is an endogenous phenomenon where entrepreneurs search for opportunities. Smith et al. (2009) also argued that discovery and creation of opportunities are not in conflict. Whether opportunities are discovered or created, it requires the entrepreneurs to have a certain foundation in terms of expertise, work experience and social networks.

Chen (2007) summarizes several influential factors of entrepreneurial opportunity recognition: 1) personal characteristics of entrepreneurs, entrepreneurial motivation, resource endowments, 2) social network, and 3) technology, market and policies and regulations.

2.2.2 Entrepreneurial cycle theory

Galbraith (1982) divided the entrepreneurial cycle into four stages. The first is the principle proved stage at which entrepreneurs mainly have an idea and conduct research and development with their own technology. The second is the prototype stage where entrepreneurs change the technology into a product prototype. The third is the sample trial marketing stage where a certain number of products are produced for trial marketing. Finally the fourth is the start-up stage where the final products are produced and the first sales begin. In turn, Katz and Gartner (1988) also proposed four stages in the entrepreneurial process: 1) on-purpose collection of information, 2) efforts to establish the organizational boundaries to make the entrepreneurial enterprise to stand out, 3) obtaining the organizational operation funds, and 4) making exchanges with suppliers and customers to establish the initial offer of products and services.

Lei (2005) divided the growth of start-up enterprises into four stages: start-up stage, learning adjustment stage, fast-growing stage and relative stable stage. Jiang and Zhang (2005) argue that the entrepreneurial life cycle includes the seeding stage, start-up stage, development stage and maturity stage. Zhang and Li (2006) found that the entrepreneurial process includes the generation of entrepreneurial motivation, identification of entrepreneurial opportunities, integration of resources, creation of new firms or new businesses, management of growth of new firms or new businesses, and rewards obtaining.

The process of entrepreneurship is identical to the growth of an enterprise. Holt (1992)

argued that the process of entrepreneurship includes pre-start-up stage, start-up stage, early growth stage and later growth stage.

2.2.3 Main characteristics of entrepreneurial enterprise

Brush (2001) made an in-depth analysis on the resource construction of entrepreneurial enterprises. He summarized four major challenges facing start-ups in the resource allocation process, namely resource concentration, resource attraction, resource integration and resource conversion.

Cai and Liu (2007) classified the entrepreneurial resources into six types: human resources, material resources, technical resources, financial resources, market resources and organizational resources, among which human resources have a broader definition. Human resources can be further divided into intellectual resources, goodwill resources and social resources. Li and Ceng (2009) divided entrepreneurial enterprise resources into technical resource model, regional resource model, enterprise resource model and policy resource model. The empirical study by Wang and Bao (2007) indicated that progressive positive relationships exist between the social network of small enterprises, resource acquisition and enterprise growth performance.

Entrepreneurial enterprises are characterized with high growth and high risk. They have the following main features:

First, the initial base is weak. Comparing with the mature enterprise, high-tech entrepreneurial enterprises, similar to the initial stage of small enterprises, are weak in many ways, such as in their small scale, lack of funds, lack of tangible assets for deposit and no experience of the whole life cycle. In the meantime, high-tech entrepreneurial enterprises generally suffer from incomplete organizational structures.

Second, the high degree of incomplete and asymmetric information is a crucial problem faced by entrepreneurial enterprises, particularly by start-ups. From the information communication between enterprises and market there are huge industry related uncertainties because high-tech enterprises are in a newly developed industry or are running a new business model. In addition, there is lack of examples for the start-ups due to their newness. At the same time, start-ups are faced with the problems of short establishment period, lack of detailed management records and obscure business information.

Third, there is a high-potential risk in the company growth as, compared to mature companies; start-ups are weak in their foundation, so there is uncertainty in technology,

market and management.

Fourth, the highly proprietary nature of the human capital that refers to all the resources formed by various investments and embodied for future earnings. It includes knowledge, skills, experience, physical and psychological strength, valuable information and social relations.

2.3 Theory of technological innovation

This section involves connotation of technological innovation, the role of technological innovation and technology innovation model.

2.3.1 Connotation of technological innovation

Schumpeter (1949) first proposed the concept of innovation. He argued that innovation is to reorganize the production factors. New combinations include the introduction of new products, new technologies, new markets, the new supply of raw materials, and new organization. Based on Schumpeter's innovation concept, many studies continuously improve the connotation of innovation from the technological innovation process, content and innovation system.

J.L.Enos (1962) first defined the technological innovation. From the perspective of behavioral collection, he stated that the"technological innovation is a comprehensive result of several behaviors, which include selection of inventions, capital investment guarantee, organizational establishment, making plans and market development". Freeman's definition (1988) on innovation includes relevant technology, design, manufacturing and business activities, which are related to the new products or new processes as well as the first application of new equipment. Utterback (1975) made a concise definition of innovation, "innovation is the practical use of the technology for the initial application".

From the process point of view, for high-tech enterprises that compete in the market and make earnings, technological innovation refers to the entire innovation process rather than to a technical development. It starts with the proposed new product or process, goes through research and development, commercialized production and achieve success in the market.

Fu Jiaji (1992), a Chinese scholar who early proposed a theory of technological innovation argues that technological innovation is a process by which entrepreneurs gain business profits through effectively organizing a business system and introducing new

products, new methods, new organizations and new markets. Xu (2000) takes a broad view to define technological innovation. He claims that technical innovation is a process to acquire, utilize and produce the products for the customers' needs. He claims that the promotion, diffusion and application of technological achievements are the composition of technical innovation.

While scholars present different views on technological innovation, government departments also discuss the definition of technological innovation. The American Industry Association, for example, defines it as "the practical application of new materials, equipment and processes, or the effective use of certain existing things in new ways. Innovation is to recognize a new need, to identify new solutions and develop an economic viable technology, product and service and finally to achieve success in the market. The Organization for Economic Cooperation and Development (2004) put it as the "technological innovation including new products, new processes as well as significant changes to the original products and processes"

The Chinese government (1999)[18] defines technological innovation as the application of new knowledge, new technology, new process, the application of new production and management by enterprises, which aims to improve the quality of products, to develop and manufacture new products, to provide new service and to seize markets to realize market value. Enterprise is the main body of innovation, and technological innovation is to develop high technology as an important premise for industrialization.

Although scholars from China and abroad define technological innovation from different perspectives, so far there has not been formed a strictly unified definition about technological innovation. This is mainly because technological innovation is a very broad concept which involves economics, management, social sciences and other disciplines, and naturally different definitions emerge in different areas.

Based on Schumpeter's definition of innovation, scholars at home and abroad made extensive and in-depth study on technological innovation. The research development abroad regarding technological innovation can be roughly divided into three stages:

The first stage was from 1950's to 1960's. Under the impetus of the new wave of technological revolution, the research on technological innovation quickly revived and gradually broke through the limitations of neoclassical economics, which caused specialized

[18] Decisions of strengthening technological innovations to develop high-tech for industrialization

studies on the origins of technological innovation, its effects, internal processes and structure. The results of these studies were reviewed by J.M Utterback, Langrish and Myers in the 1970's.

The second stage was between 1970's and 1980's during which the research on technical innovation was booming. The main characteristic of this stage is that the research of technological innovation was relatively independent from the scope of the management science and economic development cycle, initially forming the technological innovation theoretical system. The object of the study has begun to gradually decompose, causing relatively comprehensive exploration and discussion on innovation from different perspectives and levels.

The third stage started in 1980's to the present. The studies on the technological innovation theory have developed to a more comprehensive direction. Based on the previous studies, some scholars conducted in-depth research on certain topics and paid more attention to the guiding roles of the research on the socio-economic and technological activities. The main representatives of this period were Freeman, Dorsey and Utterback.

A large number of empirical studies from home and abroad indicate that sources of technological innovation are diverse. The said innovation sources refer to the individuals or enterprises that first developed a certain technology into a state of application. The sources of innovation vary from different types of innovation to different industries. Eric Von Hippel et al. (2000) based on the link between innovators and innovation, divided innovation into user innovation, manufacturer innovation and supplier innovation. Their studies show that product users, manufacturers and suppliers are all the sources of innovation. The study by American economist S. Meyers and D.G.Marquis（2010）indicate there is not consistent relationship between the size of firms and the number of innovations. Large enterprises may not necessarily have more innovations than small ones[19].

To sum up, the driving forces of technological innovation include: 1) technology-push theory, 2) demand-driven theory, 3) the government behavior theory, 4) entrepreneurs' innovation preference driven theory, 5) self-organization role of social, technical, economic system, and 6) technical track push theory. In all of the innovation power, many scholars stressed that market demand is the decisive factor to start and continue the innovative activities for success.

[19] Decisions of strengthening technological innovations to develop high-tech for industrialization

Technological innovation requires enterprises to have certain technological innovation capability. Schumpeter (1949) argues that technological innovation is not the same as innovative competence, which is the core of innovation capability structure. Barton (1992) regards the technological innovation capacity as the professional expertise, technical system and management system.

Technological innovation capability of enterprises is a comprehensive capability to use the existing resources and environment to develop new technologies (i.e., new product and new process), to enable the enterprises to meet or create market demand, to improve economic efficiency of enterprises, to enhance the core competitiveness of enterprises, to promote and support the technological innovation strategy of firms.

Technological innovation may include the risk of technology itself, market risk, funds risk, management risk and political risk. For the entrepreneurial enterprise, the technological innovation capacity includes the following capacities: organizational learning, the ability to doubt and accept new knowledge, new things, technological research and development, conversion capacity of enterprise technology in R &D results, organizational capacity of technological R & D, and risk prevention ability.

The enterprise capability as a particular core competitiveness is the key to gain competitive advantage. Bi (2010) argues that technological enterprise should identify its core resources, use its own advantageous resource to exchange for external resources, and enhance the ability to integrate resources.

The study of technological innovation started from late 1970's in China, when some scholars began to introduce the foreign studies on the subject into China. In the mid-1980s, Chinese scholars draw on the research of foreign scholars and published papers on technological innovation. In early 1990s, some scholars focused on China specific issues, such as the rigid system of state-owned companies, backward technology, lack of innovation, the need to strengthen the research from the perspective of technological innovation and promote some academic achievements. Following that, the theoretical research of technological innovation has entered a substantive stage. To sum up, there are three main aspects Chinese scholars have debated:

1) Study of technological innovation economics. In his book "Technological Innovation", Fu Jiaji (1992) explored the origins of technological innovation, technological innovation and organizational change, diffusion of technological innovation, technological innovation and economic virtuous circle, Chinese industry innovation and policies from the micro point of

view with considering Chinese reality. In his book "Economics of Technological Innovation", Liu Yulin (1993) systematically illustrated the process, mechanism, technological innovation and market structure, enterprise, industry evolution and economic growth from macro point of view. He also analyzed the issues of innovation policies and incentives.

2) Study of national innovation system and regional innovation system. The research in this area is focused on the impact of technological innovation on industry upgrading and economic growth. Through national and regional level innovation systems, a whole set of institutions, systems, and networks are formed within the systems. Therefore they can improve the efficiency and integration of resource configuration and technological innovation performance. The representative scholars and works include: "Outline of the National Innovation System" by Feng Zhijun (1999), "Innovation and Future-National Innovation System in the Era of Knowledge Economy"by Lu Yongxiang (1998),"Theory and implementation of the Regional Innovation System" by Shang Yong (1999), "Innovation Space-Enterprise Clusters and Regional Development" by Wang Jici (2005).

3) Study of every aspects relevant to technological innovation, such as the role of technological innovation, types, influential factors, motivation system (Chi, 2003; Dang and Zheng, 2007), innovation evaluation (Ma, 2002; Liu, 2009), diffusion of technical innovation (Dong, 2009) and so on.

2.3.2 Technological innovation model

The process of technological innovation is a systematic project, involving many factors. These factors constitute different innovation models due to the different combinations and structure. According to different research angles and methods, technological innovation models can be divided into different types. Technological innovation generally includes product innovation, process innovation, equipment innovation, material innovation, organizational and managerial innovation. In addition, abundant literature has studied the technological innovation model and classification from different perspectives, which are listed in Table 2-4.

So far, five innovation models have been constituted by the academia according to technological innovation processes or the causes for technological innovation. The main technological innovation modes are analyzed as follows:

Table 2- 4 Technological innovation model and classification

Type	Contents
Object pattern	Product innovation , process innovation, function innovation, style innovation, service innovation
Target mode	Functional type, green type
Velocity mode	Breakthrough type, progressive type
Main body mode	Independent innovation, imitation and innovation, cooperation and innovation
Introduction mode	Technology introduction, absorption and innovation
Industrial Chain	Backward chain type, forward chain type
Source mode	Internal innovation, external innovation, transfer innovation and cluster innovation
Timing mode	leading innovation, following innovation
Nature mode	Original innovation, imitation innovation
Complexity mode	Single technological innovation, technical cluster innovation
Incentive mode	Technology push type, demand-pull type, push-pull type

Source: Fu Jiaji (1998), Jiang Yanfu(2005), and Hu Jing (2010)

The first is a technology-push mode. This model comes from Schumpeter's (1949) view that scientific discoveries or technological inventions promote technological innovation. Technological innovation is a linear process. The second is demand-pull model by which market demand provides opportunity for innovation. The third is a combined model of technology and market demand. Innovators own or partly own scientific discovery and technical inventions and induced by market demand to implement innovation activities. This model strengthens the links of market and technology, emphasizing that the market demands and technology capabilities match. The fourth innovation mode, which appeared in late 1980s, marked a change in the concept, from sequential process to innovation involving R&D parallel to the process of design, manufacture, marketing and other factors. The fifth generation of innovation concerns a system integrator network mode, which highlights the importance of the corporate strategy and the process of multi-agency body and integrated network links. Jiang and Chen (2000) build integrated innovation system model and the related evaluation system.

Another way of classifying technological innovation mode is based on the organizations of technological innovation as criteria, including:

a) Independent innovation mode. This model proposes the enterprise as the main body of innovation, independently organizes and implements all technological innovation activities, which rely on their own strength to complete the process of technological innovation

activities. This model requires the enterprise to have strong R & D capabilities, because through the whole process of innovation enterprises need to depend themselves to carry on the activities. Independent innovation model can enable enterprises to take a leading position in the competitive market because it takes some time to imitate and decipher the technological innovations by the competitors. With the intellectual property protection in place, enterprises can become pioneers of the new market and acquire highly monopolized profits for a certain period. Although independent innovation model has the obvious advantage of enterprises, the requirements for the economic strength and technological research and development capabilities of enterprises are often very high and the risks are big. The large multinational corporations with economic and technical strength often adopt this model.

b) Innovation imitation model. This model posits that firms imitate the existing products on the market, use their own technology for the innovation activities and produce products to meet or exceed the technical level of the existing products. The mode first requires enterprises to decipher the imitated products and then make technological improvements. So the imitative innovation products can become more competitive in the market. Imitation innovation model has low cost of R& D and low risks, but subject to the constraints of the patent system. Imitative imitation does not mean to infringe the intellectual property of others, but rather conduct the second innovation on the basis of others, by which enterprises implement the innovation through absorption, digestion, and innovation. Many Japanese enterprises have experienced the imitative innovation processes.

c) Collaborative innovation mode. This model is that enterprises form technological alliances with other enterprises or research institutes. The aim is to make use of technical advantages of each other to jointly complete the technological innovation activities. With the fast development of science and technology and social progress, some enterprises do not have sufficient technological innovation capacity to independently deal with more complicated and high risk products, so they need to set up technological alliances with other enterprises to share technical resources and risks to complete the technological innovation activities and share the economic benefits brought about by the technological innovations. Currently, in some high-tech fields, this model is increasingly common.

d) The model of innovation introduction. This model states that enterprises digest and absorb the patents or proprietary technology purchased from other enterprise for their technological innovations. This model is a shortcut for enterprises to rapidly improve the technical level and narrow the gap with the world’s advanced level of technology. However, it

is noted that this model is used to introduce the foundation of a technology. It is more important to digest, absorb and re-innovate the introduced technology.

e) External innovation mode. This model is that enterprises set up research and development institutions in other countries, use the local technological resources, human resource to conduct technological innovation activities. With the increasing globalization of the world economy, the competition among firms is getting stronger. Enterprises not only compete for production resources and markets, but also compete for technological resources and human resource. Many enterprises have begun to set up research institutes in countries with rich resources in technology and human resources. This model has become a new trend for future enterprise technological innovation activities. Some Chinese companies such as Haier or Changhong, have started this trend.

Peng and Hu (2011) divide the organizational pattern of technological innovation into seven types: market, non-equity alliance, venture investment, small amount of holdings, joint ventures, mergers and acquisitions, and integration. In terms of technological innovation of entrepreneurial enterprises, Mei and Long (2012) examined the relations between entrepreneurial capability and innovation types. They divided entrepreneurial capability into opportunity capability and operational capability, and innovation types into radical innovation and incremental innovation.

2.4 Summary of literature review and implication

From the literature review of the theory on entrepreneurial enterprises, resource-based view, innovation and technological innovation theory, we can conclude as follows:

First, after several decades of development, the resource and capability theory has integrated the range of mature classic theories. Resource and capability impact the competitive advantage of enterprises and also determine enterprise's strategic behaviors. In spite of the progress in both theories, it is necessary to integrate the resource and capability theory with other theories to interpret the new phenomenon and to raise new theories so as to expand the room for research from new perspectives of resource and capability.

Second, has study of entrepreneurship has become a hot area of study for the academia. By reviewing the entrepreneurship theory, we found that most studies focus on the concept and essence of entrepreneurship, entrepreneurial opportunities and process of entrepreneurship, while the studies on selection of technological innovation and resource

integration management are relatively few. However, for high-tech entrepreneurial enterprises, technological innovation is an unavoidable question.

Therefore, this research will be based on the technological innovation strategy of entrepreneurial enterprises and the features of entrepreneurial enterprises to analyze the selection criteria of technological innovation from the angle of resource and capability. The study involves disciplines such as strategic management, industrial organization, innovation theory and economics. In addition, we use and extend the above theories to formulate the main contents of the study.

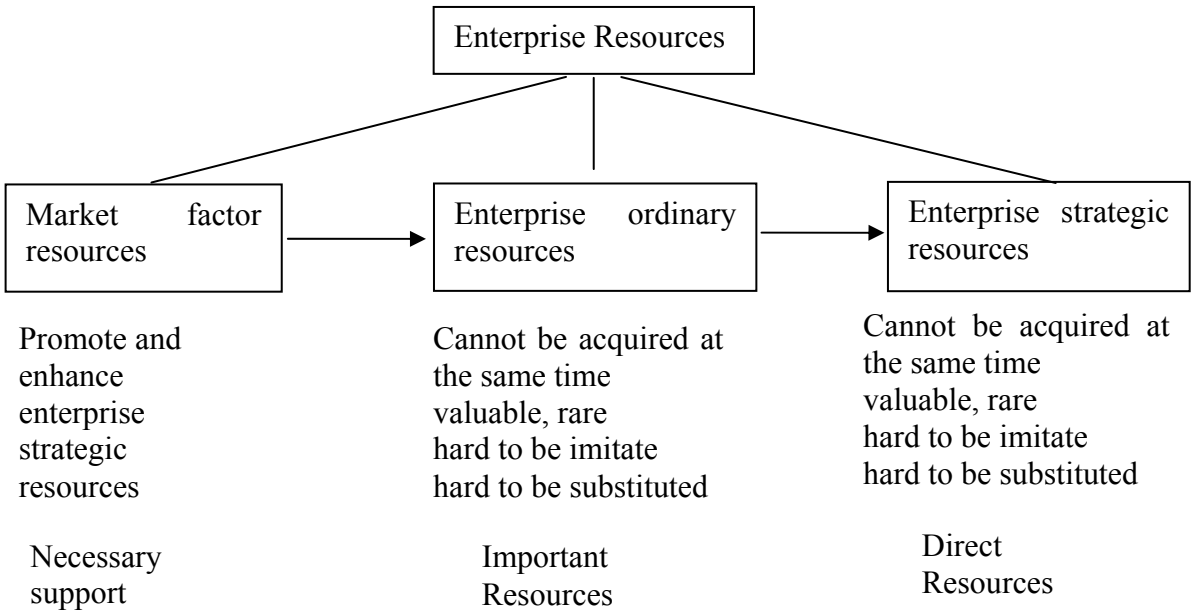
2.5 Theoretical framework of the study

According to the resource-based view, the enterprise is the aggregation of recourses, which vary from enterprise to enterprise. The heterogeneity of resources leads to the differences in terms of enterprise competitive advantage and business performance. For entrepreneurial enterprises, the entrepreneurial process must be based on a certain kind of resource or a combination of resources. Enterprises are restricted by their own resources and capabilities in the process of development, during which they must also acquire and accumulate resources and strive for competitive advantage. Therefore, on the one hand the strategic behavior of entrepreneurial enterprises is constrained by its governable and available resources and capabilities, and on the other hand the strategic behavior of the enterprises is to acquire the necessary resources and capabilities.

As explained by the existing research, resources are divided in different dimensions with infinite variety of classification and forms of expression. In this thesis the resources for acquiring technological innovation advantages of the enterprises are divided into three categories according to the dimensions of ownership of resources and the heterogeneity and incomplete mobility of resources (Barney, 1991; Peteraf, 1993). The first category is about the resources with heterogeneity and incomplete mobility, which are owned by enterprises; the second category is about the resources without heterogeneity and incomplete mobility, which are owned by enterprises; the third category is about the resources without heterogeneity and incomplete mobility, which are not owned by enterprises. The thesis refers them as strategic resources, ordinary resources and market factor resources (Figure 3-1) respectively. Strategic resources, among others, are vital for enterprise development and need to have the characteristics of VRIO (valuable, rare, inimitable, and organizable). The resource-based

theory indicates that core resources with heterogeneity are the key since competitive advantage and strategic behaviors are constrained by resources. For entrepreneurial enterprises, technological innovation selection is also restricted by resources due to their small scale, usual lack of resources and little accumulation of social relations.

It is pointed out that in different stages of enterprise development the resources owned and needed by the enterprises are different. Resources needed by young entrepreneurial enterprises are different from those of mature enterprises. For example, the financial strength of young entrepreneurial enterprises is obviously not as strong as that of mature ones. Moreover, strategic resources, ordinary resources and market factor resources not only vary from enterprise to enterprise, but also from stage to stage of development. For instance, human resources and technological resources are emphasized in the entrepreneurial period while market and customer resources are more important in the growth stage. The vital task for strategic management is to identify the key resources and their development, and then to foster and promote those resources besides of building an efficient growth path for the small and medium-sized entrepreneurial enterprises. See Figure 2-1.



Source: The figure is a summary by the author

Figure 2- 1 Three types of resources

As per Figure 2-1 resources are divided into three types. Strategic resources, the direct source for acquiring competitive advantage, are valuable, rare, and hard to be imitated and substituted, while ordinary resources are the necessary support for enterprises to gain competitive advantage. Of course, the division in three types of resource is not absolute since an interrelationship exists among them.

Compared with the static analysis of resources, the capability-based theory examines enterprise strategy in a more dynamic view. In China, as we have mentioned before, quite a few scholars have studied the capability and competitive advantage of entrepreneurial enterprises or small and medium enterprises, such as the relationship between the competitive advantages and the research and development capability, manufacturing capability, marketing and organizing capability. Dynamic capability makes enterprises to produce new products and process and to deal with the ever changing environment and therefore the core competitiveness formulated in the development of the enterprise is the source of their competitive advantage.

Similar to resources, enterprise capability is a concept with wide denotation. The analysis of this thesis is mainly based on entrepreneurial and innovation process, which is corresponding to the research topic. Generally, the process of technological innovation includes research and development, product design, manufacture, commercialization and so on. The capabilities involved in the thesis include the investment, research and development, manufacture and marketing as mentioned in Table 2-5.

The evaluation on the technological innovation of enterprises requires a multiple-level index system and an analysis of the causal effect relationship among the evaluation index. The division and selection of indicators of the technological innovation capabilities vary with each individual. Generally, the components or process of the technological innovation capacity are used to be the evaluation indicator and the factors influencing the components and process are used as the second-tier evaluation indicators, which can be subdivided according to the specific requirements.

It is noteworthy that in the previous study of enterprise technology innovation process, each capability factor (capability evaluation indicators) in the process of technological innovation was considered to be independent from each other. In fact, a certain indicator may have influenced other indicators. The studies indicate that in addition to the direct impact of each capability evaluation indicator on the technological innovation capability, the research and development capability is closely related to the investment in funding and human resource of technological innovation and the innovation management of the enterprise, which to a certain degree determines the product competitiveness in the market.

Currently, research on innovation, especially technological innovation, is always about large and existing enterprises. Less research has been made on the small and medium-sized enterprises and young entrepreneurial enterprises. However, with the development of the

knowledge economic era, innovative behaviors of young entrepreneurial enterprises have been gradually increased as more new enterprises and new businesses relying on technological innovation are being established. However, they encounter many problems such as lack of market resources, network resources, quality and reputation and many choose to form strategic alliances to seek high growth (Zhao, 2012).

Table 2- 5 Evaluation index of enterprise capability for innovation

First-Level Indicators	Secondary Indicators
Investment capacity	Capital Investment Strength
	Labor Investment Strength
Research and development ability	Innovation consciousness
	Personnel structure
	Program technical structure
	Program Management Capability
Production capacity	Technical level of production equipment
	The technical level of the production personnel
	Production management level
Marketing ability	Market response
	Competitiveness of new product
	The profitability of new products

Source: The table is a summary by the author

Table 2- 6 Technological Innovation Models

Model	Content
Independent Innovation	Research and develop reply on its own capacity, acquire pioneering technical achievement, possess related intellectual property and monopoly advantage. Common in high-technical enterprises.
Imitative Innovation	Change and imitate at the basis of existing advanced technology, always employed by minor enterprises and easily restricted by intellectual property.
Cooperative Innovation	Enterprises produce own superior resources, cooperate for technical development and share achievements. Widely applied under the uncertain economic background.
Technical Acquisition	Purchase of advanced technology for manufacture and sale and promotion of technical level. Always adopted by large companies that are technically mature.

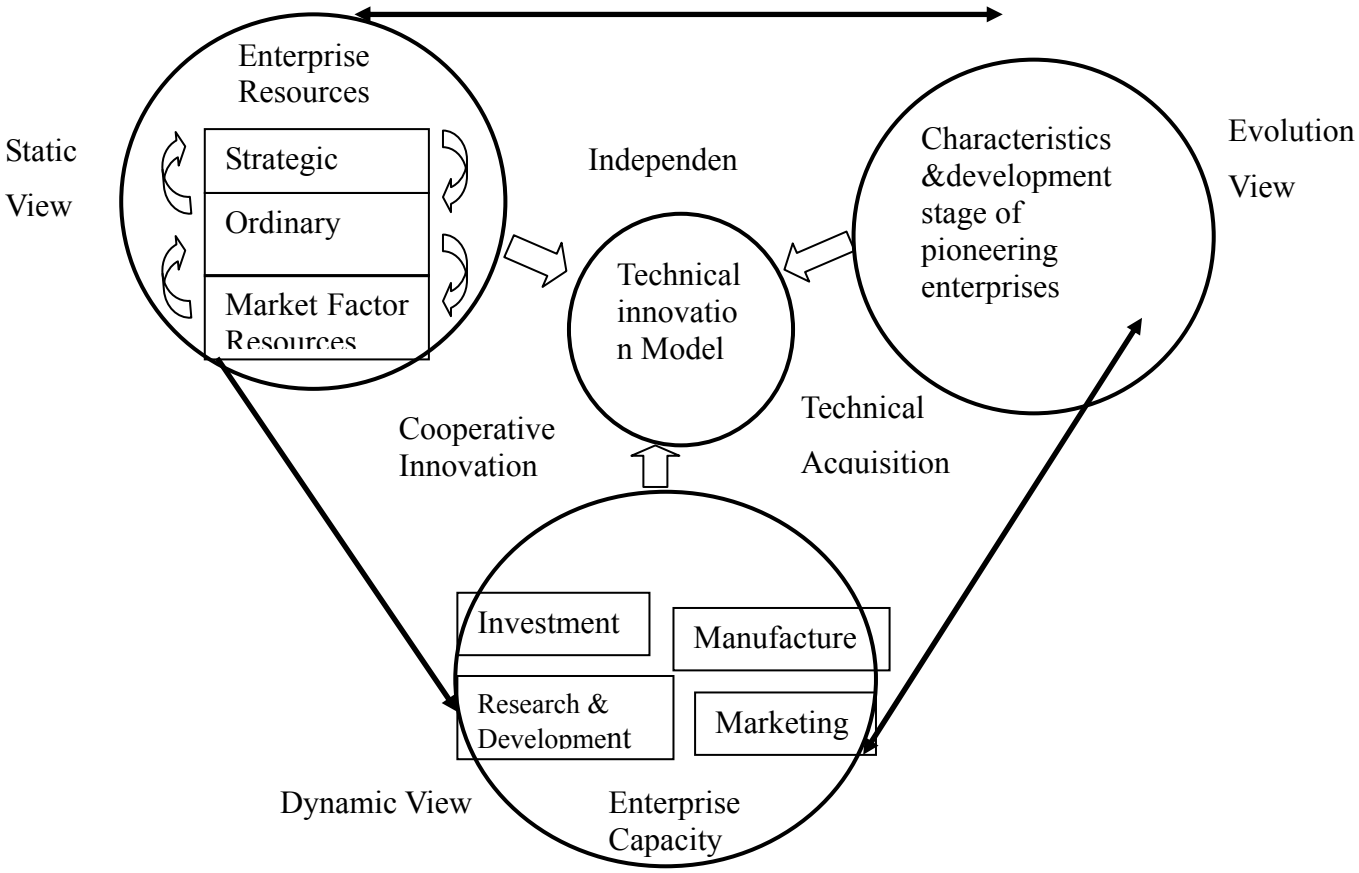
Source: The table is a summary elaborated by the author

As illustrated in this literature review, classification and model of technological innovation varies with different dimensions of analysis. The thesis selects the innovation models based on technical organization, including independent innovation, cooperative

innovation, imitative innovation and technical acquisition of innovation. Dimensions of analysis are chosen because different innovation models are common for Chinese enterprises and reflect technological innovation practices and, in addition, they are highly recognized by the academic world. It is therefore of more practical significance to adopt technological innovation models to study the entrepreneurial enterprises and Table 2-6 illustrates the comparisons among such innovation models.

In previous years, many Chinese enterprises adopted the approaches of technical acquisition or imitative innovation. Though much progress has been made, the development of related industries is still behind that in relation to developed countries. For an enterprise and even an industry, core competence is necessary for achieving a long-term development and securing competitive advantages. Therefore, an increasing attention has been paid in China to the cooperative innovation and independent innovation both by enterprises and government. The Chinese government put forward the policy that science and technology are the foundation underlying all of our efforts to build China as and innovation-oriented country and thus encourages enterprises, especially emerging industries, to carry out independent innovation. In the latest industrial planning, China clearly stated the innovative direction of green lighting industry as well as the guarantee measures to promote it.

Through making a summary of related theories and literature review, we propose the following research thoughts (see Figure 2-2). First, we argue that the selection of technological innovation of entrepreneurial enterprises is influenced by their resources, capabilities and by the characteristics of the enterprise. The specific selection is a result of combinations of three factors: enterprises resources, including strategic, ordinary and market factor resources, which are mainly analyzed from a static view and can be transformed into each other under certain circumstances. Enterprise capabilities, especially investment, manufacture, research and development and marketing, are analyzed from a dynamic view perspective and they are not independent. As for the characteristics of entrepreneurial enterprises, more emphasis is put on the growth, development and evolution of entrepreneurial enterprises and on the strategic selection by enterprises seeking competitive advantages. We argue that the innovation models of entrepreneurial enterprises are influenced by the three factors discussed above. As for making choices, we will make an exploratory analysis through a case study.



Source: Elaborated by the author

Figure 2- 2 Theoretical Framework

The thesis uses an exploratory multiple case study through which the following research questions are posed as an extension of Section 1.2 :

（1）What are the characteristics of resources and capability of entrepreneurial enterprises? All enterprises are the combination of resources and capabilities. For entrepreneurial enterprises, their resources and capabilities have gradual features at different stages, and differ from mature enterprises. Even in the same industry resources and capabilities vary from one entrepreneurial enterprise to another due to the difference in their respective background and those of their teams.

（2）Would resources and capability effect the technological innovation selection? If so, how do they affect it? Since they may influence strategic behaviors and competitive advantage, innovation must be influenced as well. The relationship among different resources, capabilities and innovation model is the focus of our study.

(3) Is there any general pattern and framework for the selection of technological innovation? Based on the analysis of enterprise resources and capabilities and on the selection of

technological innovation, the study will explore the internal relationship among resources and capabilities, characteristics of entrepreneurial enterprises and technological innovation modes.

Taking the LED industry as the research subject, our study tries to find answers to the questions above by conducting case studies on three companies in this industry.

Chapter 3: Research design and method

To sum up and as discussed in the previous chapters, the study of development strategies of entrepreneurial enterprises has become an academic hot topic. As one of the mainstreams of strategy, the resource and capability theory can best explain entrepreneurial behaviors of enterprises. However, it is rare to find research that focuses on technological innovation selection of entrepreneurial enterprises, especially research relating to the technological innovation model from the resource and capability perspective. This study considers this research gap to further examine the technological innovation selection of entrepreneurial enterprises facing constraints of research and capability.

3.1 Research Methodology

The thesis extensively involves multidisciplinary theory of economics and management, including the theory of corporate resources and capabilities, entrepreneurship theory, technological innovation theory as it has been expounded in the previous chapter. The thesis tries to understand and absorb the latest research results at home and abroad. On the basis of qualitative analysis, the study constructs a concept analysis model of technological innovation selection based on the resources and capabilities for the subject entrepreneurial enterprises.

3.1.1 Case study method

Through the analysis of the relevant literature of case study method, the thesis adopts the case study as the main research method. Through research design the case study method aims at answering “what is it like?”, “why is it?” and “how” questions. Unlike the large sample study of statistics inductive logic, case study follows the analysis of uniqueness, which uses its own research process. This study adopts multiple case study method by which secondary data and interviews will be employed to analyze the impact of corporate resources and capability on the technological innovation within the green lighting industry.

The case study method is commonly used in the field of sociology, psychology, and management studies. Relative to quantitative analysis tools, case study can implement an in-depth analysis on individual cases to prevent the influence of prior research and existing

literature. Thus, it is easier to form a new research perspective and theoretical perspectives (Eisenhardt, 1989). In general, case study is the best choice when there is a need to provide new insights into existing research topics or provide a new perspective, or when there is a need to construct a new theory by combining the literature with a new phenomenon, or when researchers take the initiative to ask questions. As our study is to analyze the technological innovation selection of entrepreneurial enterprises with resource and capability constraints, we believe that the use of case study is an appropriate method.

The case study concerns with what is happening or has happened and case study materials can be obtained from the direct observation of events or the interviews with event participants. However, the researcher of case study cannot control either the study objects or the events.

Theory not only plays a role in the explanatory case study but also is important to multiple case studies based on replication rule. Whether it is a single case study or multiple case studies, research using this method may be classified into the exploratory, descriptive and explanatory case studies (Bassey, 1999; Yin, 2004). The use of exploratory study is more suitable for a problem that is not clearly defined. This method can provide the basis for research. Descriptive case study is to describe the case in details for the further study while explanatory case study is to depict the causal relationship among the phenomena. No matter which method is adopted, the principles of being scientific, normative and rigorous must be followed. Table 3-1 synthesises this classification.

Table 3- 1 Classification of Case Study

--	**Exploratory**	**Descriptive**	**Explanatory**
Single case study	Exploratory Single case study	Descriptive Single Case study	Explanatory Single Case Study
Multiple Case Study	Exploratory Multiple case study	Descriptive Multiple case study	Explanatory Multiple case study

Source: Chen Xiaoping, Xu Shuying, Fan Jingli (2008)

The present study adopts a multiple case study. Single case study can be used to confirm or challenge a theory and can also be used to investigate unique or extreme cases while the essential characteristic of multiple case study is that it includes two analysis phases: individual case analysis and cross-case analysis. The former considers each case as independent for a comprehensive analysis, and the latter takes all cases for a unified abstraction and generalization on the basis of the former analysis, and then come to a more incisive description and more powerful explanation.

The multiple-case studies follow the replication method rather than sampling rule. For

each case of the multiple case study, the same result and conclusion can be either produced (i.e., itemized copy) or different result is made due to the different factors (differentiated copy). In the process, the most important task is to form and establish the theoretical framework.

We will employ multiple approaches to increase the scientification of the research and be concerned with the following aspects:

(1) Validity – First, the case studies use a variety of sources of evidence. The evidence includes the official statistics and reports as well as the internal files of three companies. For the main issues, we also conducted interviews (see Table 3-4) to learn the background of technological innovation projects and their implementation. In the course of writing the case study we made efforts to form a coherent, strong logical chain of evidence to enhance the construct validity. In addition, for the case database arrangement and selection, we also sought the views of the company’s employees to ensure the authenticity of the case material as well as the applicability of the data. For the theoretical explanation and causality analysis, we made efforts to seek support from the existing theories and to improve the internal validity of the study by following the logic and reasoning among the incidents.

This study takes three green lighting enterprises as its research object. Through a multiple case analysis, we will explore and reveal the mode selection of technological innovation of these entrepreneurial enterprises. The replication rule of multiple cases enhances the external validity of the thesis. Three companies in the upstream, midstream and downstream industry chain, in technological innovation go on three different paths, are all in the start-up phase of the industry. The selected three cases can represent the characteristics of the vast majority of green lighting industry start-ups. The analysis contexts in the thesis can be replicated and promoted, which has implications for the development of entrepreneurial enterprises in terms of technological innovation selection and obtain of resources.

(2) Reliability – The reliability of the case study is looked for through the repeatability in the research process with the aim to reduce the errors and biases in the study. For such purpose multiple sources of data have been used including: company documents, files, research reports and interview records.

Data collection started in 2010 when we have prepared the preliminary work through contacting the related corporations and organizations. It took two years to complete the case studies.

3.1.2 Major research procedures

Case study is the main research method used in our research and it includes the following steps:

Case selection (the research objects)

In the case study we selected the research objects taking into consideration the research topic. The study selects three companies in the green lighting industry.

The first company is Grand Technology Co. Ltd. Founded in 2006, the company mainly offers solutions to the downstream LED application. In recent years, the company has developed very fast though it is still in the entrepreneurial stage.

The second company is Kingsun Optoelectronic Co. Ltd. The company was set up in 1993 and started the LED business in 1998. In the year of 2011, the company was listed in the stock market of Shenzhen. Until now, it has become the largest R& D and production base of semiconductor lighting products. Similarly to Grand Technology. Kingsun also concentrates on the downstream of the industry chain.

The third company is Sanan Optoelectronic Co.Ltd. The company is one of the largest green lighting enterprises in China. The company's businesses are positioned at the upstream of the industrial chain, which mainly involves the R & D in LED epitaxial wafers, chips and high-power concentrating photovoltaic products.

The three companies were chosen for the research based on the following considerations:

First of all the three companies can represent the characteristics of the green lighting industry start-ups. Though Kingsun and Sanan are listed on the stock market, the green lighting business is new to them. So the study mainly analyzes the behaviors of the entrepreneurial stage. In addition, the three companies have their businesses at different stages and segments of the LED industry chain, which can better illustrate the whole industry of LED lighting.

Second, in order to integrate the theories of our study, we made a careful consideration on the selection of cases and theoretical construction to enhance research validity. The difference of the three companies in terms of resources, capabilities and innovative behaviors corresponds to the theoretical framework we proposed. So we can make a theoretical analysis on the basis of the case study.

Finally, we selected the three companies for the research convenience and continuous

tracking. The author has been involved in the lighting industry for more than ten years, and thus acquired a rich experience and knowledge of the industry. Knowing about the three companies also enabled to have easy access to their data.

Data Collection

In order to enhance the credibility of the study and provide evidence for the theoretical construction, the study adopts multiple methods to collect the data. In terms of the secondary data, we collected a large amount of industry reports, macro-data, corporate documents, meeting minutes. At the same time, we have carried out in-depth open interviews for collecting data related to the research topic.

Data collection was completed with macro and industry data, and data collection from the three companies. The data collection is detailed in Section 3.3. Through case data collection we established a database of case studies and formed several evidence chains, which gives support to the subsequent data analysis.

(3) Data analysis

Based on the information and data collection, we analyzed the data for the case studies, which is the core work of the study.

We have adopted the following analysis paths. First, we relied on the theoretical propositions. Case studies are not isolated; they need to be linked to the relevant theories. While analyzing the data, we gave a full consideration to the role of the existing theories, on basis of which we developed the theoretical logic to form hypothesis or premises. Second, we developed the case description. Each case study is a relative independent event. By analyzing each case, we can obtain the partial reasons for the technological innovation behaviors under the resource and capability constraints of entrepreneurial enterprises. Third, we summarize and make conclusions on the basis of the multiple case studies. The scenarios of the three companies are different, so the methods of mode match and differential replication of case study were adopted to make the analysis, hence increase the scientification of the conclusions.

(4) Writing the thesis

The presentations of the case study results can be with a large degree of flexibility without a standard or unified report form. However, in the field of social science research, the case study process is often required to match a given format. Case study research report is divided into several independent parts: (1) background introduction, (2) description and analysis of specific issue and phenomenon, (3) analysis and discussion, (4) summary and

suggestions.

Cast study has many advantages, including the emphasis on qualitative research, detailed in-depth description, focus on the individual study. Through searching a wide range of information and stressing a comprehensive analysis, we can draw relevant conclusions.

3.2 Data collection and process

3.2.1 Data collection

The case study method adopts varied channels and methods to collect data, providing data sources in many ways. In this study we adopt the following methods to collect the related data.

Literature review

Literature review includes the reading of papers and books on related theories, industry reports on green lighting, industry analysis data, and development report offered on newspaper and internet and business bulletins.

Related data about green lighting industry was obtained with the support of China Illuminating Engineering Society, China Semiconductor Industry Association and China High Technology LED.

China Illuminating Engineering Society, founded on 1st June 1987, is the first level society belonging to China Science and Technology Association. In the same year, China National Commission of Illumination joined the International Commission on Illumination (CIE – Commission Internationale de Éclairage) and became the only organization representing China in CIE.

The main mission of the Society is to conduct academic exchange, technological consultation and training, edit and publish illumination books and periodicals, popularize illumination technical knowledge, promote the academic exchange activities and the relationship of related workers. Besides, the society offers services for enterprises through technological program evaluation and illumination exhibition.

China National Semiconductor Lighting Association (CSA) was founded in October 2004 and was originally advocated by 43 major Chinese SSL enterprises and research institutions. The mission of CSA is to promote technological development and industrialization of lighting, establish resources shared mechanism for upstream and

downstream of lightning industry, research information and intellectual property. Besides, the mission involves establishing a platform for communication with the government, personnel training and international cooperation, pushing forward the establishment of standard, evaluation and quality inspection system, promoting development of member unit and upgrading the competitiveness of lighting.

China's senior engineers LED website is a comprehensive service provider and the strongest partner of LED enterprises, which has been dedicated to the LED industry research, LED product online, LED exhibitions, LED websites and LED printed media.

Table 3- 2 Main reports used for data collection

Name	Copyright ownership	Contents
China's semiconductor lighting (LED) industry investment analysis and forecast report (2010-2015)	Investment Adviser Industry Research Center	Global and China LED industry analysis, major enterprise LED product, introduction, technical development, investment in the future prospects
The Twelfth "Five- year" Special Plan of Semiconductor Lighting Technology Development	The Ministry of Science and Technology of the People's Republic of China	The development goals of the semiconductor lighting technology task
Semiconductor lighting industry analysis report	Business School, Sun Yat-Sen University	The world and China's semiconductor lighting analysis, the factors affecting the development of the Chinese domestic market structure and industry
The Twelfth "Five-Year" Development Plan of Strategic Emerging Industry	State Council of People's Republic of China	The development direction of certain emerging industries, the main tasks and related policies and measures.
The LED project feasibility report	Grand Technology Co., Ltd.	Introduction of certain technologies and projects
Incandescent Eliminating Roadmap	National Development and Reform Commission	From October1, 2012 to 2016, a step-by-step phase-out of incandescent bulbs.
Annual report of Kingsun	Public data of listed company	Performance of the company and major projects.
Annual report of Sanan	Public data of listed company	Basics of the company and performance. Major projects.

Source: Table elaborated by the author

Part of information is collected from lighting industry related websites, including China Semiconductor Industry Association (http://www.china-led.net/csa-index.shtml), China Lighting (http://www.lightingchina.com/) and China LED（http://www.china-led.net/）.

(2) Archival record

Information was also retrieved from the archive records of enterprises in the case studies,

including conference records, work summaries, reports and technological innovation program files. Table 3-3 lists the archive records of the three enterprises in the case studies.

Table 3- 3 Sources of three cases' information

	Document	Other information
Case 1	Business plan (2012), conference record (2008-2011)	GG-LED、China LED website
Case 2	Corporate Annal reports (2008-2011), program proposal (2006, 2011)	Lighting Forum
Case 3	Corporate Annal report (2007-2011), innovation program summary (2010)	Lighting Forum

Source: Summary elaborated by the author

（3）Interviews

Interview is one of the most important information sources in a case study. The purpose of the interview is to collect information related to cases. Frequently used forms of interview are open-end interview, structured interview and semi-structured interview. What is mainly used in the study is open-end interview, which does not mean that the content is arbitrary. What we discuss is about technological innovation mode, therefore the main questions were asked about the basic understanding of the company, such as "what is the background at the starting of the business?", "What resources and capabilities the enterprises did possess?", "How have the enterprises obtained these resources and capabilities?", "How is the background and social relationship between the entrepreneurs and the entrepreneurial team?", "Which technological innovation modes have been adopted?", "What was put into consideration when making technological innovation choices?" "What is the performance of technological innovations?"

Interviewees who first accepted the interviews were the founders or key managers of the enterprises for they have better understanding and deeper thinking about the founding background and development strategy. We also interviewed the employees who had directly participated in technological innovation programs, who provided information about the program process and influencing factors. Tape recording was adopted in the interviews in order to guarantee the integrity of information.

Throughout the data collection process, we tried our best to access as many sources as possible to collect data in order to enhance the reliability of the research and form a complete case study database.

In summary, we mainly used the secondary data collection and interviews in the process of data collection. Through the analysis of the development of green lighting industry and the

interviews with the managers and employees of Grand, Kingsun and Sanan companies, we can further learn the influencing factors and modes of the technological innovation in examples of entrepreneurial enterprises facing resource constraints.

Table 3- 4 Main interviewees and interview content

Intervieweee	Title	Interview Content
Niu	Vice sales manager, Sichuan Grand Technology Co., Ltd.	Basic situation, development strategy, market share, core advantage and independent innovation advantage of the enterprise.
Lin	Technical director, Sichuan Grand Technology Co., Ltd..	Technological innovation mode, innovation program and achievement.
Zhu	Deputy General Manager, Kingsun Optoelectronic Co., Ltd.	Basic situation, development strategy and background and advantage of cooperative innovation.
Guo	Deputy General Manager, San'an Optoelectronic Co., Ltd.	Basic situation, development strategy, technological innovation mode and achievement of the enterprise.
Zhang	Deputy director of electrical power supervision office of Sichuan Province	China's energy policies, current situation and trend of lighting industry

Source: Elaborated by the author

3.2.2 Data analysis and processing

Data processing means the processing methods of the collected data, including recording, sorting out, calculating, analyzing and so on. The processing methods can vary with the different research content and requirements.

The study first adopts the general data statistics and description. Descriptive statistics is used to analyze the data in the document to show the development and business circumstance of the case enterprises in green lighting industry. Because the data was collected from different sources, the difficulties of processing data increased. For the data in the case base, we have conducted a preliminary screening by using EXCEL tool for a simple processing such as classification, sorting, summing and then listing the related data.

Then we encoded and stored the case data. Considering the research questions and objects, we encoded the collected data for use of case study and to facilitate the subsequent evidence collection. Specifically, the study uses A, B, C to represent the three case companies, I, II, III to represent the enterprises' resources, capabilities and technological innovation activities respectively. In addition, D represents the data of the entire semiconductor lighting

industry. For example, The AI represents Grand data resources while CIII represents Sanan's Optoelectronic data in the technological innovation (Table 3-5).

Table 3- 5 coding schedule

Coding	Data Type	Examples
AI	Resources data, Grand	AI-1 number and structure of employees, Grand AI-2 Patents amounts and distribution of Grand
AII	Capabilities data, Grand	AII-1 yearly capacity and production facility, Grand AII-2 foundry vendors, Grand
AIII	Technological innovation data, Grand	AIII-1 Sichuan High-tech Enterprise Certification AIII-2 feasibility report on the second generation of high-power high- brightness LED energy-saving lamps
BI	Resources data, Kingsun Optoelectronic	BI-1 Executives composition of company
BII	Capabilities data, Kingsun Optoelectronic	BII-2 Production capacity
BIII	Technological innovation data, Kingsun Optoelectronic	BIII-1Technological innovation interview information
CI	Resources data, San'an Optoelectronic	CI-1 Patent data
CII	Capabilities data, San'an Optoelectronic	CII-1 Qualification data
CIII	Technological data, San'an Optoelectronic	CIII-1 Patent result and market application
D	Industrial data	D1Analysis on semiconductor lighting industry chain D2 Analysis report on semiconductor lighting industry

Source: Elaborated by the author according to the research and case study

Data analysis was conducted strictly in accordance with the procedures of case study. Focus was given to both the existing theories and the replication rules and mode matches in the multiple case studies.

Chapter 4: Technological Innovation Selection in Green Lighting Entrepreneurial Enterprises

This chapter analyzes three LED lighting companies in China to identify the different models of technological innovation and the criteria of each model selection. Through the interviews, documents and data analysis, the study identifies three types of technological innovation selections under the constraints of resources and capabilities. The findings provide the practical implications about the innovation strategies implemented by Chinese high technological enterprises.

4.1 Current situation of green lighting

Green lighting is a concept proposed by the U.S. National Environmental Protection Agency in the early 1990s. It means using high-performance energy-saving lighting products with scientific lighting design to achieve energy saving, protecting the lighting environment and improve the quality of lighting.

The setback faced by the existing green lighting market is mainly due to the fact that the advances in green lighting technology cannot meet the demand of customers, which leads to the failure of sales. The fundamental reason is the lack of innovation in technology, reliability and high cost of the products. Complete green lighting generally includes four indicators: (i) highly efficient and energy-saving; (ii) environmental protection; (iii) safety; and (iv) comfort. Although several existing lighting products have met the criteria above, usually green lighting industry specifically refer to LED (Light-Emitting Diode) lighting, which is also the main topic of this study.

4.1.1 Features of green lighting industry

So far, the lighting of the human society has gone through four revolutions: the first one is the use of fire, which enabled mankind to bid farewell to the dark ages, though the luminous efficiency of fire is very low; the second one is when The British DE la (1809)produced the incandescent lamp, where the efficiency of the conversion from power to light is 3-5%; the third one is fluorescent, which belongs to the cold light source and the

energy conversion efficiency is 7-11%. Currently, we are in the transitional period of the fourth generation of lighting, i.e. LED lighting.

LED lighting is the trend of the next generation of lighting products. On the one hand, LED lighting has incomparable advantages over traditional lighting with its endurance, high luminous efficiency, and low energy consumption. In addition, the LED industry is in accordance with the current national promotion of energy conservation and environmental protection, and of creating a "green low-carbon life".

LED lighting generally uses low-voltage power supply and it consumes 80% less energy than an incandescent one with equivalent luminous efficiency, so it is very energy saving. In addition, it is more advantageous over traditional lighting in terms of applicability, stability, environmental-protection, and long life cycle (Table 4-1). The problem is that it is currently quite expensive, which has a strong impact on its promotion in the mass market.

Table 4- 1 Comparison of the efficacy of several lightings

Name	**life（H）**	**Luminous efficacy（lm/W）**	**Starting**	**electromagnetic interference**	**environmental protection**
Incandescent	≤1000	15	Quick	No	—
Fluorescent lamp	≤6000	50-70	Slow	Much	mercury pollution
High pressure sodium lamp	≤8000	80-120	Slow	Much	mercury pollution
LED	>50000	100-231	Very quick	Little	Green

Source: The table was derived from the senior engineer LED Journal, the related journals published before September 2012.

In terms of environmental protection, compared with incandescent lighting, LED spectrum does not include ultraviolet and infrared and produces neither heat nor radiation. It is a cold light source and is touchable. Compared with the energy-saving lamps, LED does not contain mercury elements and is typical of green lighting.

Semiconductor lighting (LED), with its advanced technology and wide applications, is considered the most promising high-tech industry in the 21st century. LED has developed from indicator to lighting, which is usually divided into two major areas: general lighting and special lighting. With the increase of the LED luminous efficiency and lighting intensity, LED has reached special lighting, and has gradually entered the field of general lighting. Semiconductor lighting industry has covered many fields, like energy saving, environmental protection, high-tech, micro-electronics and basic equipment manufacturing. The development of semiconductor lighting industry has played an important role in promoting

the development of information industry, automotive electronics, raw materials and equipment manufacturing, consumer electronics, aerospace, solar photovoltaic as well as the entire photonics industry. Many countries provide support to develop semiconductor lighting as an industrial priority.

Currently, the whole world is seeking for a solution to economic development and energy shortage as well as the way to the harmonious development of human society and the environment. Therefore, the semiconductor lighting industry will bring tremendous investment opportunities. In 2011, the power consumption in China reached to 4700 billion KW, increasing by 12% compared to 2010. The power consumption of the world is about 23500 billion KW which is 5 times more than that of China. The power production consumes about 70000 billion standard tons of coal. The adoption of green lighting can save 30% of energy, which is about 21000 billion tons of coal.[20]

As illustrated in Figure 4-1, as an emerging industry, LED has formed a complete layout of the global industrial chain. LED industrial chain, including the upstream epitaxial wafer growth and chip manufacturing industry; midstream industry includes LED devices and LED sealing. LED application belongs to downstream industries. The epitaxial wafers growth at upstream is a key technology, and the largest value-added part. LED applications in downstream industry continue to expand, and constitute the largest market including indicative lighting, traffic signals, landscape lighting, automotive lighting, handheld devices, backlight and general lighting and so widespread adoption of LED lighting.

4.1.2 The current situation of green lighting industry

(1) The Global current situation of green lighting industry

LED lighting seems to be the future of lighting so governments in many countries have introduced a policy of supporting semiconductor lighting industry, which banned the use of high-energy-consuming lighting products, and announced the phase-out of incandescent bulbs across the world (Figure 4-2).

[20] China Statistic Bureau, published on Feb 22, 2012.

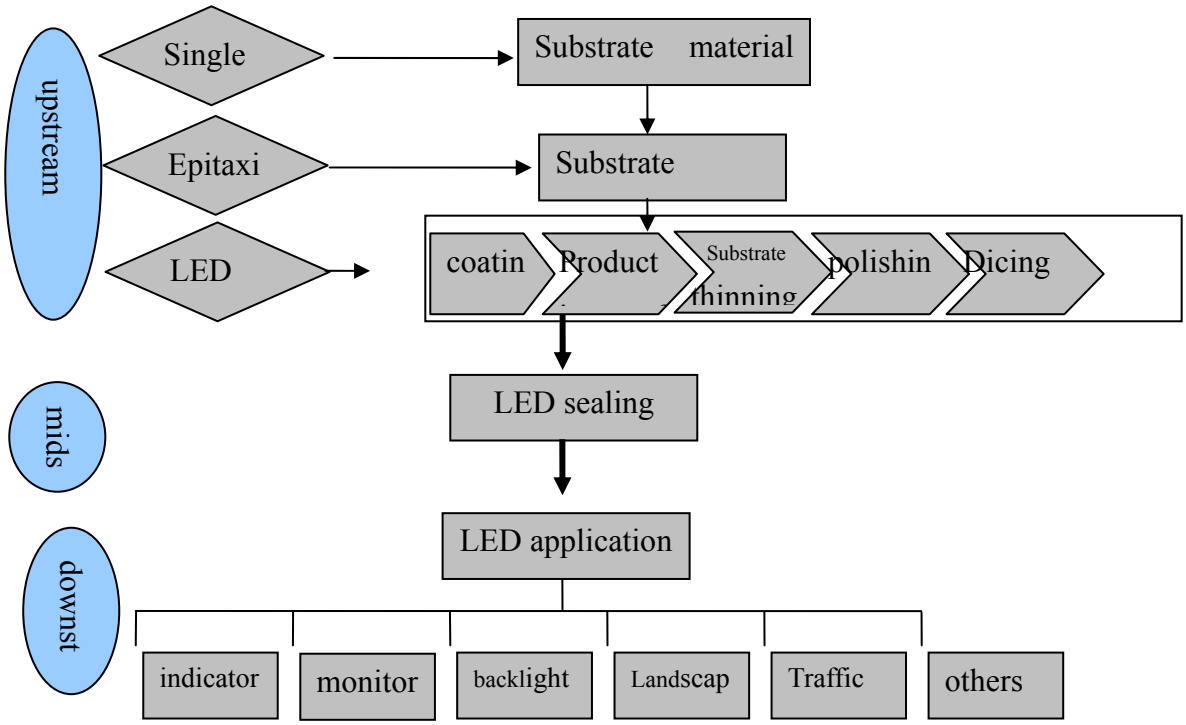


Figure 4- 1 LED lighting industrial chain

Source: Liu Zhihui, The Analysis Report of Semiconductor Lighting Industry (2010)

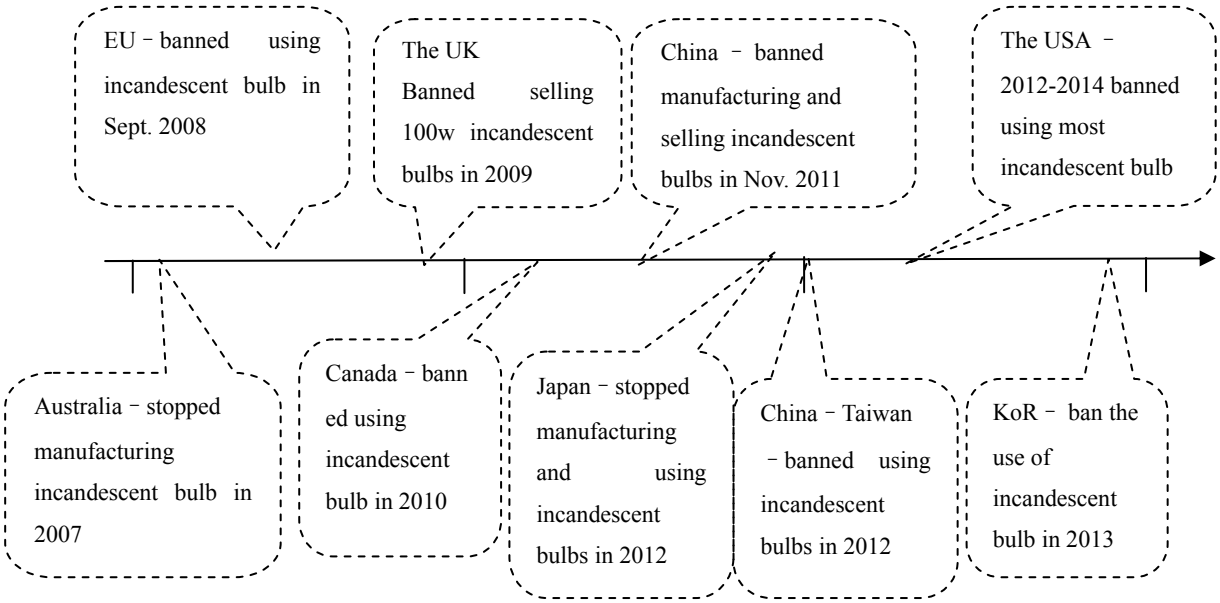


Figure 4- 2 Time of banning the use of incandescent bulbs in different countries

Source: DIGITIMES, 2012/12

According to a market research report released by McKinsey, the next 10 years LED market share will rise to 65 billion Euros in 2020 thus envisioning broad market prospects for the global LED lighting industry.

Table 4- 2 2010-2020 LED backlighting, automotive lighting, as well as the proportion of the general lighting and revenue forecasting

Projects		2010	2016	2010-2016 CAGR	2020	2016-2020 CAGR
LED backlighting	Ratio	47%	98%		100%	
	Value of output	2 billion Euro	4 billion Euro	13%	2 billion Euro	-16%
LED automotive lighting	ratio	12%	20%		34%	
	Value of output	2 billion Euro	3 billion Euro	15%	6 billion Euro	16%
LED general lighting	Ratio	7%	43%		64%	
	Value of output	3 billion Euro	33 billion Euro	46%	56 billion Euro	15%

Source: The Industry Research Center of China Investment Consultancy, The Analysis Report of Semiconductor Lighting Industry (2010-2015)

Since 2010, the global LED general lighting has been developing rapidly. Many countries introduced policies to promote its application, among which the most outstanding policies are the eco-point system in Japan and the Energy Star certified products subsidy system in the US. [21] China has a large lighting industry so the government attaches great importance to the development of LED lighting industry. China is catching up with the pace of the global industrial development, the relevant national industrial policy came to emerge and the support efforts are gradually increasing.

Currently, the semiconductor lighting industry has formed the competitive landscape of three regions, where the United States, Asia and Europe led the three pillars of the industry. Cree and Lumileds in the US, Nichia, Toyoda Gosei in Japan and Osram in Germany have dominated the monopoly market of high-end products. From the competitive landscape of the industry organization, it is basically formed by the monopolistic competition of these five major industrial giants that own most of the core LED patents, and occupied the high-end of the upstream industry, have obtained the most profitable part of the LED industry chain, and are enjoying the most favorable position in the competition in the industry chain. With their strengths of innovation in new products and new technology, enterprises in Japan and the USA are mainly engaged in the production of the highest value-added products while the European companies absorb and convert the latest technology in the field of applied

[21] ENERGY STAR ENERGY marking plan is by the U.S. environmental protection agency (EPA), launched in 1992, aims to help consumers choose and buy higher ENERGY efficiency of appliances products, in order to achieve the ultimate goal of protecting the environment.

technology development and are mainly engaged in production of high value-added products. China Taiwan LED industry, in recent years, is enjoying a rapid rise of its chip production and sealing, which is ranked the first place in the world (taking more than 60% of business in the world). However their products, like red or yellow chip or sealing are mainly middle- and low-end products. Chinese mainland market has also been developing rapidly and has become an important force in the global market.

The current situation of green lighting industry in China

LED industry in China started in the 1970s. After 30 years of development, China's LED industry has initially formed a relatively complete industrial chain, including the production of LED epitaxial wafers, LED chips preparation, LED chip sealing and LED product applications. The number of people engaged in the green lighting industry in China amounted to more than 50,000 people, and more than 20 research institutions, 4,000 enterprises, including more than 50 upstream companies, over 1,000 sealing companies, over 3,000 enterprises downstream applications are involved in LED lighting industry (2010).[22]

Chip production is capital and technology-intensive. In China, only a small number of enterprises have a strong technical advantage and financing capabilities so the degree of industrial concentration is high. Sealing and application has been developing rapidly in China, which in terms of production or technology gap, are significantly better than the upstream epitaxial materials and chip preparation link. It is estimated that worldwide 80% of the number of LED device sealing are conducted in China in various types of US-owned, Taiwan-funded, Hong Kong, or domestic sealing companies.[23]

LED industry in China has initially been formed in four regions, such as the Pearl River Delta, Yangtze River Delta, Fujian Triangle (Southeast), Beijing and Dalian and in each region there is a relatively complete industrial chain. As an emerging industry, China's green lighting is also facing some problems. First, the size of the industry and of the enterprises is comparatively small, and need to be developed; they are dependent on the supply from foreign countries in terms of the core equipment and raw materials; in addition, they lack high-end technology.

In 2011, China's LED industry output value reached 154 billion RMB and is expected to

[22] In-depth analysis of China LED Greeen Lighting Industry Development, http://www.cnledw.com/info/newsdetail-14905.htm

[23] The current situation of China LED Sealing Industry and its Prospects. http://www.chinajnhb.com

reach 200 billion RMB in 2012. The data shows that from January to July in 2012, China plans to add 125.6 billion RMB totally in the investment in LED industry, of which more than 40% of the funds are invested in a number of industry sectors, or even the whole industrial chain. It needs to pay attention to the fact that the investment from non-LED enterprises has become an important part of the LED industry investment and such projects accounted for 45% of the ratio of the total investment, and counted more than 65% of the total investment. [24]

Figure 4-3 shows that the Chinese semiconductor lighting is "located" in a favorable industry environment. In terms of the economic environment, LED market prospect is broad and the supply and demand will continue to increase. The downstream application areas will further expand and the cost of production and sales of LED products will further reduce. In terms of the policy environment, the Chinese government has introduced a number of policies to actively support the development of the LED industry. The local government is investing greatly in the relevant infrastructure. For the public, energy-saving and environmental protection has gained the popularity of the new generation of lighting. In technology, enterprises gradually emphasize on technological investment and have made a breakthrough in some technologies and have significantly enhanced international competitiveness, though on the whole Chinese technology still lags behind that of Europe and the United States.

It is expected that in the next few years, LED lighting, while growing as a whole, the overall industry is also facing integration problem and the competition will be more intense. In particular, some small-sized enterprises that lack core competencies will be merged or kicked out of the LED industry.

Attaching importance to promoting the development of key areas across China's 12th Five-Year Plan, energy saving, and environmental protection has become one of the focus of the development of strategically emerging industries. In October 2010, the General Office of the State Council issued the decision of the State Council on accelerating the development of strategic emerging industries and semiconductor lighting was categorized as one of the seven strategic emerging industries; National Development and Reform Commission, the Ministry of Housing, the Ministry of Transport jointly carried out a demonstration project of semiconductor lighting products, and organized public tender in September 2010. Subsequently, the Ministry of Science and technology launched semiconductor lighting

[24] the senior engineer LED Journal ， Nov.2012. http://www.gg-led.com

technology support plans and 863 plans during the"12th Five Year Plan”, which provided a comprehensive plan of technology R&D, and the detection method research, testing platform construction. Currently, semiconductor lighting has been included in the "12th five-Year Technology planning” focusing in the field of special materials. In addition local governments have formulated a development plan of the semiconductor lighting industry and have introduced relevant policies. At the end of 2010, the Development and Reform Commission started the “12th five year plan” semiconductor lighting industry planning that brought the financial subsidies policy to the agenda.

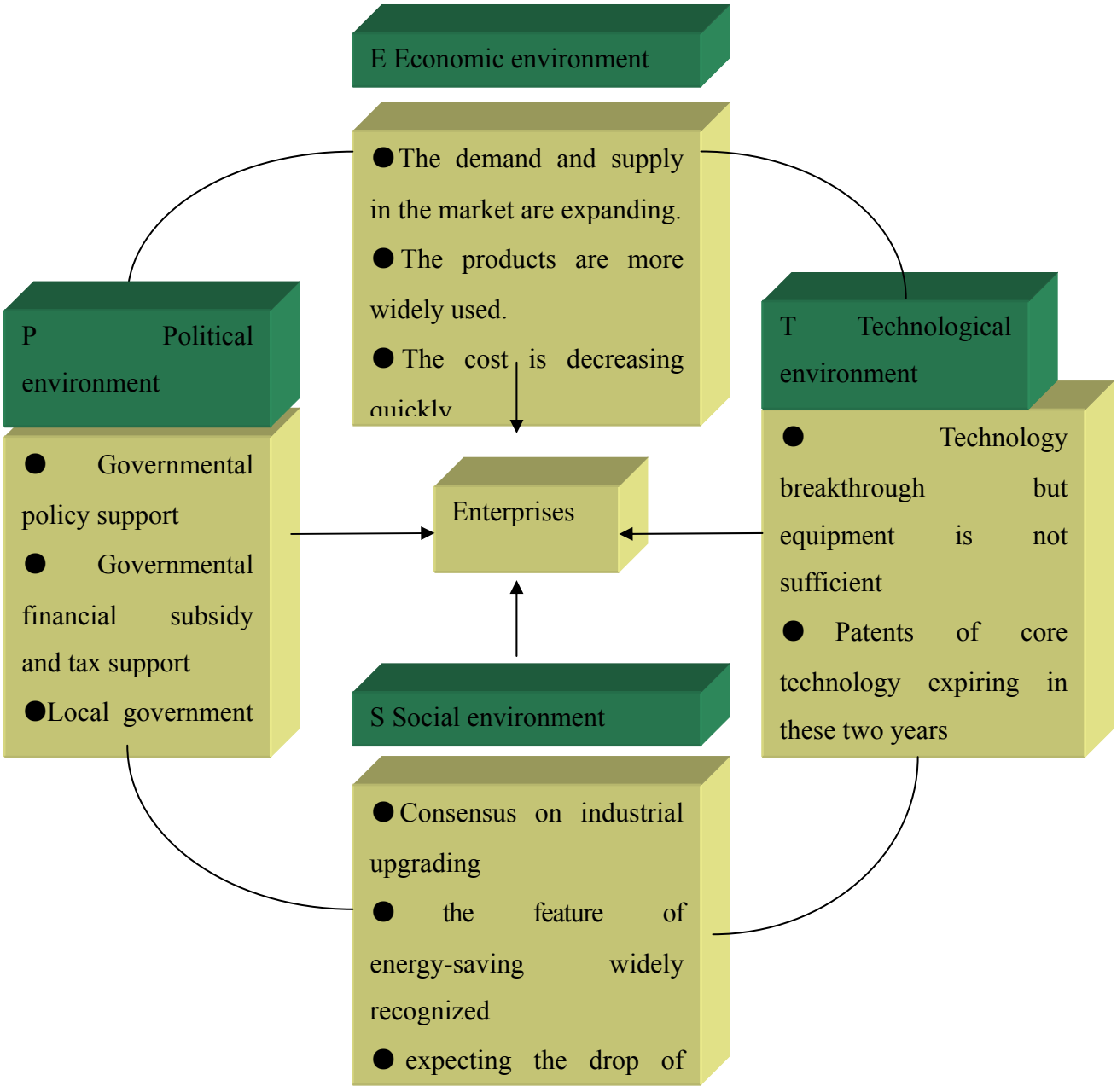


Figure 4- 3 External environmental analysis of Chinese LED industry

Source: Liu Zhihui, The Analysis Report of Semiconductor Lighting Industry (2010), adjusted by the author

In 2011, more favorable policies that can facilitate the cultivation of the market began to be rolled out, among which the most influential one was the releasing of a "roadmap of phasing out incandescent lighting" in November 2011, saying that from October 1, 2012, China would begin to phase out high-energy- consumption lighting products. That means that the phasing-out of high-energy- consumption lighting products was supported by national regulations.

In June 2012, the State Council has issued a notice on the energy-saving and environmental protection industry development plan in the "12th five year plan", which required the integration of existing resources and improvement of industrial concentration to achieve the industrialization of semiconductor lighting technology and equipment. Then, efficient green lighting products were defined as the second ones to be targeted to develop in the field of the energy-saving industry. This will give energy-efficient LED industry a huge impetus pushing the development of LED lighting products.

"The planning" advocates the gradual promotion of semiconductor lighting products. In 2015, general lighting products market share of LED lighting will reach 20%, the LED backlight more than 70%, landscape decorative products more than 80%, and the semiconductor lighting industry output value will reach 450 billion RMB with an annual saving of power of 60 billion kwh and an internationally competitive semiconductor lighting industry will be formed in China.

According to "the planning", the integration of existing resources and the improvement of industrial concentration are fundamental to achieve the industrialization of semiconductor lighting technology and equipment industry. To this goal it is essential to cultivate 10 to 15 leading enterprises in China which own core technology and independent intellectual property rights and well-known brands; the critical production equipment and important raw material should be localized and high-end applications products should meet the standards of world advanced level; an international-standard detection platform should be built and emerging semiconductor lighting industry area with complete industrial chains and innovation ability as distinctive characteristics should be constructed.

On July 11, 2012, the Ministry of Science and Technology of China issued a special plan on the development of semiconductor lighting technology during the 12th Five-Year-Plan. Obviously, green lighting industry has received consistent concern of the government. The same Ministry further improved the semiconductor lighting industry goal raising the targets that had been set before: the scale of the industry will reach 500 billion RMB; the government

will nurture 20 to 30 leading enterprises with core technology; and more independent intellectual property rights and their own brands would be promoted. In addition the government will support 40 to 50 innovative high-tech enterprises and build 50 pilot example cities and 20 industrialized bases with strong innovation capability and the distinctive characteristics to improve the industrial chain, optimize the industrial structure, increase market share, and enhance the international competitiveness of Chinese semiconductor lighting industry.

Although China's LED lighting industry is facing unprecedented opportunities there are still many problems. The current LED lighting industry in China is mainly dependent on the international markets and nearly 70% of its products are sold in Taiwan and overseas markets. As the uncertainties of the current international economic situation are getting more serious, the risk of being affected by the international market is higher. Therefore, it is urgent to develop the domestic market to sustain the continued development of the industry. At the same time, China's LED lighting industry has some disadvantages, for instance, industry concentration is low, and there is a lack of leading industries which are less competitive in high-end markets and domestic lighting chips are highly dependent on imports. The main reasons are as follows:

Firstly, the domestic product technical support is inadequate and patents are restricted, especially in the case of the patents of epitaxial wafer chips and phosphor for LED lighting products.

Secondly, due to the fact that currently in China LED lighting applications are mainly used for street lights and tunnel lights as a whole, the domestic LED lighting applications are lagging behind Europe, United States, Japan and other major lighting market. In addition, compared with the needs of the market, the concrete implementation of the standards and norms are still inadequate and need to be strengthened in terms of co-ordination of the relevant departments.

The cost of LED lighting products is relatively high so customers are concerned when purchasing a large number of products and the acceptance of the brands also needs time. As the technical value of LED lighting products is relatively high, professional services and technical support will be more important in the competition of LED lighting products in the market. If the company cannot integrate technology, design, manufacturing, marketing, it cannot win this competition in LED lighting.

In addition, LED lighting companies in China lack core technology and the technology

of epitaxial growth control as the structure of the chip design and manufacturing processes are monopolized by very few foreign companies. Chinese enterprises lack core technology and homogenization between enterprises is obvious, thereby resulting in more intense competition.

4.1.3 The future of green lighting technology innovation

The development of emerging industries needs more innovation. Semiconductor lighting source is now sold in the lighting field, but there are still many problems in energy efficiency, reliability, quality of light and color, as well as the cost, which must rely on technological innovation and technological progress. In terms of technology trends, the luminous efficiency will further be enhanced and the development of the technology will continue to focus on enhancing the electro-optical conversion efficiency and reducing costs.

Semiconductor lighting technology is developing fast in terms of LED luminous efficiency. In April 2011 the American company, Cree Inc. announced that the latest high-power white LED light efficiency has reached 231lm/W while the South Korean Soul Semiconductor Company has manufactured AC LED products with luminous efficiency of 100 lm / W. This innovation has exceeded expectations.

Guided by the National Science and Technology Plan and the market demand, China's semiconductor lighting technology has also developed rapidly and the key technology is gradually catching up with international level. In the system integration technology Chinese companies are expected to achieve innovation by leaps and bounds.

Table 4- 3 Comparing the international power-type white LED indicators average level (at the end of September 2012)

Types		**luminous efficiency (lm/w）@350mA**	**Color index**
Domestic industrial level	Current level	100-120	>80
	The level at the end of the 10th five year plan	30-40	>70
Level of South Korea and China Taiwan		110-130	>80
Level of the US, Japan and EU		120-231	>80

Source: Liu Zhihui, The Analysis Report of Semiconductor Lighting Industry (2012) , adjusted by the author

Semiconductor lighting as a strategic emerging industry in China, is listed in research projects and in 863 projects by the Ministry of Science and Technology and has received special support during the "tenth five year plan" and the "eleventh five year plan". During the current "twelfth five-year plan", the Ministry of Science and Technology listed semiconductor

lighting as one of the six key projects in the field of new materials, which are jointly supported through 973 plans[25], 863 plans[26], and the construction of condition platform.

Although China's semiconductor lighting industry started late, it has developed very rapidly and the growth rate of patent applications in the past five years has consistently reached the first place in the world. Currently, the patent applications in China have accounted for 27.2% of the total in the world, which is almost equal to that in Japan and the United States. In addition, it has become one of the most active markets in the patented technology.

The strategic objectives of semiconductor lighting during the “twelfth five-year plan” is to achieve a breakthrough in terms of basic research, cutting-edge technology, the application of technology, the industrialization demonstration of the whole innovation chain by 2015. At the same time it should solve the fundamental scientific problem of ultra-high efficiency nitride LED chips and obtain the core technology of a new generation of white light illumination. Other measures include: white LED luminous efficiency (150-200 lm/W) shall reach the international corresponding advanced level; the epitaxial growth of the substrate by the high efficiency of large-size sapphire, SiC and Si, should be achieved; the localization of 80% of the chips should be reached; the localization of large-scale key equipment and key supporting material (not less than 40 inches) such as MOCVD should happen; the manufacture of standardized and specified products that are healthy and environmentally-friendly in the field of general lighting, backlight and automobile should also be promoted. By 2015, the value of the industry will reach 500 billion RMB and save 100 billion kwh electricity every year and a national R & D platform and industrial base to cultivate a number of leading brands and to train a group of science and technology leaders in terms of technology and entrepreneurial talent should be formed.

Despite of China's support for the development of the LED industry, many companies have not yet made a fundamental breakthrough in core technology and do not have the professional and technical personnel and research and development teams thus refraining the progress of LED luminous efficiency.

Compared with the increasingly fierce international competition, China’s investment in

[25] 973 Program is a key basic research development plan of China. It aims to solve the key scienctic questions to meet the needs of national strategies and the frontier issues of science for human being to understand the world.

[26] 863 program is the Chinese high technology research and development plan. It aims to improve the self innovation capability of China. Putting the frontier research and development as a core, it integrates the application of high technology and models the commercialization, hence leading a role in the developpment of high technolgoy.

R & D of semiconductor lighting technology is scarce and scattered and China lacks internationally competitive, innovative institutional mechanisms which is also one of the factors that holds back the comprehensive upgrading of China's industrial technology. To address this problem, dozens of domestic enterprises initiated the establishment of the "semiconductor lighting joint innovation State Key Laboratory (chips)", with the goal of relying on semiconductor lighting industrial technology innovation and strategic alliances, building around the industrial technology innovation chain, combining domestic and international prime innovation resources under the new institutional mechanisms to obtain industry common key and leading technologies, create sustainable international development in terms of common technology research and development, and personnel training platform to support China's semiconductor lighting industry.

LED is an emerging high-tech industry. However, government support or money cannot solve all the problems. The lack of core technical staff has become the bottleneck in the development of the enterprises so the priority now is technology. Currently, there is a lack of experienced core technical staff in upstream LED industry that can be trained in more than three years. In the last couple of years, one of the key factors of enterprises sustainability to the next round of high-speed growth is to find talented technical staff and experienced front-line operators.

In fact, LED companies in China are well aware of the importance of technology. Many enterprises went to the United States, Russia and other countries to learn and currently are also applying for patenting their technologies. Market demand and technology have determined that the start-up of green lighting enterprises have taken the road of technological innovation to survive and to develop sustainably.

Table 4- 4 LED lighting "12th Five-Year-Plan" Technology Development Key Indicators

No.	Index
1	White LED luminous efficiency of industrialization reaching 150-200 1m / W, the cost being reduced to 1/5
2	The luminous efficiency of white OLED device reaching 90 1m / W
3	Localization of core equipment and critical materials
4	The LED chip localization rate reaching 80%
5	Constructing public technology R & D platform and detection platform
6	Three hundred applications for invention patents
7	Issuing twenty standards

Source: The Twelfth "Five-year Plan" of Semiconductor Lighting Technology development of China

Chinese government is strengthening the policy guidance and the promotion of the industry, and is urging the construction of public R & D platform and the nurturing of leading enterprises. They will provide support in different ways such as coordinating testing standards, strengthening international exchanges or cooperation and training creative talents and teams.

4.2 Case Study One: the technological innovation selection of Sichuan Grand Technology Co., Ltd.

4.2.1 Introduction of Sichuan Grand Technology Co., Ltd

Sichuan Grand Technology Co., Ltd. (hereinafter referred to as "Grand") is a professional power energy-efficient solution supplier. It was founded in September 2006 with a registered capital of 50.07 million RMB in Chengdu High-tech Zone. Grand has been seeking for the development of energy saving and environmental protection of electrical equipment resources, Owns more than 20 core patents, products through the China compulsory product certification and the China energy conservation product authentication, has successfully completed more than 30 engineering case, obtained the customer consistent high praise。

In 2007, there were only eight employees and it was mainly engaged in the agency of electricity transmission and distribution equipment. Thereafter, as green lighting industry started to receive great support from Chinese government and attracted by the business opportunities of new industries the company set up R & D and marketing plan for the green lighting industry.

In 2008, the company fully concentrated in the field of R & D, design and sales of green lighting products and expanded its R & D team with a focus on the development of sample testing of green lighting energy-saving lamps. Grand saw technological innovation as the main task of the enterprise, and was actively engaged in applying for certification of patents, brands, national high-tech enterprise, and gradually has established a scientific and technological innovation system and related management regulations.

In 2009, the company's R & D team expanded to 35 people and Grand started to take a series of actions to strengthen its technological innovation: experimental production of small batches of semiconductor energy-saving sample lamps; development of a number of technology projects expecting the approval of the National authorization institution, R & D

personnel getting involved in academic exchanges at home and abroad, formulation of product standards, exploration of market demands, collection of customer demands, improvement of product performance. Thus the company's technology strength and market performance has improved greatly through the actions mentioned above.

In 2010, the company's semiconductor energy-saving lamps were put into the market. The project of "the industrialization and application of high-brightness great-power light-emitting diode multi-chip assembly technology" was included in the National Torch Plan Project[27]. In November 2010, Grand participated in the national semiconductor lighting product demonstration project organized by three ministries and was successfully nominated. Through the whole country, only 28 companies were selected and Grand was the only one selected in the southwest region.

In 2011, Grand had built a professional and efficient service team. Through continuing efforts in R & D, the company received energy saving certification in the field of street lights and tunnel lights issued by China Quality Certification Center. Following quality management and environmental management system and occupational health and safety management system, the company is now operating smoothly and its products have met the National and industrial standards in Europe, North America and other regions.

Grand gives credits to the joint efforts of a number of electricity transmission and distribution experts. Through six years of hard work, the company has formed a core team with an achieving spirit. The management team has years of team building and operational management experience to lead the teams of product development and production, marketing, technical services. The existing core R & D staff of 35 people, includes five doctor-degree holders, five master-degree holders, and all the other core staff have at least bachelor degrees. Majority of the staff has obtained their degrees in electricity and electrical equipment industry and possess keen insights in market and technical innovation capability. The 15 external experts are all experienced scientists, professors and senior engineers in the field of materials, optoelectronics, power electronics, optical and illumination engineering, mechanical, electrical, power engineering，These experts as part-time technical consultant company, provide technical support for the company, at the same time assist the R&D team in technical innovation. At the same time, the upgrading of the human resources in Grand benefited from

[27] National Torch Plan is a instructive plan to develop the new and high technological industry. Approved by the Chinese government in August, 1988, it is implemented by the Ministry of Science and Technology.

the company's collaborations with renowned universities, research institutes, and multinational companies.

In 2008, the company received high-tech enterprise certification by Sichuan Province and in June 2009, LED energy-saving lighting products were identified by Sichuan Province Economic and Trade Commission and the Department of Science and Technology as a strategic industry for development. Since 2009, in the field of high-power LED energy saving lights Grand continued to obtain many patents and exclusive technologies. In December 2010, as the second generation of LED energy-saving lamps was included in semiconductor lighting products demonstration projects hosted by the National Development and Reform Commission, the Ministry of Housing and Ministry of Transportation, Grand became among the 28 national finalists the only one selected in the southwest region. In May 2010, the project of "the industrialization and application of high-brightness great-power light-emitting diode multi-chip assembly technology" was included in the National Torch Plan Project,[28] by the Ministry of Science and Technology. The third generation of LED street lamps and tunnel lights developed by the company has obtained energy-saving products certification granted by the China Quality Certification Center (CQC) in March 2012.

Grand follows the quality management system ISO9001, environmental management system ISO14001, OHSAS18001 standards of occupational health and safety management system to operate and their products are approved by CQC energy saving certification, 3C (China Compulsory Certification),[29] UL (Underwriter Laboratories Inc)[30], CE (Communeuté Européenne) [31]Certification, and are in line with national and industrial standards in North America, Europe and other regions.

4.2.2 Analysis of Grand resources and capacity

In the early years Grand’s team was composed by a small number of electricity transmission and distribution experts who were competent in carrying out the power system technology design, manufacturing, marketing, management of supply chain. During China's

[28] National Torch Plan Project is a plan to guide the development of China's high-tech industry, the Chinese government approval, in August 1988 by the ministry of science and technology (the former state science and technology commission) to organize the implementation.

[29] 3C is a complusory certification system in China.

[30] UL is a short name for Britian Underwriter Laboratories Inc. It is the most anthoritative and world recognized non-governmental agency for safety test and assement.

[31] CE is a symbol of safety certification, which is regarded as the passport for maunufacturers to enter EU market.

11th Five-Year Plan (from year2006 to 2010), energy-saving key projects included the inefficient coal-fired industrial boiler (kiln) transformation, regional cogeneration, the utilization of residual heat and pressure, conservation and alternative oil, motor system energy saving, energy system optimization, green lighting, architectural energy saving, government agencies, energy-saving, energy-saving monitoring and technical service system construction. Among the ten projects, regional cogeneration, motor system energy saving, energy system optimization, green lighting, government agencies, energy saving, energy-saving monitoring and technical service system construction are all related to electricity. And only motor system energy saving and green lighting have broad market prospects and business opportunities. Due to the entrepreneurial team background and resources, Grand preferred green lighting industry as the main business of the future.

Table 4- 5 Introduction of executives of Grand

Positions	Name	Responsibilities	Major	Degree	Special talents
Chairman of board	Tan**	In charge of overall strategy	Electric Power Automation (undergraduate) / Management Science and Engineering	PhD	Working in the power industry for 23 years, with keen market insight
General manager	Xing**	in charge of operation	Machinery and automation (undergraduate) / MBA		Being engaged in the management of three photoelectric enterprises
Deputy general managers	Xiong**	In charge of financial operation	Finance (undergraduate) / MBA	Master Degree	Not only understanding technology, but also familiar with the finance
	Xiang**	In charge of human resources and administrating	Electrical Engineering (undergraduate) / MBA	Master Degree	Being familiar with LED lighting application technology
	Niu**	In charge of marketing	The instrument automation (undergraduate) / MBA	Master Degree	responsible for the certification of the company's affairs
	Lin**	In charge of technology	Mechanical and Electrical Engineering / MBA /MBA	Master Degree	Deep technical background, presided over the innovative project has won a patent
	Chen**	In charge of manufacturing	manufacturing /MBA	Master Degree	LED professional background

Source: Elaborated by the author based on company documents

Different resources make different contributions to enterprise and the strategic resources directly influence the enterprise strategic actions and comparative advantages. Through our interviews with 35 members of Grand entrepreneurial team, we found that Grand's success is

closely related to their early concern to human resources, financial resources, technical resources, customer resources and supplier resources that are all are Grand's strategic resources. A senior executive said, "Our team directly determines what we can do and how we can do".

At present, the company senior management team has a professional background and experience in management as is shown in 4-5. The company's organization structure is as shown in Figure 4-4.

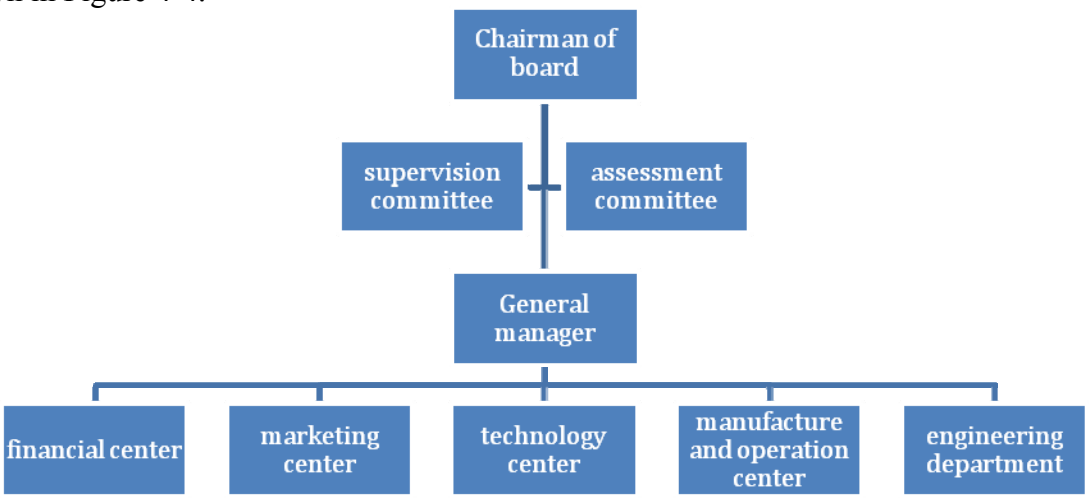


Figure 4- 4 Grand structure frame

Source: Elaborated by the author based on company documents

As mentioned before, there are now 35 members in Grand's core R & D team, including two doctor-degree holders and five master-degree holders. All core staff has a Bachelor of Science degree, including three electrical engineers from electricity and electrical equipment industry and they all have a wealth of market and technology experience.

The company has set up a national standard testing laboratory staffed with 12 people. The Quality Manager has 12 years of experience in quality management and all staff in this department has passed the domestic quality testing and management of training and they have been assigned to the positions only after obtaining their qualifications. The company follows ISO 9000 international standardization of product quality control system, and also signed an agreement with Sichuan Provincial Quality Supervision and Inspection Institute for regular testing and quality management training.

The company has set up a special pre-sale and after-sales service team, and has established a perfect service system according to ISO 9000. The company's existing service team is made up of 13 people. They are professionals who have been engaged in R & D or manufacturing for more than two years, have received training and evaluation and are very

responsive to customer needs.

The 15 external part-time job experts are all experienced scientists, professors and senior engineers in materials, optoelectronics, power electronics, optical and illumination engineering, mechanical, electrical, and power engineering. They have helped to build up and maintain a cooperative relationship with Testing Technology Research Institute of China, Sichuan University, China University of Science and Technology, and other related institutes in R & D.

Grand attaches great importance to human resources and its technical capabilities. This is reflected in the following actions:

a. Training of expertise: The company attaches importance to staff professional and technical background, but also encourages employees to do further study. The company's senior executives entered the University of Electronic Science and Technology of China, Sichuan University, Southwest University of Finance and Economics, Peking University and Tsinghua University for master degrees.

b. Training of skilled workers: The company sends middle-level managers and technicians to vocational colleges to study. At the same time, the company has established its own training system. The general manager who is responsible for personnel management stated that the company emphasizes on professional background and technical skills of the employees in the recruitment, and learning abilities and learning attitude are also stressed.

c. Introducing core talents: Through the analysis of its advantages and disadvantages, the company realized the talent shortage in LED technology field. In a short period of time, this problem cannot be solved, so the company spared no expense on importing talents from outside, and formed a system of bringing in, evaluating and training employees.

d. Establishing and perfecting the system of keeping core talents in company. The company carries out the system that some employees own stocks, others have stock options, and some other staff holds company some stocks at their positions. Particularly for key employees, the company prefers to use the equity incentive, long-term incentive to attract them. A technical staff claimed that working in Grand gives a feeling of growing together with the company.

Thanks to the human resource training, a high-quality team was formed which has provided strong support to the company's technological innovation, and has ensured the

sustained, stable and healthy development of the company.

Grand has plenty of technical resources. The core technology is the first production force of enterprise's strategic resources for competition. Grand gained the strategic resources through its technological innovation patents and apply the core technology to its new product development. In addition, Grand emphasizes the brand building, for example, it registered its trademark GRANDIDEAL in 2008, which promoted the value of its products. The products passed all the tests by China national Electric Light Source Test Center and were recognized with certificates by China Quality Certification Center. This move improves the branding effect of the products.

Entrepreneurship has become an important element for the technological innovation of Grand. The entrepreneurs of Grand not only control the strategic resources, ordinary resources and market factor but also the implementers of operation of the company.

Grand has a strong technical innovation team. After nearly six years of hard work, it has a wealth of experience in technological innovative projects. Strictly following the ISO 9001 quality management and technology innovation capacity management system, it continues to make advanced technological innovation, mature technological innovation and economic innovation. From the first generation of green LED lighting products to the third generation product technology innovation, Grand has successfully transformed the technological innovations into industrialization. The company is working on the national China Torch plan Program projects, technology projects of national key products, the national project of major technical equipment, and is identified as one of the high-tech enterprises in Sichuan Province. In 2011, it received innovation-oriented enterprises medals issued by Sichuan Provincial Department of Science and Technology.

Due to geographical constraints and limited supply resources, Grand is mainly committed to the R & D and sales of core products therefore it has outsourced other factories to process their products through the way OEM (Original Equipment Manufacturer).[32]Through the analysis of innovation process, the capabilities of Grand in the early days were limited to technology research and development capability, which was closely related to their strategic human resources management. In 2007, the research and development center was set up and was included into the list of high-tech enterprises in

[32] OEM is authorized manufacturer according to manufacturer's requirements and to sample a trustee, in accordance with the manufacturer for specific conditions and production. All drawings are completely in accordance with the manufacturer to sample design for manufacturing processes

Sichuan Province in 2008. Relying on the core team, the R & D team has formed its own core competencies, and has completed the development, design, manufacture, testing and demonstration application of the company's first-generation and second-generation high brightness and high power LED energy-saving lights with high capabilities of product development, manufacturing and promotion.

Strategic resources and technical capacity has brought Grand comparative advantages. On June 9, 2009, its products were verified by Sichuan Provincial Economic Commission and the Office of Science and Technology; in the same year the Ministry of Science and Technology granted financial support to Grand chip-related patents. In October 2010, it became one of the companies of the national semiconductor lighting demonstration project through bidding hosted by the National Development and Reform Commission, the Ministry of Transportation and Communications, the Ministry of Construction.

Grand attaches a great importance to the ability of market element resources and it focuses on the training of social network abilities. The executives of the company pursue double doctorate degrees, such as doctoral degrees in management besides of engineering doctoral degrees and actively engage in building up social network resources, and laying a solid foundation for the company to dominate the market. At the same time, the company through the following measures, ensures the utilization of other resources:

(1) Training of workers: collaborative training program between enterprises and education institutions. The company, in cooperation with local vocational schools, trains workers in accordance with knowledge and skills required by their jobs.

(2) Finding distributors: active and consistent pursuit of agents for the sales of the products and establishment of a national network of marketing, logistics and distribution.

(3) After-sales service outsourcing: supply of good services in the regional areas where the products are sold. In order to reduce operating costs, Grand chooses the nearest local service agencies for maintenance and asks for customer satisfaction regularly.

(4) Transportation outsourcing: for the optimal use of resources, reducing investment in fixed assets and the risk of the transport process, the company outsources the transportation of the products demanded by the customers.

Table 4- 6 Summarization of Grand's combination of resources and capacities

Resources and capacities	Main features
Human resources	Core team has strong technical background and a professional advantage; emphasis on the training of human resources.
Market element resources	Supplier resources are easier to obtain while client resources are insufficient.
Manufacturing capacity	It mainly relies on OME production.
R&D capacity	Reliance on core technology team, with strong R & D capabilities and a number of patents and qualifications.

Source: Summarized by the author

4.2.3 Grand's selection of technological innovation

Based on the company's strategic resources and relatively strong research and development capabilities, Grand chose to carry out independent technological innovation. A company's R & D department official said, when interviewed, that small and medium-sized enterprises must seek a differentiated road for survival and development and innovation is the best way to achieve this purpose. Grand advantages in human resource, and the technological innovation and project management capabilities they brought in enabled their independent innovation.

Of course, independent innovation requires more resources. During the start-up period, the company suffered the shortage of funds and ineffective management. However, combining the strategic resources and core competencies, independent innovation proved to be the best choice of Grand.

On the technical side, Grand's chip rack module technology has solved the problem of high-power chip cooling and, as to financial resources it has obtained financial support from the Ministry of Science and Technology. This technology guaranteed the distinctiveness of Grand products. Chip rack module, with unique light, simple structure, high luminous efficiency and high uniformity has become the leader in semiconductor module lighting technology.

4.2.4 An analysis of technological innovation resources selection of Grand

A model studying the technological innovation resources of Grand, as illustrated in Figure 4-5 (the gray area).

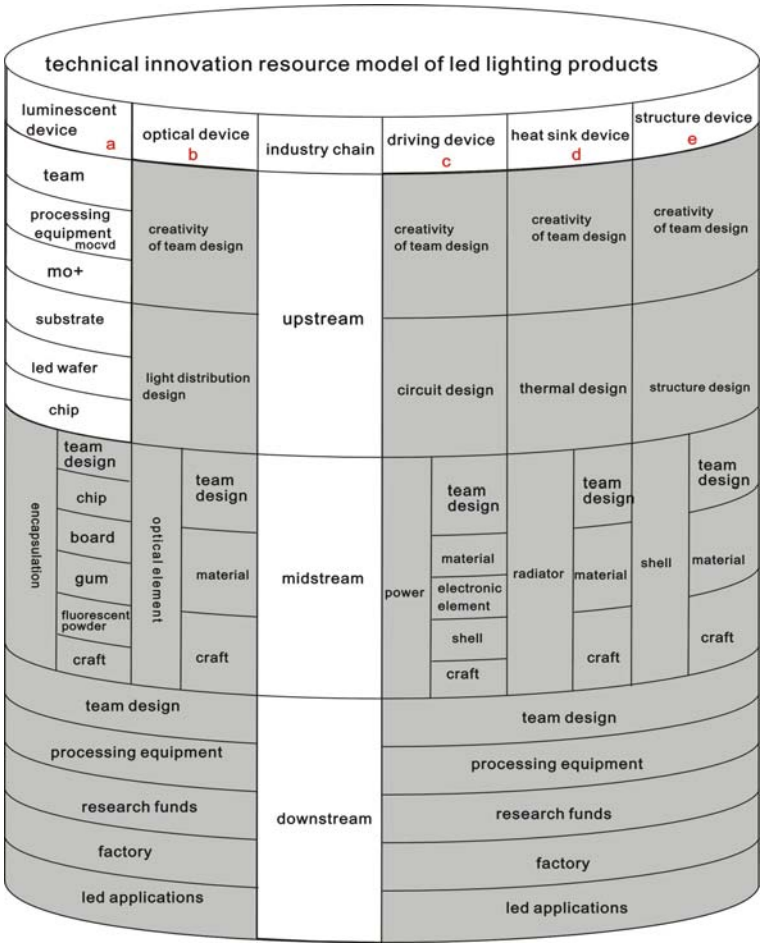


Figure 4- 5 A analytical model of technological innovation resource of Grand's products

Source: developed by the author

(1) The strategic resources of Grand

The strategic resources allocated at the start-up stage of Grand was very appropriate for the technological innovation as it has excellent innovation team, approved patents, recognized brand, established corporate culture, with which the strategic resources have been fully utilized to lay a solid foundation for the development of the company.

(2) The ordinary resources of Grand

The ordinary resources of Grand were weak, for example, the registered capital of the company was 8 million USD. In the seven year's research and development, the expense for the R&D was very tight and the financial resource for purchasing materials and social networking was even less. So, the ordinary resource became a bottleneck for the development of the company.

(3) The market factor resource of Grand

At the start-up stage the resource of market factor of the company was scarce. For example, the company did not have an established credit system and well known brand. Due to its incomplete marketing system, the company did not develop a close link with the suppliers, causing high costs and unstable partnership with suppliers.

4.2.5 An analysis of technological innovation capability of Grand

A study model of technological innovation capability of Grand, as is shown in Figure 4-6 (gray area)

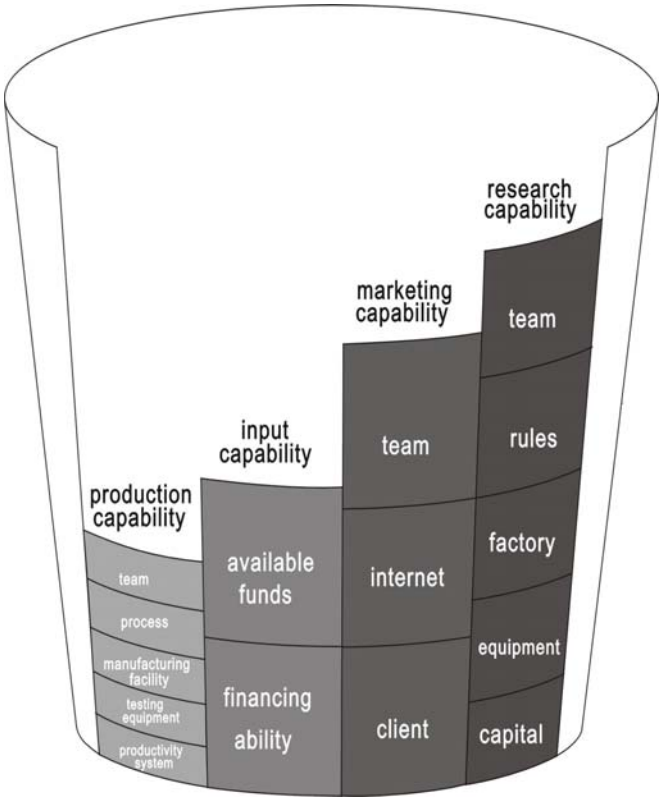


Figure 4- 6 Grand's an analytical model of technological innovation capability

Source: developed by the author

Under the constraints of resources, Grand was constrained in terms of production capability, investment capability, marketing capability. To make up this weakness, Grand had to leverage its social resources to improve its operation capability. Only in this way can Grand not be left behind the expected development.

Grand's specific technological innovation projects are as follows:

In December 2010, the second generation LED energy-saving lamps of Grand Corporation was included in the final list of the National Development and Reform Commission, the Ministry of Housing, the semiconductor lighting products demonstration

projects. Grand is one of the 28 National shortlisted companies and it is the only company in the southwest region to be shortlisted. Among the total 99 candidates participating in the bidding, most of the companies have strong technical innovation ability, quality management ability, strong cost advantage; therefore, Grand's success through independent innovation fully illustrated that Grand has made large market outcomes through innovation.

In May 2010, the Ministry of Science and Technology granted Grand the National Torch Plan Project for "the industrialization of high-power high-brightness light-emitting diode multi-chip assembly technology applications" which is highly recognized by the National Ministry of Science and Technology. Now, the company has applied three core technology patents and seven other patents. This technology will be the future of the development of the green LED lighting technology. The company successfully developed the third-generation LED energy-saving lamps with this technology and in 2012 received China Energy Conservation product certificate issued by China Quality certification Center. The company's LED energy-saving lamps last 6000 hours without light decay, and Grand is the only company to possess this technology, which has guaranteed a market share for Grand LED green lighting products.

With the support of the core technology and independent innovation strategy, Grand products have strong core competitiveness. Currently the research and development of and manufacturing of high-power semiconductor (LED) green lighting energy-saving lamps are Grand's main mission, including LED lights, tunnel lights, LED mining lamp, LED down lights, LED Bulb which are widely used in roads, squares, factories, shopping malls, hotels, offices, schools, hospitals and homes. The advantages of their existing products over those from domestic and foreign competitors are as follows:

(1) The advanced features of products

Their high power LED green lighting products are human-oriented and artistic and fully demonstrate the features of energy saving, health and safety. Its main characteristics are shown in Table 4-7.

Table 4- 7 Main performance and technical features of Grand's products

The characteristics of high power LED green lighting products		
No.	**Performance and features**	**Advantages over traditional lighting products**
1	Energy-saving and efficient (Under the same illumination conditions)	more than 90% of power saving over incandescent over high pressure sodium lamps saving 70% of power over traditional energy-saving lamps saving 60% of power

2	Long service life	50 times as long as that of Incandescent 7-8 times as long as that of high pressure sodium lamps 5-6 times as much as that of regular energy-saving lights
3	Healthy Lighting	Only providing visible light: avoiding UV damage for skin; No flash: being able to see clearly without tiring the eyes.
4	Safe lighting	High CRI and no flashing can improve safety and comfort when driving or working in a rotating environment; No harmful ultraviolet light changes the color and quality of the illuminated objects; No infrared light changes the temperature or the quality of the illuminated objects; There is no solid-state light source and the flammable the friable explosive substances so they are seismic-proof.
5	High-quality lighting	Starting without any delay and being able to start and stop frequently; No vibration, no noise; No light pollution;
6	A high degree of intelligence, reliable and flexible to achieve further energy saving in the running process	Easy to implement automatic and remote monitoring; Easy to control brightness and light color and being flexible.
7	Environmentally-friendly	No harmful gas and liquid is produced during production, transportation, storage, installation, operation, and being damaged or being recycled. It is lead-free, mercury-free, sodium-free; the atmosphere. It causes no pollution to soil and water. No electromagnetic interference with public grid, and no radio interference;
8	Reducing investment and operation and maintenance costs of the energy-saving lamps facilities	Reducing the equipment capacity of the supply network thereby reducing investment (costs of equipment and materials, electricity subsidy fees, cost of construction, etc.); Energy-saving lamps saving energy, reducing the tariff of the lighting system; reducing the operating losses of supply networks; Long life energy-saving lamps reducing maintenance costs; Ideally suited for solar cells, wind power generation, or a combination thereof free from being affected by power supply and distribution system and or the lines.

Source: Case study documents, summarized by the author

(2) Patented products

With stressing technology research and development and implementing independent innovation, Grand has obtained a series of patents in the field of LED. These patents have become important technical resources for the company and enabled it to expand its market and enhance its performance, Its main Patents are shown in Table 4-8.

Table 4- 8 List of Grand's patents

No.	Name of Patent		Number of patent
1	Patents on application	LED tunnel light with the fins of the heat pipe radiator	ZL 2009 2 0082687.2
2		LED street lamp with the fins of the heat pipe radiator	ZL 2009 2 0082686.8
3		LED mining lamp with the fins of the heat pipe radiator	ZL 2009 2 0082685.3
4		A LED chip carrier with a heat spreader plate	ZL 2009 2 0082688.7
5		A LED chip carrier with a heat spreader plate	ZL 2009 2 0082689.1
6		A cascading white LED lights	ZL 2012 2 0007662.8
7		A curved LED light	ZL 2012 2 0007663.2
8		A white LED light	ZL 2012 2 0007664.7
9	Patents on designing	High-power LED panel light	ZL 2008 3 0344320.4
10		High power LED street light (Explosion proof)	ZL 2008 3 0344321.9
11		LED chip rack (with average temperature board)	ZL 2009 3 0109235.4
12		LED Panel Light	ZL 2009 3 0109234.X

Source: Company documents, summarized by the author

Grand chip rack module technology solved the problem of the cooling of high-power chip, which received financial support of the Ministry of Science and Technology. This technology distinguished Grand's products from those of other companies. With its modular chips, unique lighting, simple and nice structure, high luminous efficiency and high uniformity, the company aims at leading the semiconductor module lighting technology in the future.

In the days of starting-up, Grand, by choosing the way of being independent and innovative and the development of the push-pull double-action-mode, their technical innovations achieved in the recent four years are shown in Table 4-9.

Table 4- 9 Time Line of Grand's Technological Innovations

No.	Year	Technological advantage	Sales
1	2008-2012	25 patents	
2	March, 2012	The third generation of high-power and high-brightness LED street lamps and tunnel lamps has been granted CQC Voluntary Product Certification and 6000 hours CQC energy-saving certification	reach 100 million

3	December, 2010	The second generation of high-power high-brightness LED energy-saving lamps was selected into the semiconductor lighting products demonstration project hosted by the National Development and Reform Commission, the Ministry of Housing, the Ministry of Transportation. Grand was one of the 28 National shortlisted companies, and the only company selected in the Southwest.	50 million RMB
4	May, 2010	The Ministry of Science and Technology awarded "the industrialization of high-brightness high-power light-emitting diode multi-chip assembly technology" of Grand National Torch Plan Project.	30million RMB
5	June, 2009	The first generation of LED energy-saving lighting product was approved by Sichuan Provincial Economic Commission and the Department of Science and Technology.	12 million RMB
6	October, 2008	Grand is one of the first batch of high-tech enterprise certified by Sichuan Province.	8 million RMB

Source: Company documents summarized by the author

Table 4- 10 Grand's business distribution as of 2011

Types	**Composition of major business**	**Revenue (RMB)**	**Proportion of revenue**	**Cost (RMB)**	**Proportion of cost**	**Profit (RMB)**	**Proportion of profit**	**Gross margin(%)**
Categorized by industries	Semiconductor lighting application	127.7 million	100.00%	82.3 million	100.00%	44.7 million	100.00%	35%
Categorized by products	Outdoor lighting	76million	59.51%	47 million	57.1%	29 million	55.22%	38%
	Landscape lighting	21million	16.4%	14.7 million	17.9%	6.3 million	14.09%	30%
	Indoor lighting	26.1million	20.43%	17.5 million	21.26%	8.2 million	27.51%	33%
	Monitors and others	4.6 million	3.6%	3.17 million	3.85%	1.42 million	3.18%	31%
Categorized by region	Domestic	127.7million	100.00%	82.3 million	100.00%	44.7 million	100.00%	35%
	Overseas	---	---	---	---	---	---	---

Source: Company documents, summarized by the author

Summary:

Enterprises are composed of heterogeneous resources (Barney, 1991). So, different resource structures vary from one company to another. As the entrepreneurial enterprises have relative scarcity of resources, they need to fully utilize the existing core resource to develop their businesses.

According to resource-based view, enterprise is a body of knowledge which is heterogeneous. Its competitive advantages stems from the creation, storage and application of knowledge (Zander and Kogut, 1995; Spender and Grant, 1996). Broadly speaking, knowledge also fall into a category of resource.

The core resource of Grand Company is its human resource and the knowledge resource created by the human resource. Drawing on the resources, the technological capability has become the core competence of the company, which makes the innovative choice in favor of independent innovation. Depending on the core technology and related patents, Grand Company has made significant achievements in technological innovation and business development.

We found in the research that Grand started to choose the way of independent innovation to develop its business. However, after six years the resource and capability of the company have also changed. At present, the company has taken a partnership innovation. One of the examples is the cooperation with China Test Technology Institute in 2009, which demonstrates the way of technological innovation is constrainted by its resources and capabilities.

4.3 Case Study Two: Technological innovation selection of Kingsun Optoelectronics Co. Ltd

4.3.1 The introduction of the company

Kingsun Optoelectronics Corporation Limited (hereafter referred to as “Kingsun”) was founded in 1993. In the following year, it began to produce and sell outdoor decorative lights. In 1998 the company started to develop low and medium power LED products and in 2004 it started the R&D of high power LED applications. Through the cooperation with Tingshua University to pursue a “production, learning and research” strategy and a huge investment in LED application technology in 2007, Kingsun realized the upgrading from the traditional industry to high-technology industry, from labor-intensive manufacturing to the upper high-tech industrial chains, from functional lighting products to energy-saving lighting and intelligent lighting solutions. It has gradually explored a way of industrial development to closely integrate the semiconductor lighting with renewable energies such as wind and solar energy.

On November 25, 2011, Dongguan Kingsun Optoelectronics Co. Ltd (Stock Exchange name: Kingsun Optoelectronics, Stock Code:002638) was officially listed on the SME (Small and Medium Enterprises) board in Shenzhen Stock Exchange. In terms of revenues, Kingsun has become the largest listed company of LED applications in China and is also the first high-power LED semiconductor lighting among listed companies.

Kingsun is a partner of Tsinghua University in the field of semiconductor lighting, a member of China's semiconductor lighting technology standards working group, a high-tech enterprise of Guangdong Province, and holds the rotating presidency of LED Industry Alliance of Guangdong province. The company has more than 2000 employees, including over 400 engineers and technicians. Its products are high-power LED street lights, tunnel lights, basketball court lights, tennis court lights, golf lights, stadium lighting, Christmas lights, floodlights, wall wash lights, digital pipes, point lights, buried lights, footlights, underwater lights, garden lights and indoor lighting products. The company has become a large semiconductor lighting enterprise which provides a streamline of services from semiconductor lighting products, R & D, production, city lighting engineering design, construction and maintenance.

The sales of the company have maintained a fast growth in recent years. In 2011 the total income amounted to 769 million RMB, with a 16% profit margin. Thanks to the stable operation of the company, the liability/asset ratio is only 15%. As for the business structure, the main products of the company are mainly in the area of outdoor lighting and scenery lighting. As half of the business is made in overseas markets, the company has a strong international market competitiveness. Tables 4-10 and 4-11 illustrate such performance.

Table 4- 11 The financial reports of Kingsun Optoelectronics between 2008 and 2011

Type	2011	2010	2009	2008
Sales	769Million	552million	424million	457million
Net profit	125million	81.1million	66.4million	59.57million
Net profit rate（%）	16.20	14.68	15.66	13.02
Total asset turnover	0.43	0.55	0.56	---
Liability/Asset ratio（%）	15.49	29.94	49.47	53.71

Source: Financial reports of the company

4.3.2 Resource and capability analysis of Kingsun

Kingsun considers the LED Lighting industry as its new mission and opportunity. Committed to technological innovation, the company strives to lead the green lighting

industry trend, build the harmonious wealth creation channels, and forge well-known brands in the green lighting optoelectronics industry. Through the building of a professional core team, the company develops innovative products, builds a special benefit distribution system, establishes a global marketing system, and leads the LED international trend and direction. In its entrepreneurial process, Kingsun has made great contributions to China's green lighting and energy-saving environmental protection industry. The Kingsun people take the green lighting as their own cause for which they are working hard.

As one of the first batch of domestic enterprises to enter the LED industry, Kingsun has thirteen years of LED R&D and application experience and six years of high-power LED lighting application experience. So far, it has 343 industry patents and 59 national invention patents. On the basis of achieving the leading position in the area of LED street lighting, LED indoor lighting, LED decorative lights, solar LED, LED display, the company has currently increased its investment in LED indoor lighting and with the support of its professional team will further enrich the product line of indoor lighting.

Mr. Li Xuliang, the founder of Kingsun, was a typical Dongguan local. Having resigned from his official post in 1993, he started his entrepreneurial career with only 2000 RMB (approximately 240 euro) that he had earned by riding a bicycle along the streets in Dongguan Town – a South China city in the Heart of the Pearl River Delta region – collecting fees from the orders of hardware accessories. Now the Dongguan Kingsun Optoelectronics Co. Ltd he founded has developed into a group of high-tech enterprises, with more than 2,000 employees and a floor area of 300 thousand square meters, which is the largest semiconductor lighting R& D and production base in Asia. It is also a comprehensive application solution supplier and an excellent business model provider of LED street lighting, LED display, scenery lighting, business lighting, household lighting, solar energy and wind energy and special lighting products, which make it the leader in the domestic LED lighting industry.

In the course of the entrepreneurial process, Kingsun has accumulated broad social relations and networks. The company has implemented strategic cooperation of "industry, university and research" in the area of semiconductor lighting technology and R&D and industrial design with well-known universities such as Tsinghua University, Sun Yat-sen University, Tsinghua Academy of Fine Arts, Central Academy of Fine Arts, China Academy of Fine Arts, Guangzhou Academy of Fine Arts and other universities. In addition, the company has established a research institute of semiconductor lighting technology with the universities mentioned above and Guangdong Province semiconductor lighting technology

and application engineering center. Kingsun has formed a complete LED industrial chain of LED sealing factory, lights manufacturing factory and lighting decoration factory. It has a lab with full reference to the configuration of the United States UL laboratory. Taking the national key lab of integrated optoelectronics of Tsinghua University as the supporter, Kingsun has found a way to enlarge its talent pool of top-level researchers in domestic semiconductor lighting area.

Kingsun has kept good relations with Dongguan Government. So, the government actively supports the development of the company. With the support of the government, the company attaches high importance to the production quality improvement and marketing promotion. At present, many projects across the country have been smoothly completed, including the oversize LED display works of Tiananmen Square for the 60th anniversary celebration, the lighting project for the National Theater, the street lighting project for Beijing Green Olympic Games, the Shanghai F1 Race track lighting project, the lighting project for Guangdong Science Center Square and the surrounding area, the lighting project of the indoor stadium of Tsinghua University, and street lighting remold project in Zhongshan City, Dongguan City and other towns. The company undertook the drafting of street LED lighting standard for Guangdong Province, the demo project of "ten thousand high-power LED street lights in five hundred kilometers" of Guangdong Province, and LED street lighting remold project in Dongguan.

At the same time, Kingsun has developed an extensive marketing network. The products are not only sold very well in Beijing, Tianjin, Shanghai and Guangdong province, but also in the southeast Asian market and EU and America market. It is the largest production base of high-power semiconductor lighting products in Asia and the leading enterprise in the continent with the most successful business case of LED lighting at home and abroad. The successful completion of the projects above shows that, on the one hand Kingsun enjoys high quality product advantage and technical strength, and on the other hand it maintains good relations with the local government.

Taking the optoelectronic industry as its basic industrial chain, Kingsun produces a range of products from LED lighting, LED decorative lights, solar LED lighting to storage racks, wire and cable, mold manufacturing, which makes of it a large enterprise combining R&D, production and trade. The production capacity is over one million lamps and the company has introduced first-class international production and testing equipment in over 50 standard production lines. The workers have years of work experience with the production and the

company has established a complete sale networks which covers a series of marketing outlets at home and abroad. In China, it has set up offices in 34 provinces and cities and 21 marketing outlets around the world.

At present the main shareholders of the company include Dongguan Kingsun Group Co. Ltd, Guangdong Tongying Venture Investment Co., Daqing Zhongkehuiyin Venture Investment Co. Ltd., and Shenzhen Innovation Capital Investment Co. Ltd.. Under the guidance of "human-based" talent development, Kingsun has launched a prospective talent "wealth" scheme, which is to recruit high-level talents from home and abroad, to set up a core talent pool, to grant options and equity awards to excellent talents. The scheme formulated a very competitive "talent highland" effect in the industry, which is a driving force for the sustainable development of the company. The company has over 2000 employees including 400 high level researchers and technicians, among which 17 people hold PhD degrees or Post-Doc, 48 have master degrees and 70% have Bachelor degrees.

Table 4- 12 Resources and capabilities of Kingsun

Resource and Capability	Main features
Technical resource	In the early stage it was not in LED industry, the related technology storage was scarce during the transformation stage
Social relations resource	The company obtained a full support from the local government. The central government also gives aid to the company.
Ordinary resource	Kingsun has solid capital and physical resource, which was able to support the innovative projects.
input capability	By means of the accumulation in the early stage, the company has made a strong input.
Marketing capability	Kingsun has an extensive marketing network, which covers a large area. It enjoys a good reputation among the customers and in the industry. Its brand has influence.

Source: Company documents and interviews summarized by the author

4.3.3 Technological innovation selection of Kingsun

In the early period, Kingsun was engaged in the production of lighting decoration. Several years later, Mr. Li Xuliang slowly felt the potential crisis of the industry as a larger quantity of orders would bring less and less profit. After giving it a careful thought, Li decided to make a transformation together with over two thousand employees to seek a new development path. Since the company has been in the lighting decoration industry, Li began to rethink the future development direction within the industry at the time when EU and USA promoted a series of policies to encourage the application of semiconductor lighting and LED products, showing the whole world a concern about green environmental protection products.

The fact that the company had R&D experience of LED products enlightened Li to judge it with his sharp eyes as the sunrise industry, which was suitable for the development of the company and the saving energy industry. So, Li Xuliang started the transition to increase the investment in R&D production of LED lighting products in 2004.

Under the circumstance of resource constraints, Kingsun followed the demand theory to analyze the market demand; then it made a technical cooperation with Tsinghua University and used the brand and market effect of stock market listing. As a result, the company chose to take a partner innovation and demand-pull type technological innovation model to seek its survival and sustainable development. By gradually increasing its brand awareness and gaining market share, the company became a well-known enterprise of the industry.

Kingsun has a strong production and marketing capacity and social network resources. However, the company was relatively lagged behind in terms of technology, especially in the core R&D technology. Realizing that Tsinghua University, Sun Yat-sen University and other higher education institutions have relative advantages in the technology theory and experimental studies and need to commercialize the technological innovations, Kingsun can make it possible to commercialize these scientific and technological achievements. To complement the resources from both sides, Kingsun adopted the partnership innovation model, hence reducing the time of cultivating the high-level professionals and technicians. The weakness is that the company lacks the leading technicians and internal coordination.

From 2004 to 2006, Li Xuliang strongly invested in human and physical resources but the few years' investment did not turn immediately into output, and Li Xuliang did not find a breakthrough, which could suit the development of the company. Until 2007 when Dongguan Government gave the guidance and support, Kingsun started to extensively cooperate with some well-known universities such as Tsinghua University, Northwest Industrial University, University of Electronic Science and Technology, Beijing Science and Technology University. Through the "production, learning and research" scheme, they jointly set up the Guangdong Semiconductor Lighting Technology and Application center, the Enterprise Technology Center of Guangdong province, the Dongguan Semiconductor Lighting Technology Institute and the Branch Lab of Tsinghua University that is an integrated optoelectronics state key lab. In addition, the company, in a short period of time, invested to expand its LED sealing factory, the lamp factory, the lighting decoration factory and other supporting production facilities. The model of technological innovation resources of Kingsun is shown in the Figure 4-7, (gray area).

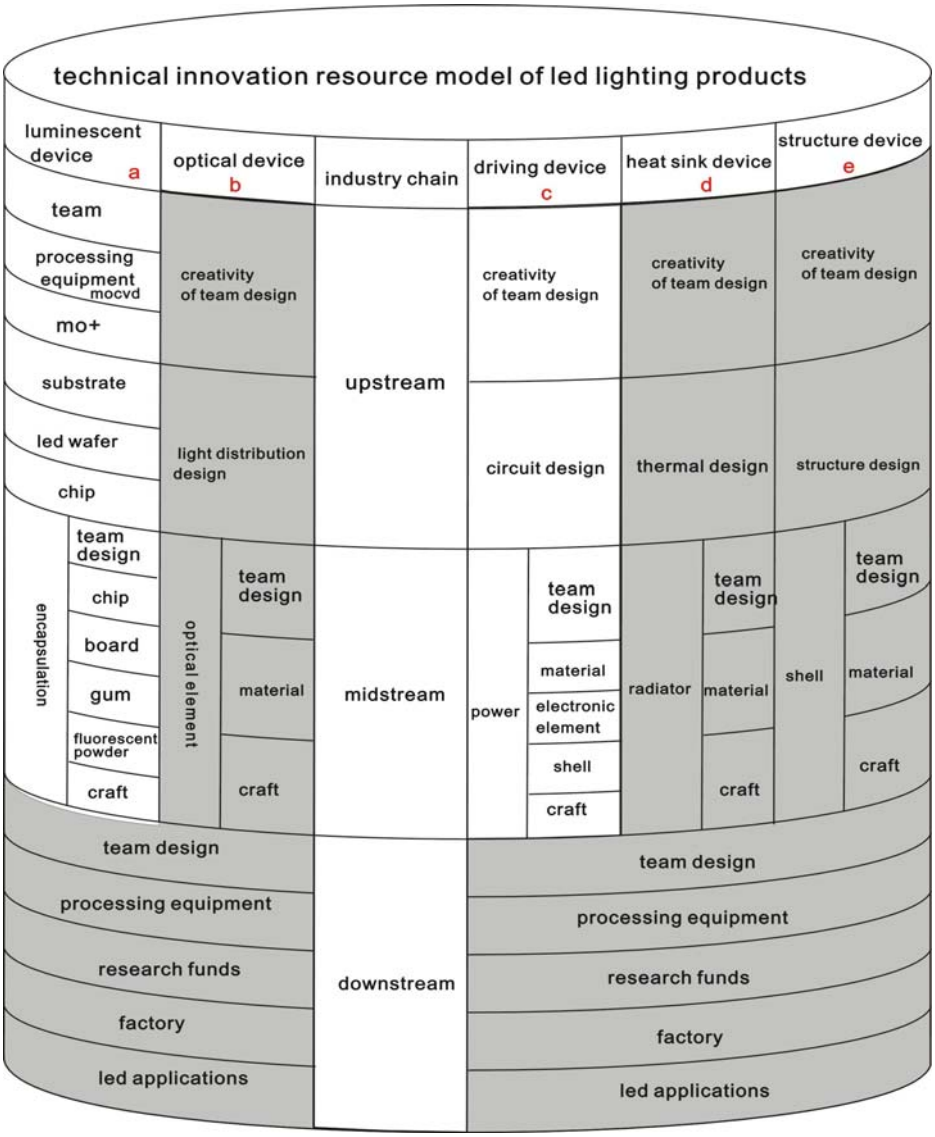


Figure 4- 7 An analytical model of technological innovation resources of Kingsun

Source: developed by the author

With the government's support and the R&D cooperation with Tsinghua University, Kingsun gained strength to speed up its development. The top R&D talent and experience in the field of semiconductor lighting gradually brought the high-power LED street lights and tunnel lights of the company to the markets. Comparing with the traditional energy-saving lights, LED lights have longer service life, more energy-saving and environmental protection benefits as well as advantages of high brightness, light decay, good stability and automatic reduction of deep night luminous efficiency, the high-power LED street lights, spot lights and indoor lighting products passed the energy-saving, safety and reliability tests set by the national Optical Power Quality Supervision and by the Inspection Center and the 5th Electronics Research Institute of the Ministry of Information Industry and have been awarded

with multiple certificates.

Relying on professionals, Kingsun has strong production capacity of LED semiconductor lighting sealing and application and a complete sales channel. The company and Tsinghua University jointly established the Dongguan Kingsun Semiconductor Lighting Technology Research Institute, the Semiconductor Lighting Technology and Application Center of Dongguan City, the Semiconductor Lighting Technology and Application Center of Guandong Province. Other projects include the key industrial projects of Guangdong province, the national 863 plan, Torch plan and the National Semiconductor Lighting Technology and Application Center. The company invested heavily to build its world level LED sealing factory and ensure its leading position in China. To forge a strategic alliance with international top chip suppliers, the company becomes the first domestic enterprise of scale production of high-power LED lighting products. The products passed the American UL, Canadian CSA, German GS, EU CE certifications, forming an operation structure featuring technological cooperative innovation and industrial diversification.

Through the cooperation with Tsinghua University, the company has developed the technology of second light distribution of lens applied to the LED street lights and LED tunnel lights. The technology solved the technical problem of the uneven ground illumination of LED streets and tunnel lights and it can increase the ground illumination uniformity to be over 0.7 and lens efficiency of more than 93%.

Through the cooperation with Sun Yat-sen University, the company solved the problems of short service life of LED lights, easy dead lights and ineffective matching with LED light source. By the joint efforts, Kingsun and Sun Yat-sen University designed and produced LED switch power controller with up to 6 years life. This product has a good thermal performance with an efficiency of over 92%.

An analysis of technological innovation capability of Kingsun

Kingsun has plenty of ordinary resources and market factor resources, which enables it to have a strong capability in production, investment, and marketing. However, due to its weak technological innovation at the start-up stage, it lost an increasing number of clients and suffered from high level stock and receivables, which could cause the company a big problem. Figure 4-8 shows a model of technological innovation capability of Kingsun.

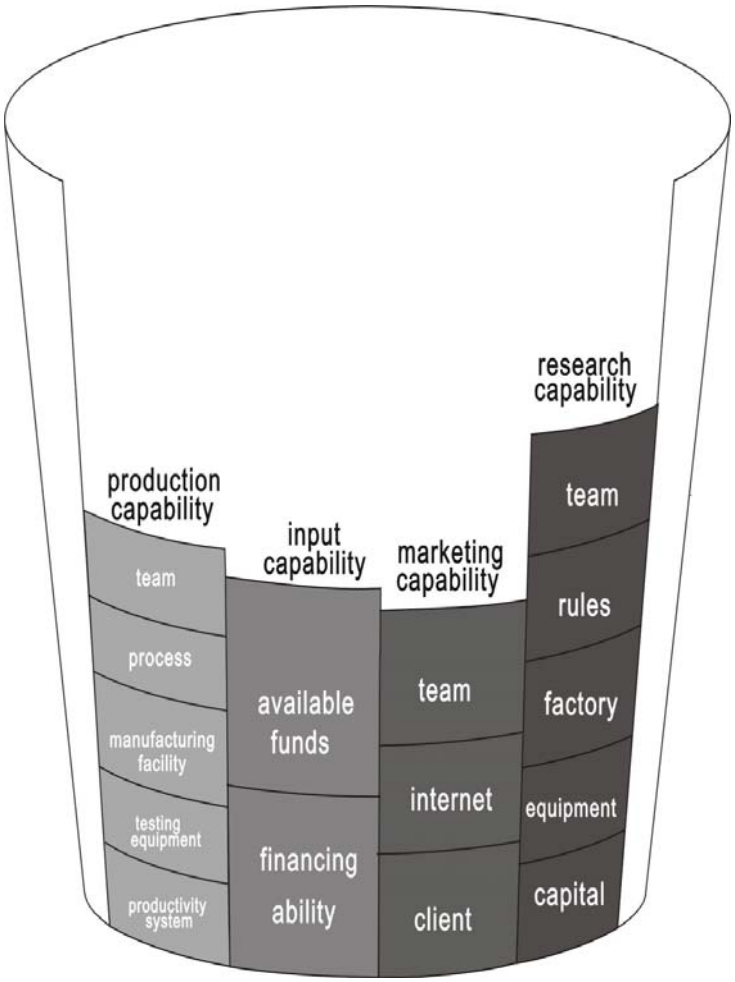


Figure 4- 8 An analytical model of technological innovation capability of Kingsun

Source: developed by the author

The model of partnership innovation brought huge benefits to Kingsun. On the one hand, the company has made a big leap in terms of technology resources, technical capability, and product development; on the other hand, through cooperative innovation Kingsun further expands its influence and leading advantages in the industry. The innovation achievements are demonstrated as followed.

15 years' LED development and application, 8 years' high-power lighting experience

The largest LED R&D and production base in Asia；

National level lab to guarantee the product quality；

People Insurance Corporation of China insured the quality of products；

5 years' warranty；

National level high-tech enterprise；

Multiple LED cooperative patents；

Project taker of National 863 Plan；

Project taker of National Development and Reform committee and Ministry of Industry and Information Industry

Electrical Magnetic Compatibility energy saving service company filed with National Development and Reform committee;

Exclusive partner of Tsinghua University in LED industry；

Workgroup member of China's LED Lighting Technical Standard；

Transformation of the new EMC [33] energy saving projects

Today, Kingsun has taken "win-win cooperation" as its basic business philosophy. On the specific rules of the strategic cooperation, once the relevant LED enterprise forms the strategic partnership with Kingsun, it will share all the existing achievements which Kingsun has, which include the brand, technical output, joint R&D and project application, production line, R&D system, testing system construction, ODM/OEM procurement, design, marketing support, joint investment, business model design and related financial support.

Summary:

The social network of entrepreneurs helps to promote enterprise's innovation. Innovation activities of enterprises are mainly organized and promoted by entrepreneurs. In the process of promoting innovation, entrepreneurs are definitely influenced by their rooted personal networks and social networks (He and Qin, 2005; Wu, Wang and Tang, 2007).

The entrepreneur of Kingsun is a Dongguan local, who established a good relationship with the local government and other local entrepreneurs. This provides an important resource for its technological innovation and also enables it to take a partnership innovation possible. Besides the extensive social networks, the company enjoys a complete sales channel. Due to its inadequate original technology accumulation, the cooperation with outsiders becomes its preferred strategy. Partnership innovation has the advantage of sharing costs, reducing risk and accessing to technology (Luo and Tang, 2000). The partnership innovation between Tsinghua University and Kingsun reflects the above theory.

[33] EMCBT Is used to reduce energy costs to pay the full cost of the project investment of energy conservation

4.4 Case Study Three: Technological Innovation Selection of Sanan Optoelectronics Co. Ltd

4.4.1 Introduction of Sanan Optoelectronics Co. Ltd

Sanan Optoelectronics Co. Ltd (hereinafter referred to as "Sanan Optoelectronics") is China's earliest, largest production base producing the best quality of full color ultra high brightness light emitting diodes epitaxial and chips. It is also a "National High-Tech Industrial Demonstration Project" approved by the National Development and Reform Commission and a "Leading Enterprise of Semiconductor Lighting Engineering" recognized by the Ministry of Science and Technology. The company has undertaken multiple major national projects such as "863" and "973" projects. In addition, the company hosts the national level Post-doctoral research station and the state-level enterprise technology center. The headquarters of Sanan Optoelectronics are located in the beautiful Xiamen City in Southeast China and, besides Xiamen, its industrialization base is located in Tianjin, Wuhu, Huainan, Quanzhou and other cities.

Sanan Optoelectronics is principally engaged in full-color high brightness LED epitaxial wafers, chips, compound solar battery, high-power concentrating photovoltaic products R&D, production and sales. The product performance indicators reach the international advanced level. At present, the company has over 100 modern clean factory workshops, thousands of the most advanced epitaxial wafers and chips production equipments and high-power concentrating photovoltaic automated production lines, which provide a strong guarantee for the production and operation of the company.

The founder of Sanan Optoelectronics and chairman of Sanan Group board—Mr. Lin Xiucheng was born at Hutou, Anxi city, Fujian Province. Together with his son, Mr. Lin Zhiqiang, they hold 100% of shares of Sanan Group and directly hold 49.14% equity of Sanan Optoelectronics, which is equal to 11.267 billion RMB. They rank among the first rich people on the list of China's New Energy tycoons. In June 2001, Lin Xiucheng set up Quanzhou Sanan Group in Fujian Province. In 2003 the Quanzhou Sanan Group was renamed the Fujian Sanan Group and in the following year the headquarters were moved to Xiamen City, which marked the company formally entering the electronic industry. Fujian Sanan Group became the actual holder of the listed Sanan Optoelectronics.

Sanan Optoelectronics mainly operates in the domestic market of China. Its main

business focuses on the production and sales of LED chip and epitaxial wafers. In recent years, it has extended its upstream advantages to the downstream industrial chain. Due to the advanced nature of the technology, Sanan Optoelectronics has achieved a profit margin as high as 50% (see Table 4-13).

Table 4- 13 The financial report of Sanan Optoelectronics 2007-2011

	2011	2010	2009	2008
Revenue （RMB）	175million	863million	470million	213milliion
Net profit（RMB）	936million	419million	180million	52.05million
Net profit margin（%）	53.58	48.60	38.31	24.42
Total asset turnover	0.23	0.21	0.32	0.50
Liability/Asset ratio（%）	37.22	18.41	29.14	44.12

Source: Financial reports of the company

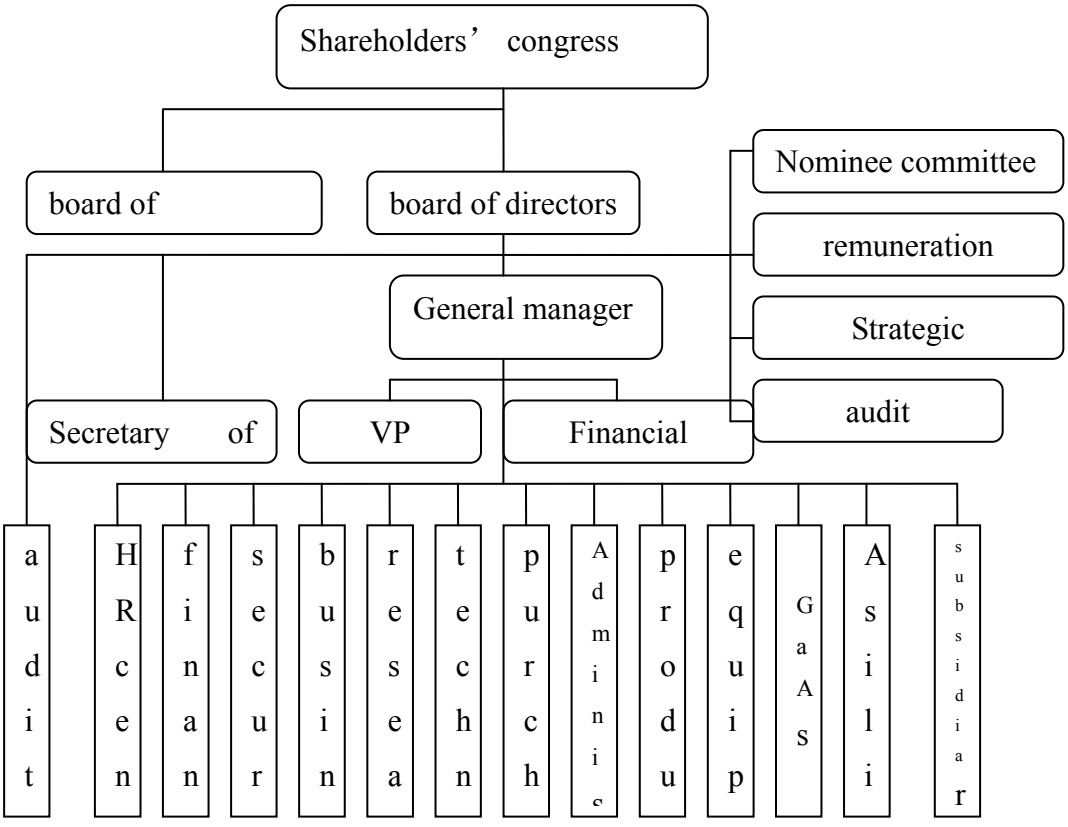


Figure 4- 9 Organizational structure of Sanan

Source: The annual report of Sanan Co. Ltd for 2011 year

4.4.2 Resource and capability analysis of Sanan Optoelectronics

Sanan Optoelectronics has a high-quality team of experts from the USA, Taiwan, Japan and China, who are the top talents in the field of optoelectronic technology. The company has

applied for and obtained nearly 200 invention patents and proprietary technologies. A number of independent research proprietary technologies filled some of the gaps of China. Strictly complying with international quality management systems and international environmental management systems, the company was awarded ISO 90001 certificate in 2003, 2000 quality system certification, ISO 14001 in 2003, 2004 environmental management system certification. In 2009, the company passed the quality management system certification of ISO/TS16949 automotive production and relevant service parts.

Sanan Optoelectronics products have been widely used in indoor and outdoor lighting, backlight, display, signal lights, electronic products, aerospace, solar power and other fields. The products are sold in China and abroad, receiving recognition from customers.

Sanan Optoelectronics takes the responsibility of building up a national high-tech enterprise with independent intellectual property rights. By leading the trend and dedicating to the new energy as its vision, the strong technological force and advanced equipment, with its higher position, faster speed and higher goal, the company promotes the optoelectronic industry of China and became a world's influential optoelectronic industry base. Sanan achieves a production scale of annual output of 450,000 epitaxial wafers, 15 billion chips, which accounts for over 58% domestic capacity.

Table 4- 14 Resource and capability of Sanan Optoelectronics

Technical resource	In the early period, the company was not in the area of Green lighting, the relevant technology was very lack. The fast accumulation and development of the technology was benefitted from the introduction of mature technology from Germany.
Capital resource	Through the capital market, the company has strong investment and financing capability. It has even made equity investment in or acquired some high-tech enterprises.
Marketing capability	The company has a complete industrial chain and strong marketing capability. Some of the products enjoy the absolute advantages in the Chinese market.

Source: Company documents and interviews summarized by the author

4.4.3 Technological innovation selection of Sanan Optoelectronics

From its establishment in 2000 to 2012, Sanan has introduced 144 sets of equipment in total from German AIXTRON and American VEECO to obtain the technology of producing the epitaxial wafers. The main focus was on the upstream chips and epitaxial wafers. Its subsidiary, Anhui Sanan Optoelectronics was granted the government subsidies because of its

successful introduction of the technology.

Sanan chose the introduction of technology as its technological innovation mode. Through purchasing the equipment and technology, Sanan advanced its technological innovation. The model of technological innovation resource is shown in Figure 4-10 (gray area).

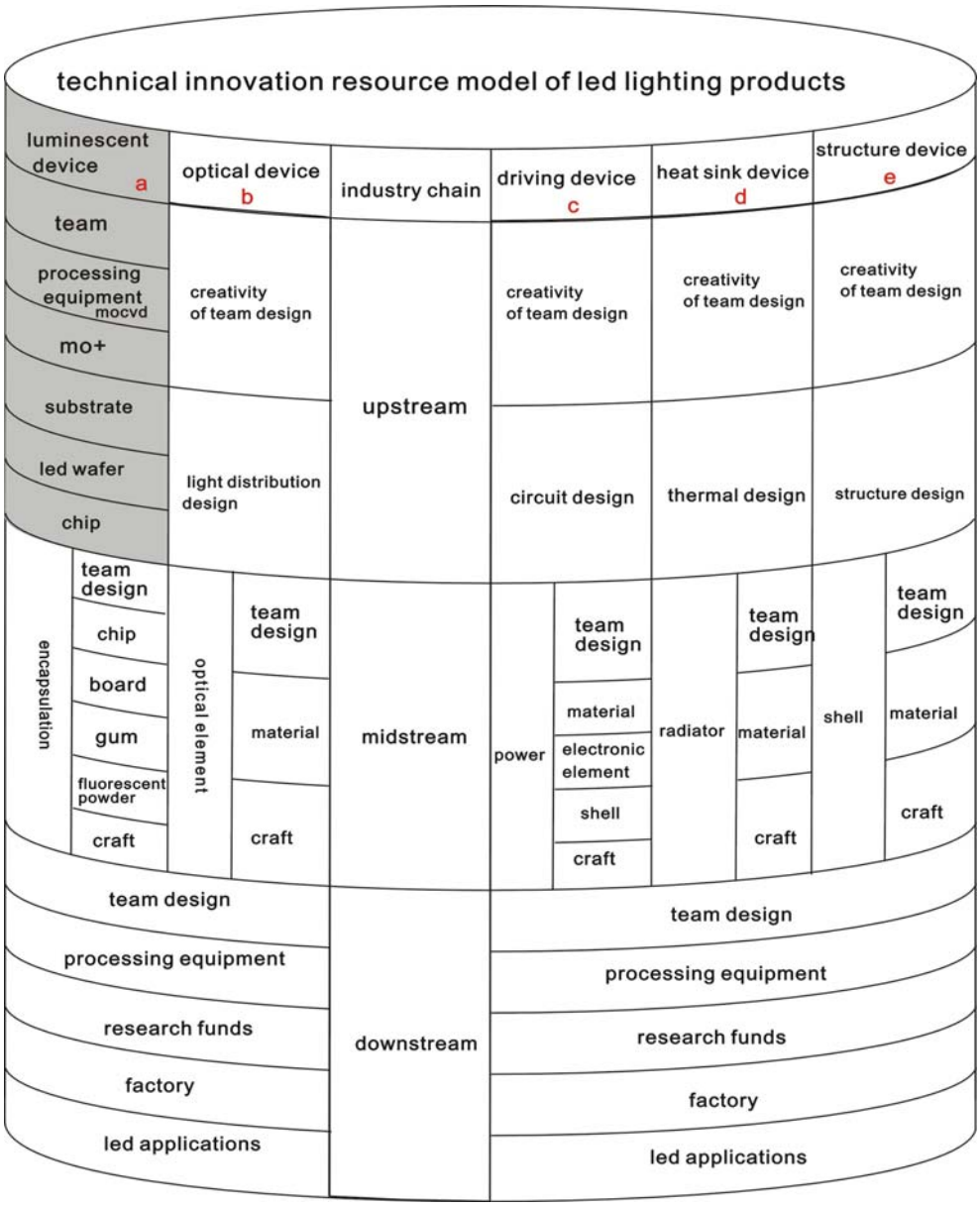


Figure 4- 10 An analytical model of Sanan technological innovation resource

Source: developed by the author

(1) The strategic resources of Sanan

Sanan obtained its technological resources through purchasing the manufacturing equipment. Within a certain period of time it can use the technology to manufacture epitaxial wafers and chips and further promote its brands and corporate culture resources. However, the upgrading of core technology restricts its development in a long run.

(2) Material resources

The registered capital of Sanan was 1.4 billion RMB and increased its accounting capital to be 11.267 billion RMB after listing on the stock market, which enjoys a strong financial standing. The ordinary resource of Sanan is abundant. For example, with 144 sets of MOCVD equipments it has the largest capacity in the nationwide. In addition, it has a complete marketing network.

(3) Market factor resource of Sanan

Sanan enjoys plenty of market factor resources. Not only it has a good relationship with the local government but also established a partnership with a local sealing company to enter the international market. This move accelerates its integration of the whole industry chain.

Though Sanan owns a whole industry chain and strong marketing capability, its core technology has been seriously constrained by the foreign suppliers of equipment. Comparing with the chip manufacturing technology in US, Japan and Taiwan, some gaps still exists in Sanan. A model of technological innovation capability of Sanan is shown in Figure 4-11 (Gray area)

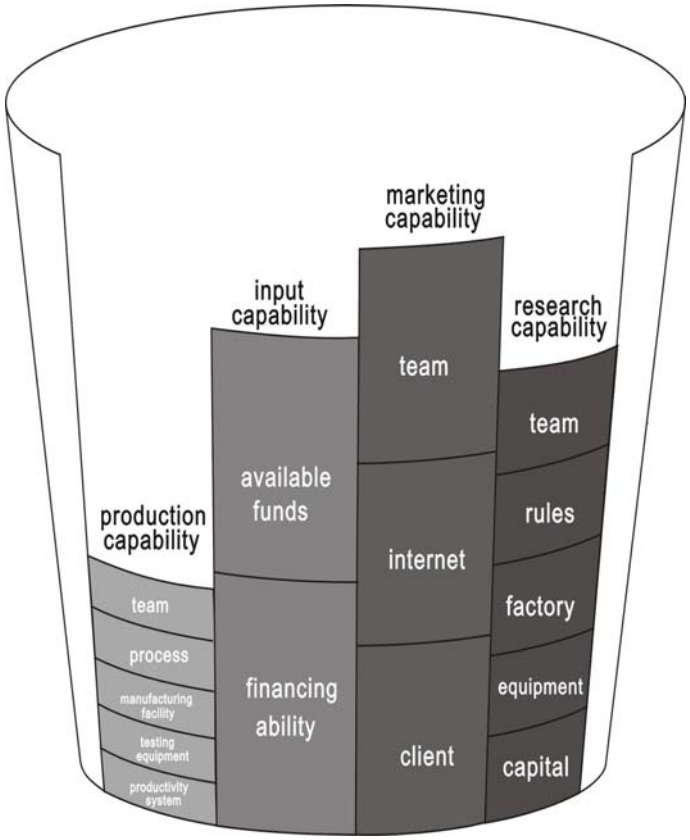


Figure 4- 11 An analytical model of technological innovation capability of Sanan

Source: developed by the author

In short, Sanan enjoys plenty of ordinary resources and market factor resources. It has strong capability in terms of production, investment and marketing and also has advantages in the upstream of the industry. However, due to the constraints of upgrading the properties of its products, it has faced great challenges from the competition of other players in the industry. In the same time, it is relatively slow to promote the technological innovations in the downstream of the industry, which results in the declining sales and increasing stocks.

The development of LED enterprises requires not only advanced hardware MOCVD equipment, but also the leading professional and technician and R&D team. In recent years, the domestic LED industry has developed rapidly but most enterprises have purchased MOCVD hardware while they have relatively neglected the software such as technology and talents. Sanan, however, to ensure its normal expansion, has nurtured a large number of LED technology professionals by recruiting and training. As an enterprise post-doc workstation recognized by the National Ministry of Personnel, the company not only introduced the world advanced LED Epitaxial and chip equipment, but also formed a research team composed of top optoelectronic talents from home and abroad who can grasp the leading epitaxial wafers and chip technology. The company became the largest enterprise producing full-color high brightness LED chips and the production base of full-color high brightness LED chips. Sanan has strong R&D capabilities and complete product lines and is able to reduce the cost by improving the product quality and mass production, which achieves the economies of scale. Some products reach the international advanced level so they enjoy strong market competitiveness.

Table 4- 15 Sanan's main technological achievements and honors

Time	Events
January 2003	The company passed the full-color high brightness LED chip technology appraisal, and became the first domestic manufacturer to produce full-color super brightness light-emitting diode chips.
Nov, 2004	The project "The development of semiconductor lighting high power white light diode chips and its commercialization" was listed into the key supporting projects of 2005 Information Industry Fund by the Ministry of Information Industry.
December, 2005	The Tenth "Five-Year" National Key Science and Technology project "Semiconductor lighting Industrial technology development" undertaken by the company passed the evaluation of the expert's panel organized by Ministry of Science and Technology.
December, 2006	The Project "100lm/W Power white light LED Manufacturing technology" undertaken by the company was approved by the Ministry of Science and Technology to be the National high-tech research development project (863 Plan)

Oct. 2008	The technology center of the company was awarded with the title of "National Level Technology Center"
November, 2008	The project "LCD display backlight using Ultra high brightness semiconductor red diode (LED chip development and industrialization" was listed by the Ministry of Information Industrialization to be the key supporting project with 2008 Information Industrialization funds.
December, 2008	The project "The industrialization of super brightness LED chips applied to TFT-LED" was listed by the National Development and Reform Committee into 2008 the fourth batch high-tech Industry development of Technology R&D Funds.
Nov. 2009	"RS-B1 ultra-high brightness power red light-emitting diode chip", identified as a national initiative through the identification of new product experts, product performance reached the international level.
Aug. 2009	The project "Semiconductor lighting device R & D and industrialization" undertaken by the company was listed by the Ministry of Information Industry into the supporting projects included in the 2009 Information Industry Development Fund.
March, 2010	The company was awarded the title of " National Demonstration Unit introducing Foreign Experts"
May, 2010	The Class A project of "863 Plan" undertaken by the company was approved, which made it the first semiconductor lighting LED enterprise in China.
December, 2010	The project "The industrialization of super brightness LED chips applied to TFT-LED" was awarded as the important technological invention by the Ministry of Industry and Information in 2010.
December, 2010	It entered "Shanghai and Shenzhen 300 Index"
August, 2011	"LCD Display backlight using LED chip" was recognized as the key new product by the Ministry of Science and Technology.
Nov, 2011	The company's invention" a space-type three-dimensional distribution of the electrode of the light-emitting diode and its production method "was awarded the China Patent Excellence Award.
April, 2012	The trademark of the company was recognized as a China's famous trademark by National Commerce and Industry General Administration.

Source: Archive of Sanan Development, adjusted by the author

In addition, the top management of the company also supports the acquisition of the relevant technology. In 2012, Sanan acquired several LED companies from Taiwan either through acquisition or equity investment. "Sometimes, the huge investment in R&D is not as good as the direct purchase of relevant technology" as quoted an interviewee in charge of the technology department of Sanan Optoelectronics.

Summary:

Entrepreneurial activities refer not only to the establishment of new enterprise but also exist in the established firms. Miller (1983) argued that entrepreneurship is associated with product, market and technological innovation and other activities within the company. Sanan

entering into the LED industry is mainly based on the purchase of technology. The company was large in size, strong in finance and better with market opportunities. Through introducing the technology from Germany, it took initiatives to acquire the market and become a leader in the LED industry of China.

Purchasing technology for use is an effective way of enhancing the competitiveness of less developed countries and companies (Wang, Feng, Hou, 2010). However, purchasing technology is not ultimate goal, which is rather an innovation approach for making profit through the product marketing. Through the introduction of technology, Sanan not only obtains the benefits from the market, but also has accumulated technical capabilities for its subsequent development. Currently, Sanan has achieved competitive advantages in terms of technological innovation.

4.5 The comparative analysis of case study and implications.

4.5.1 The comparative analysis of three case studies

Through the brief description of the above three case studies we can make the following comparative analysis. Among the three enterprises, the establishment time of Grand is the shortest and its scale is the smallest, but Grand chose the independent innovation mode in the LED field. Because each enterprise is composed of heterogeneous resources and the resource composition and the entrepreneurial team varies from enterprise to enterprise, the selection of technological innovation of each company is different. The strategic resources and core competences have the most impact on the selection of technological innovation, which decides the basic mode of the technological innovation. The enterprise resources and capabilities provide the possibility of the selection of various technological innovations (Table 4-16).

The reason why Grand chose the independent innovation mode is essentially due to the technical background of its entrepreneurial team. In the case of the relative lack of other resources (financial for example), the company obtained its patents through self-independent innovation to enhance its market position. This is a very realistic option for a small business and many Chinese entrepreneurial enterprises have a similar feature to Grand which although small in scale possesses core technology. In Grand's case, technology is a "push" factor for entrepreneurship.

Table 4- 16 Comparing the Selection of Technological Innovation by the Three Companies

Enterprise	Core resource	Core capability	Innovation mode	Innovation mode choice
Grand Technology Co.	HR, Technology	R &D capability	Independent Innovation	= A^5*B*C*D*E*F*P
Kingsun Optoelectronics	Social network	R &D capability、pruduction、market capability	Partnership innovation	=B*C*E*F*P
Sanan Optoelectronics	Finance	Inptut and market capability	Technology introduction	= A^1* A^2* A^3* A^4 *A^5*P
Case conclusion	Must be integrated industrial resources go the way of integration innovation		Integrated innovation	=A*B*C*D*E*F*P
remark	Industrial chain model of the technical feasibility A= A^1* A^2* A^3* A^4 *A^5*A*B*C*D*E*F*P			

Source: Summarized by the author

Both Kingsun and Sanan have been operating in the power-related field for a number of years before they entered into the LED industry. So their entrepreneurial behavior is much more a kind of entrepreneurship. LED industry in China is a relatively new industy and most enterprises are new entrants in the competition. In particular, there is not much difference among the enterprises in terms of technological starting point. Although the two enterprises have large business scales, they are not strong enough in terms of technological reserves. In the context of the rapid development of the market, it is time and energy consuming for the two enterprises if they had chose independent innovation and this is why they have adopted alternative solutions.

There are two reasons that Kingsun chose to cooperate with Tsinghua University and Beijing University of Science and Technology. On the one hand, the company has a certain technical strength and strong financial and HR resource for its chips while the universities and research institutes need to put their technology achievements into practice. So the cooperation is a win-win strategy. On the other hand, the management of the company has social relations and networks, which facilitate entering into partnership cooperation. For example, Dongguan Government helped to bridge the cooperation between Kingsun and the universities to strongly support the development of the company.

Sanan adopted the technology purchase as its way of innovation. As the market develops rapidly, the company took advantage from having a complete sales channels and relevant resources to make the choice. Due to the short time of technology introduction and quick response to the market, this was the best choice for Sanan, which has been in the other

photovoltaic industry for many years.

In the course of research and case analysis, we also found that at present the technological level of the three companies is very high. In particular, Kingsun and Sanan have not only been successfully listed in the stock market, but also became the leaders in their respective field (Kingsun mainly focuses on the LED downstream application while Sanan focuses on the chip manufacturing of the upstream). Although entrepreneurial enterprises may make different choice of technological innovation mode under their resources and capabilities constraints, there are no good or bad modes among different innovation modes. No matter whether it is technology innovation, partnership innovation or independent innovation, enterprises can acquire technological resources and improve their research level through these diferent processes. The innovation achievements and business success of the three companies in the case study fully illustrate this issue.

4.5.2 Research significance and implications.

The analysis of the development of the LED industry in China and the three case studies illustrate the following points:

First: Technology is the key factor to enter this emerging industry. Technological innovation is an important option for enterprises to enhance the competitiveness as technological progress can improve the performance of products, reduce production cost and promote consumers' acceptance.

In the LED industry, technology is the basis of competition therefore, in order to make considerable development it is only through technological innovation that firms can obtain the technological resources they need and gradually form their core competitiveness. Through the case studies, we found that technology can be acquired through the following approaches:

By the entrepreneurs themselves or by commissioning innovation to a development team;

By cooperating with famous universities and research institutes;

By purchasing the technology or hiring talents from other companies;

Second: the strategic resources and core competencies of entrepreneurial enterprises determine the choice of technological innovation modes. Various resources that enterprises have are not equally important. Strategic resources and core competences reflect the nature of scarcity, inimitability, non-substitutability and strategic resources of different enterprises are

also different so the selection of technological innovation also varies. Generally speaking, enterprises with strong technological resources and capabilities and other base installation resources tend to choose independent innovation, while enterprises with average technology but substantial capital and complete market channels tend to select the partnership innovation or introduction of technology.

Third: the enterprise resources and capabilities of enterprises guarantee the possibility of innovation and support the realization of innovation. The technology innovation requires multiple resources among which financial resources. Innovation means huge input in terms of human and physical resources, which needs for strong financial support. Kingsun and Sanan in the case studies confirmed this point.

Suppliers are also a source of technological innovation. All the technological innovations rely on the materials provided by the upstream suppliers. The proper selection of upstream suppliers can reduce the development costs and shorten the development cycle. Grand is preparing to work with the world's top five suppliers to build strategic partnerships. As time comes, Grand will participate in the product technological development of upstream suppliers in order to obtain the guarantee for the technological innovation of Grand. At the same time, the suppliers will be invited to join the product design of Grand to transform the human resources of suppliers into Grand's strategic resources and their physical resources into Grand's ordinary resources.

All the technological innovations are made for customers so the main body of evaluating the technological innovations is the user. Users are also the first hand source of innovation information and the source of error correcting after the use of products. Kingsun establishes a system of regular visits to customers, which collects the information of customers' needs, and listens to customer feedback to improve the products and services.

Fourth: with the development of the strategic resources and core competencies of entrepreneurial enterprises ordinary resources may be upgraded to a strategic resource. Taking Kingsun and Sanan for example, both companies were weak in terms of technology when entering the LED industry. However, with their continuous input into innovation, the two companies have improved their technological capabilities and the technological resource has become the core strategic resource. On the basis of the technology, both companies have now a large number of independent innovation projects, some of which have become the leaders in the industry. This also confirmed the conclusion that the role of resources and capabilities may change with the development of enterprises.

Chapter 5: Research conclusion and outlook

5.1 Research conclusion

With the development of the socio-economic and technological environment and the acceleration of globalization, environmental issues have gradually become a global problem. In order to address the increasingly prominent energy and resource shortages, countries around the world stepped forward legislation to encourage the use of energy-saving light sources, which brings tremendous business opportunities and broad prospects for the development of LED green lighting.

The study first evidenced the need for the development of green lighting industry, and pointed out that technological innovation is an important factor to promote the industry. Enterprises should adopt appropriate technological innovations to suit the industry development and actively participate in the competition. Entrepreneurial enterprises should pay more attention to this issue in the dual constraints of resources and capabilities.

Second, through literature review the thesis summarizes the basic problems of the resource theory of enterprises. Taking it as the main thread, a systematic review was made about the resource and capability-view and the basic mode of technological innovation, connotation and features of entrepreneurial enterprises were also discussed. The theoretical contribution of this thesis is that, based on the literature, it has established the technological innovation selection model for entrepreneurial enterprise based on resources and capacity constraints. This model takes into account the segment dimensions of resource and capability and major performance, which contribute to be a valuable reference for the selection of entrepreneurial enterprise technology innovation.

Third, the research design and methodology were introduced. In accordance with the research requirements, the section proposed a practical research design. The model used in the study takes into account the resources of the enterprise, technological innovation capability based on the process and the characteristics of entrepreneurial enterprises. In terms of methodology, a multiple case study was adopted to further improve the theoretical model. In addition, a detailed introduction was given to the data collection (how to collect the data, the data description), data sorting and the process of case study.

Finally, the study uses three case corporations to discuss the relevant models. The study

selected the three corporations, namely Grand, Kingsun and Sanan, to describe and analyze their major resources and capabilities and the selection of innovation modes. Among the three companies, Grand has the shortest establishment time and a small size, however, Grand chose the mode of independent innovation in LED industry. Both Kingsun and Sanan have strong marketing capability but their technology resources are relatively weak. So, they adopt the innovation through partnership or purchasing approach.

As enterprises are composed of heterogeneous resources and the leadership of each enterprise is different, enterprises vary from one to another in terms of technological innovation. The strategic resources and core competence may determine the patterns of technological innovation while the general resources and competence make innovation possible (table 5-1; table 5-2). In addition, no cross-industry strategic resources have been identified since strategic and general resources are determined by the features of individual enterprise. Therefore, enterprises should select the most appropriate technological innovative strategy based on their resources and capability.

Based on the analysis of the technological innovation of the three enterprises, as illustrated in figure 5-1 (analysis of technological innovation resources of LED enterprises) and in figure 5-2 (analysis of technological innovative capability of LED enterprises), a mode of the feasibility of technological innovation with semi-conductor lighting products could be produced as A= A1* A2* A3* A4 *A5*A*B*C*D*E*F*P.

Table 5- 1 LED enterprise technology innovation mode analysis (barrel principle)

<table>
<tr><th rowspan="2">Area</th><th colspan="12">Enterprise resources</th></tr>
<tr><th colspan="2">A
Luminescent device</th><th colspan="2">B
Optical device</th><th colspan="2">C
Driving device</th><th colspan="2">D
Heat sink device</th><th colspan="2">E
Structure device</th></tr>
<tr><td rowspan="5">upstream</td><td>MOCVD</td><td>A^1</td><td colspan="2" rowspan="2">Team design (B1)</td><td colspan="2" rowspan="2">Team design (C1)</td><td colspan="2" rowspan="2">Team design (D1)</td><td colspan="2" rowspan="2">Team design (E1)</td></tr>
<tr><td>MO+</td><td>A^2</td></tr>
<tr><td>substrate</td><td>A^3</td><td colspan="2" rowspan="3">Design concept (B2)</td><td colspan="2" rowspan="3">Circus design (C2)</td><td colspan="2" rowspan="3">Thermal design (D2)</td><td colspan="2" rowspan="3">Structural design (E2)</td></tr>
<tr><td>Led wafer</td><td>A^4</td></tr>
<tr><td>Chip</td><td>A^5</td></tr>
<tr><td rowspan="7">Middle stream</td><td rowspan="7">Packaging（A^6）</td><td>Team</td><td rowspan="7">Optical element</td><td rowspan="2">Team</td><td rowspan="7">Power</td><td>Team</td><td rowspan="7">Radiator</td><td rowspan="2">Team</td><td rowspan="7">shell</td><td>Team</td></tr>
<tr><td>Chip</td><td>Material</td><td>Material</td></tr>
<tr><td>Board</td><td rowspan="3">Material</td><td>Electronical elements</td><td rowspan="3">Material</td><td rowspan="3">material</td></tr>
<tr><td>Gum</td><td>shell</td></tr>
<tr><td>Fluorescent powder</td><td rowspan="2">technology</td><td rowspan="2">technology</td></tr>
<tr><td>technology</td><td>Technology</td><td>technology</td></tr>
<tr><td>downstream</td><td colspan="12">LED products（C）</td></tr>
</table>

Source: developed by author

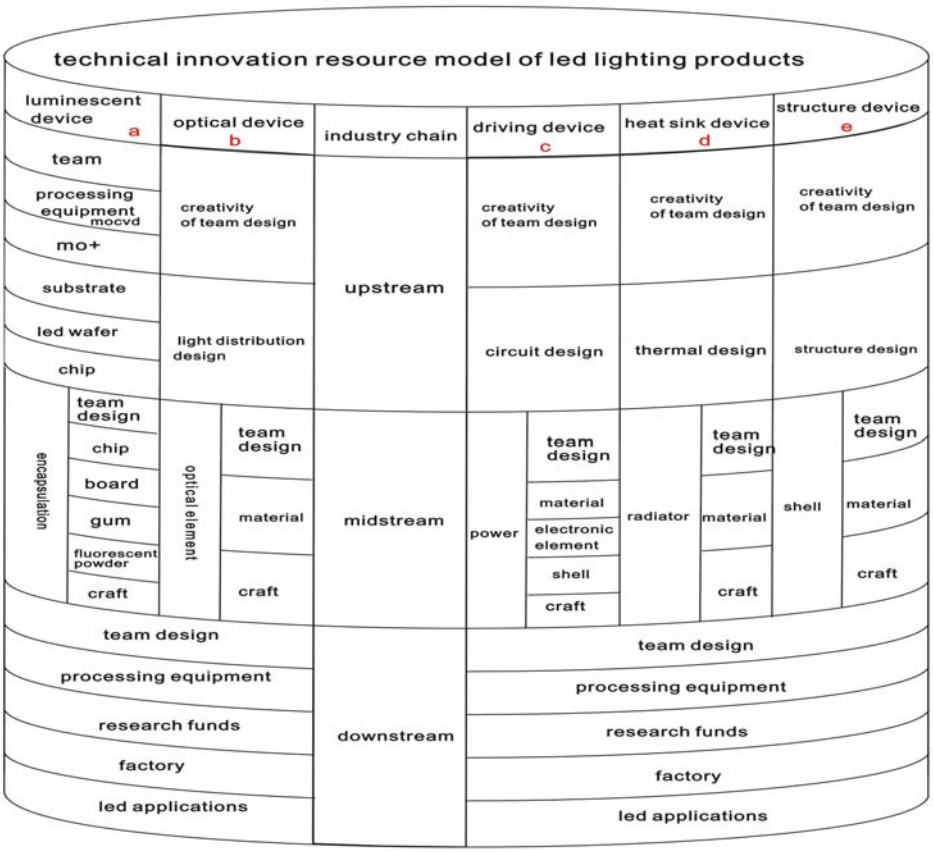


Figure 5- 1 LED enterprise technology innovation mode analysis

Source: developed by the author

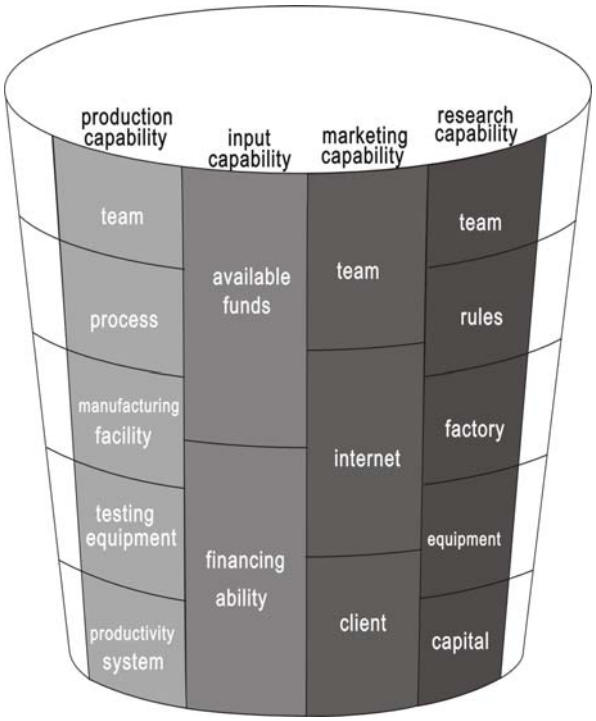


Figure 5- 2 Three cases of corporate innovaion mode selection

Source: developed by the author

Table 5- 2 LED enterprise technology innovation capability analysis (barrel principle)

Enterprise	**Strategic Resource**	**Core capability**	**Innovation modes**	**Mode selection of technological innovation**
Grand	HR resource Technology resource	R&D capability	Independent Innovation	= A^5*B*C*D*E*F*P
Kingsun	Social network resources	R&D, Operation、marketing	Partner innovation	=B*C*E*F*P
Sanan	Financial resource	Input、marketing	Innovation through purchasing	= A^1* A^2* A^3* A^4 *A^5*P
Conclusion	Integrated innovation through integrating industry chain		Integrated innovation	=A*B*C*D*E*F*P
remarks	Technological feasibility model: A^1* A^2* A^3* A^4 *A^5*A*B*C*D*E*F*P			

Source: developed by the author

By the replication principles and matching multiple case analyses, we draw the relevant research conclusions, which are illustrated as follows:

(1) Technological innovation mode is constrained by the resources and capabilities of enterprises. The resources of enterprises can be divided into strategic resources, general resources and market resources, three of which exist in different forms. In addition, the impact of resources and capabilities on technological innovation plays its own role in certain industries and policies but also in the cultural environment. In different industries, resources and capabilities that enterprises require are different.

The integration of entrepreneurial opportunities with resources and capabilities jointly affect the technological innovation behaviors. Generally, when the strategic resource is technological resource and the enterprise has the ability to acquire general resources, the enterprise tends to adopt independent innovation. When an enterprise has a certain technical capability and entrepreneurs enjoy rich resources of social networks, it often adopts partnership innovation. When the strategic resource is market or policy resources and abundant capital, the imitative innovation is often chosen.

(3) Strategic resource and capability of enterprises are not constant; they change along with the growth of entrepreneurial enterprises. The development of entrepreneurial enterprises is also a process of constantly obtaining resources and capabilities. With the development and competition of industries the competitive factors for the enterprises need to be compatible with businesses and industry cycles. Although the resource endowments in the start-up stage determine the technological innovation mode, companies will seek the optimal allocation of

resources to enhance the competitive advantages, and make efforts in this regard.

(4) Entrepreneurs or entrepreneurial teams and their social relations can influence the choice of technological innovation of enterprises. In the start-up stage the resource and capabilities are epitomized in its entrepreneurial team, so the characteristics of entrepreneurial teams have a direct impact on the strategic behaviors of the enterprise (including technological innovation behavior). If entrepreneurs enjoy a rich social network, enterprises tend to seek the external resources (such as partnership innovation) to reduce the time for self-development, which is also a common choice of many entrepreneurial enterprises.

5.2 Future research work

In our study we explored the status quo of China's green lighting industry and analyzed the technological innovation selections of entrepreneurial enterprises with resource and capability constraints. The conclusions we drew have significant implications for the development strategy of LED enterprises and the entrepreneurial enterprises to select their technological innovation approaches. Likewise, they can be applied to the technical strategy in other industries.

Our study is just a beginning of such research field and there is much room for further studies.

First, as a booming industry, green lighting is still at an early stage. We can track the industry's long-term development, focus on the key enterprises for their development, and further improve the study of technological innovation mode of the industry. During the interviews we have conducted for this study we found that China's LED industry lacks collaborative innovation in the upstream, middle stream and downstream of the whole industrial chain. However this is the key to advancing the LED industry. Several leading companies in the industry are needed to imitate and construct platforms and systems to push innovation forward.

Second, taking Grand, Kingsun and Sanan as the case corporations, we proposed the development model of technological innovation of the entrepreneurial enterprises. To further integrate the strategic resources, general resources and market factor resources with the technical capabilities of enterprises, future researchers can raise hypotheses based on the relevant theories and test them on large-scale samples. By exploring the topic of technological innovation selection of entrepreneurial enterprises, researchers can study in depth and further

test the conclusions of this study. Case study has comparative advantages in questioning or proposing a theoretical framework, but can not be generalized. However, the scientific conclusions should have withstood the test of various methods.

Third, the study focuses on enterprises in their entrepreneurial stage. Future research can extend the study to technological innovation measures and models at different stages of enterprises according to the theories of the life cycle of enterprise and industry, which companies in LED industry will go through.

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