

Technology Innovation and Global Competition-evidence from Global 500 Strong Construction Enterprise

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Abstract

Technology innovation plays a key role in strengthening the competitiveness of the enterprises. It is a good method for the company to win the market within background of global economy and fierce competition. Based on the literature review of the enterprise innovation and technology development status, choosing the construction enterprise listed in top 500 companies of 2015 as an example, this paper firstly analyzed the enterprises' basic ranking status and overall competitiveness. From the perspective of technology innovation management, then explored the differences among the construction enterprises from five aspects of technology innovation: (1) R and D human resources, (2) capital investment, (3) organization management, (4) incentives mechanism, and (5) innovation cooperative mechanism. The comparison between Chinese construction companies and international construction companies are presented as well with the root cause analysis of the difference on innovation management. Research found that Chinese construction enterprises are dominated the global leading position, but the technology innovation management mode and internationality is not strong. Finally, the paper put forward corresponding countermeasures and suggestions on how to improve the innovation performance for Chinese construction enterprises. It pointed out that the Chinese construction enterprises should strengthen technological innovation management, establish a professional technological innovation system and incentives mechanism to maintain international competitiveness and achieve sustainable development goals.

Keywords: Construction enterprises; Technological innovation; Innovation management; Top 500

Introduction

FORTUNE announced the latest top 500 companies of 2015 on May 18th, which includes eight construction enterprises. It has three companies decrease compared with eleven companies engaged in 2014. There are five construction companies from China, two companies from France and one from Spain. The famous American construction company Fluor and other international company are no longer within the top 500 strong companies due to the grim competitive market. Under the background of international economic depression, how these eight companies could keep leading position in construction industry and why the Chinese construction companies can dominate their realm in such fierce international competition background? From the perspective of technology innovation, this article firstly analyzes the companies' international performance, then explores the companies experience on innovation management from five elements of technology innovation like "R and D human resources, capital investment, organization management, incentives mechanism, and innovation cooperation mode to find the innovative or creative capabilities differences between the Chinese construction enterprises and other international corporate. This will help the related construction enterprises to figure out the potential opportunities for the future development and aid the sustainable development for the construction enterprises with a benchmark and experiences reference for domestic and foreign corporate.

Literature Review on Technological Innovation

The concept of innovation was initiated by economist Schumpeter in 1912 in his *Introduction to Economic Development*, he defined that innovation is a "new combination" to introduce new production elements and production conditions into production system [1]. Enterprises are the main participants of technology innovation. Michael Spence and Heather A Hazard [2] believed that enterprise competitiveness is the ability of one country's enterprises to do business internationally. Therefore, it is critical for the enterprise to

form the competitive advantages by means of reform through the well distribution of various resources, through which the enterprises can cultivate its survival ability in the process of products service period. Competitive analysis is one of the best methods for enterprises to know the competitive environment and get self-awareness against their own strengths and environmental opportunities. It is also a path for enterprises to verify their ability of technology innovation through the whole cycle of technology market demand analysis, conception formulation, planning, decision-making, R and D, engineering, mess production and market adoption.

Kharbanda [3] thought that, under the background of business trade freedom, globalization and fierce international competition, The establishment of strategic development plan on technology management could help the enterprises (especially for those in developing countries) to strengthen their corporate technical competency and enhance their international competitiveness. Barnett [4] introduced a model called Red Queen evidenced from some big hard drive manufacturers and verified the importance of enterprise organizational strategy plan, then concluded that the large enterprises can lead the technological competition in the market but cannot win the competition with other small-scale companies.

There are some scholars studied the influence of R and D activities to corporate competitiveness like Kumar and Aggarwal [5], Belderbos Rene [6]. Based on the case study of laser disc player industry

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development in China, Lu Feng and Mu Ling [7] studied the engine of enterprise's innovation and its competitive advantages, and found that the product innovation with market demand orientation, the efforts on technology learning and the development of capability are the reasons why the enterprises in technology backward countries can gain the competitive advantages in open market. Xie Wei [8] thought that innovation can be divided into system innovation, core technology innovation and external innovation, he pointed that most innovation strength of Chinese enterprises performed are external innovation.

Wei Xin-ya and Lin Zhi-yan [9] pointed that the innovation ability of Chinese construction enterprises is weak with limited value-adding. It should focus on the development of science and technology to really confirm the pillar position of construction industry. The development strategy for construction industry China lies in conception reform and enhancement on innovation measures. Based on the main problems of the development construction market, Wang Tong-zhou put forward a reform path for the large construction enterprise to develop through the resources integration and system reform, then enhance the core competitiveness of enterprises [10]. Some scholars have studied the organization form of technology innovation in construction industry Wang Bo and Liu Hua, [11], enterprise innovation motivation and capability Chen Jian-guo and Cai Wen-lu [12,13], innovation system and regulation Jin Wei-xin et al. [14], innovation mechanism Guo Hui-feng et al.[15]. Moreover, the research on enterprise technology innovation for construction industry is relatively scarce. Most of the themes discussed are just the advance technology introduction from abroad brand companies instead of management reviews Chen and Xie [16].

About the evaluation of technology innovation, the initial indexes released by European Union(EU) in 2001 only covered with human resource, knowledge production, knowledge dissemination and application, financial innovation, innovation output and innovation market. Late on in the year of 2008~2010, EU put the innovation assessment indicator like "innovation-drive, enterprise innovation behavior and innovation output" as the first-level indexes, the indicators like "enterprise human capital investment, enterprise investment, entrepreneurship, productivity and innovation effectiveness" are put in the second level system [17,18].

While Chinese scholar Zhang [19] argued that the assessment of enterprises' competition need to be evaluated from seven aspects, like "social influence, technical ability, ability of financing, financial status, marketing ability, project management capability and resource management capabilities". Then Pu Xiang-ping [20] made a comparison of enterprise competitiveness indexes for constructions industry and abroad, and pointed that the indicators selected lies in the perspectives of assessment, the evaluation dimension may different is different assessment purpose.

Based on the study of Japanese construction enterprises, Kangari and Miyatake [21] found that the development success of construction technology innovation is attributed to four aspects, namely, strategic alliance, effective information collection, innovation reputation and technology diffusion.

Yeung JFY et al. [22] proposed eight key indicators to evaluate the success of construction enterprises, namely, customer satisfaction, cost, quality, time, communication, security, trust and respect, and improvement on innovation, etc.

Radujkovic et al. [23] studied nearly 37 innovation evaluating indicators based on more than 30 construction companies in southeast

Europe and found that the top ten key assessment indicators could affect the enterprise competitiveness, they are including quality, cost, number of investors, sustaining reform on project, time increase, customer satisfaction, employee satisfaction, innovation and learning ability, efficiency and identification of customer requirements, etc.

Shang Mei, Du Yan-yan [24] found that the output of technological innovation and its major affecting factors has a long-term integration relationship in construction industry; enterprises need to define the technological assessment indexes together with the tasks of the projects.

From the above literatures review, we found that the research on enterprise innovation and technology development has been relatively mature, but most of the contributions are based on the empirical study and technology introduction. For the research of technology innovation management from construction industry, most of them China just stay at the level of macro perspective and qualitative analysis. The themes about technology management and analysis of technological competitiveness are relatively short.

Herein, this paper selects the construction corporate from Fortune Global 500 strong companies of 2015 as the sample to study their innovation effectiveness from five aspects, namely, R and D human resources investment, capital investment, organization management, incentives mechanism, and innovation cooperative mechanism. Based on the construction enterprises performance in global market and the comparison analysis on technological innovation management among those global construction enterprises, this paper is trying to put forward the corresponding countermeasures for construction industries on technology management to enhance the enterprises' competitiveness ability.

Global Construction Corporate Competiveness Analysis

There are eight strong construction enterprises engaged in the global 500 companies in 2015 (Table 1). Five constructions corporate are from China, namely China State Construction Engineering (CSCE), China Communications Construction (CCC), China Railway Group (CRG), China Railway Construction (CRC) and China Metallurgical Group (CMG). These five Chinese corporate are enlisted in global 500 strong companies for more than 10 years (CCC and CMG only enjoys eight years history) and dominated the leading position since 2005,

Item	Company	6	7	8	9	10	11	12	13	14	15
1	China State Construction Engineering (CSCE)	v	v	v	v	v	v	v	v	v	v
2	China Communications Construction (CCC)	**	**	v	v	v	v	v	v	v	v
3	China Railway Group (CRG)	v	v	v	v	v	v	v	v	v	v
4	Vinci Group (Vinci)	v	v	v	v	v	v	v	v	v	v
5	China Railway Construction (CRC)	v	v	v	v	v	v	v	v	v	v
6	Bouygues Group (Bouygues)	v	v	v	v	v	v	v	v	v	v
7	ACS Group (ACS)	v	**	v	v	v	v	v	v	v	v
8	China Metallurgical Group (CMG)	**	**	v	v	v	v	v	v	v	v
9	Fluor Company (Fluor)	**	**	**	v	v	v	v	v	v	**

Note: "**" means the enterprise is not in top 500 companies in this year or the enterprise hasn't joined the assessment, "v" means the enterprise are listed in top 500 companies in the year.

Table 1: Top 500 construction industries list in 2015.

which indicates that Chinese construction enterprise are getting more internationally and stable. The rest three international constructions companies are Vinci Group and Bouygues Group from France, ACS Group from US. Vinci and Bouygues have been ranked in global 500 strong companies for more than 10 years since 2006. While another famous construction enterprises, Fluor Company in US, has no longer within global 500 strong companies list due to the violent competition. Fluor ranked in top 500 more than 6 years from 2009 to 2010 (Table 1).

Per the enterprise's business turnover and profit record within the decade 2006 to 2015. Chinese construction companies dominated their leadership position, since 2010, CSCE caught up and outstripped Vinci Group with average annual growth rate of 23.4%. The average turnover growth rate from the enlisted eight global construction enterprises in 2015 is 13%. The highest growth rate in CCC is 40%. In terms of profitability, the annual average growth rate increased with 1.35% against the dada in 2014. But two of them have negative profit growth, which reflects a limited growth trend compared to the other global foreign corporate.

Anyway, as the members of global 500 strong companies, their competitive strength cannot be ignored. Considering the enterprises' operation stability and enterprises history, we modestly take nine global construction companies enlisted in Fortune 500 strong companies with terms of stable business turnover and at least with five consecutive years in the list. Based on the companies' annual reports and enterprise's website information, the author decided to study the competitive strength and the rule of the technological innovation in construction industry from five technical innovation elements mentioned above.

R and D human resource investment

Technological innovation is an important production outcome of R and D activities. The R and D human resources investment is the most original engine anchored the technological innovation performance. The R and D human resources here refer to personnel engaged in the technological innovation. The numbers of R and D personnel in enterprise engaged in technology development activity will directly determine the benefit output of technology innovation. Herein, the investment on R and D personnel of technology innovation is a critical indicator. In fairness, this article only takes the data in the year of 2014¹ to have a transverse comparison of each construction company and explore the R and D personnel distribution including their education level. The information or data is mainly

Collected from the companies' annual report or the company's website. A detail comparison on R and D human resources investment is shown in Table 2.

From above data we can see that the rate of technology development

Item	Company	R and D personnel (%)
1	China State Construction Engineering (CSCE)	46.8%
2	China Communications Construction (CCC)	30.8%
3	China Railway Group (CRG)	33%
4	Vinci Group(Vinci)	0.13%
5	China Railway Construction (CRC)	19.5%
6	Bouygues Group	1.5%
7	ACS Group	2.2%
8	China Metallurgical Group (CMG)	12.64%
9	Fluor Company	1.44%

Table 2: R and D humane resources investment rate of global nine construction companies.

personnel in Chinese construction enterprise is accounted for more than 10% against the company's total quantity of employees. The highest one is 46.8% in CSCE, the lowest one is 12.64% in CMG. While the rate of the other four global foreign construction companies is relatively different, Bouygues group shows 1.5%, Fluor Company reflects 1.44%, ACS is 2.2%, Vinci group shares 0.13%. We understand it may have some difference on the statistic and the definition of R and D personnel in different companies. The number of R and D personnel of the foreign construction companies (Bouygues, ACS, Vinci and Flour) only counted their professional R and D personnel. While for the construction company in their statistics is including engineers, technicians and technical support personnel.

Moreover, during the review process, we found that the Chinese construction enterprises have a high proportion with highly educated² workers, like in CCC, the high educational portion is 47.5%, and the lowest one is 21.7% in CRG. This shows that the investment of Chinese construction companies in science and technology human resources gets more and more attention³.

Capital investment

Most countries in the world pay great attention on the investment for the development of science and technology and create related science and technology development strategy to ensure the investment funds in all fields. There is no exception for in enterprise' development, because the science and technology innovation investment is one of the key measurements for the enterprise sustainable development. The engineering projects long duration industry characteristics in construction industry requests the company must have a certain sustaining capital investment to enhance the enterprise's innovation strength on workmanship, technology, construction and service management to save the cost and improve the efficiency. From the comparison of those eight construction companies, we found that science and technology innovation investment in every construction company has received high attention, and the investment strength is increased year by year.

In 2014, the average investment growth rate of those eight corporate is 12.8%. The investment strength from China's corporate is very big, such as CRG invested \$1.447 million in 2014 on innovation, 13.8% increase compared in 2013. This is due to the rapid growth of overseas business for Chinese construction companies in recent decade. Compared to the other global construction companies, like Bouygues, ACS, the investment degree is relatively slow and flat hovering between 5%~10%.

R and D investment percent of sales turnover in Chinese construction companies also shows a strong strength, like China Railway Group (CRG) and China Railway Construction (CRC), the investment portion in 2013 is 0.7% and 1.5% respectively. It is much higher than the average level of 0.7% internationally. But for the other four construction companies, namely, Vinci, Flour and ACS, their investment rate is just within 0.1% ~ 0.3% of the yearly sales turnover.

Above data reflects an obvious difference among the global

¹Some listed company annual report is not officially published till June-10 as the authors drafted this paper.

²Per the practice China, high educational level works refer to the employees with at least bachelor education degree or above.

³Due to statistic dimension problems, the authors cannot get the educational structure data or frame from the foreign construction (Bouygues, ACS, Vinci and Flour), herein, above analysis only discussed the state we can get to indicate the investment on human resource.

#	Corporate	Technological innovation organization management mode
1	China State Construction Engineering(CSCE)	Have sound science and technology R and D system from decision-making mechanism, implementation, consultancy, to capital investment, process management, performance assessment and incentive mechanism(Figure1)
4	China Communications Construction(CCC)	Have the plan of "core talent height" and "Four-Five-Five" core talents system. It is formed a science and technology management system of "one system, five standard, ten ways" and set up a three level science and technology R and D system (namely, headquarter, branch company and subsidiary factory) with a feature of "up and down interaction, three-level linkage, reasonable structure and high efficient" innovation operation.
2	China Railway Group(CRG)	Have particular department of science and technology (technology center) belongs to the group managers of board
3	China Railway Construction (CRC)	Have a strong enterprise technology innovation system with perfect network, it is formed a four-level innovation system of "general headquarters, group companies, engineering companies and project department. It has an own characteristics of technological innovation organization structure to promote technological innovation.
5	Vinci Group	Have a special R and D department belongs to the chief executive of science and technology development and is responsible to the director of the commission. The core task is to carry out R and D innovation and internal information exchange to support and coordinate the innovation work among the various departments. The company has innovation City factories and regional R and D club to have a regular technology innovation theme discussion or case analysis timely
6	Bouygues Group	Has a sustainable development department lead by acting CEO who should response for the supervision and coordination with all internal affairs including low carbon strategy, green IT, R and D management, quality assurance and global procurement according to the priorities of each project and the R and D progress of each branches.
7	ACS Group	Equipped with specialized technical development committee to carry out R and D activities cooperating with the related scientific research institutions, colleges or universities
8	Fluor Company	No particular introduction on the company's technology management mode

Table 3: Global construction corporate technology innovation management mode (portion).

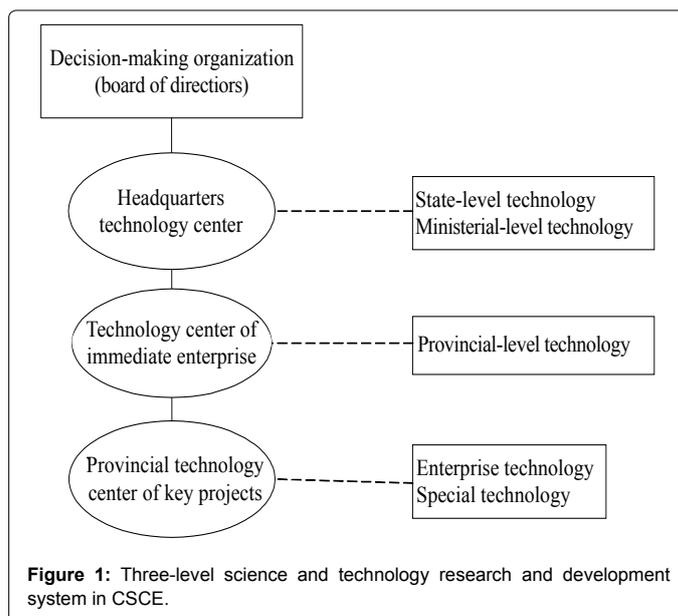
construction companies. The investment percentage of sales amount from Chinese enterprises seems a little big but with dramatic shaken during the decades. While the other four international construction companies show a robust investment trend on technology innovation. It indicates that the investment maturities of Chinese construction enterprises need to be strengthened.

Organization management

Effective organization management can ensure the implementation of technical innovation activity. The author summarized the technological innovation organization management mode states of above mentioned construction enterprises based on the review of the companies' annual report in 2014 and website information or other public report collection shown in Table 3.

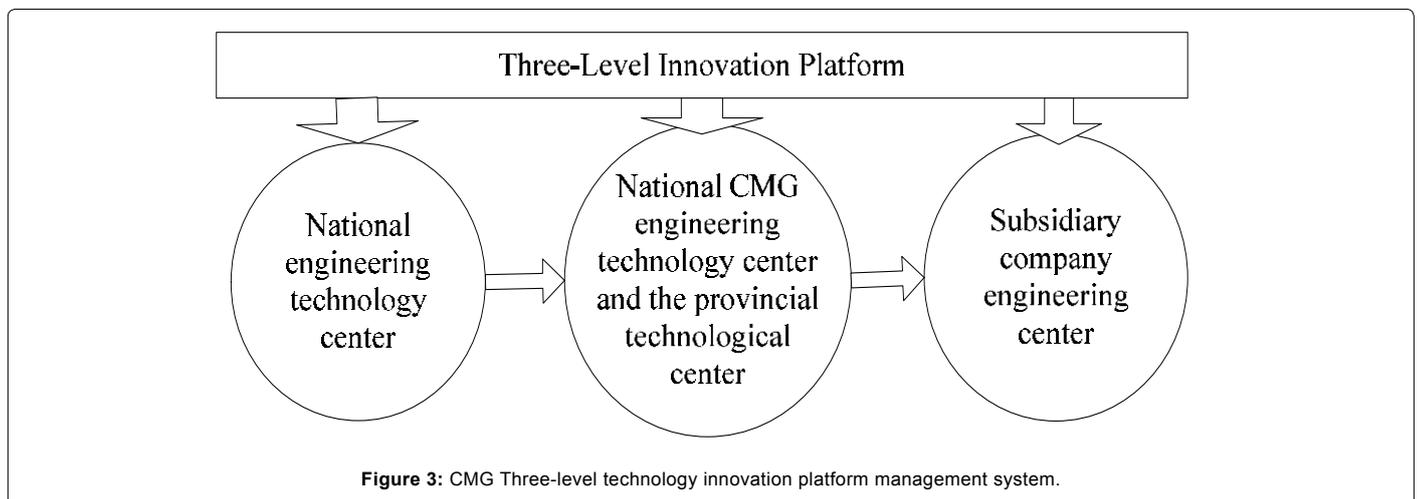
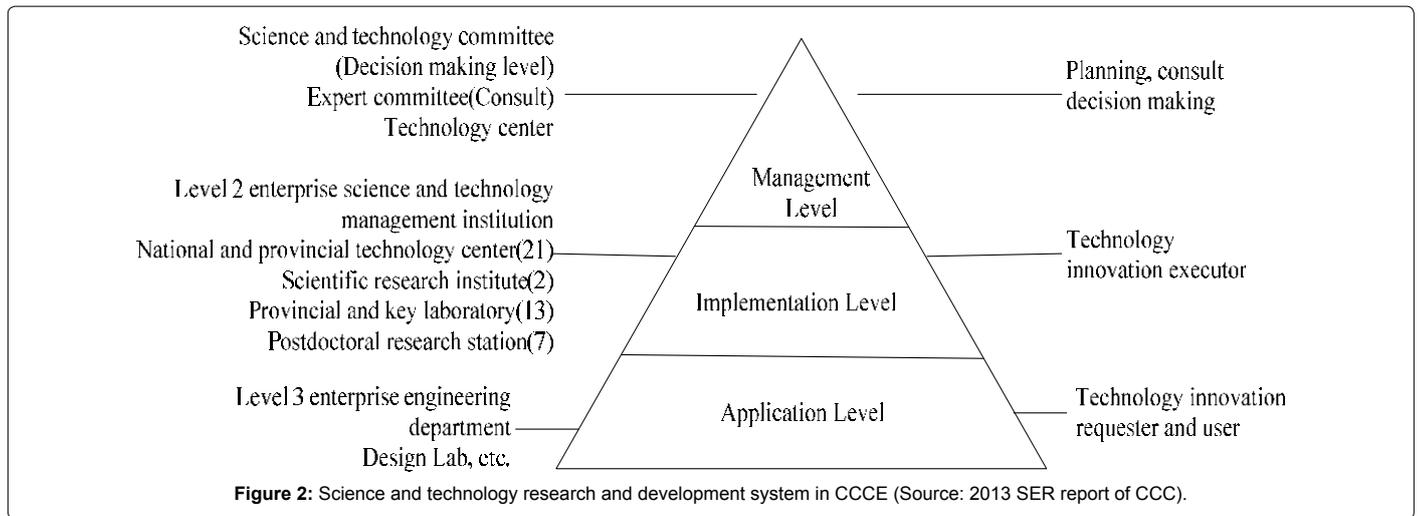
From above summary shown in Table 3, it indicates that the organization structure of technology innovation in construction companies is core organization for the enterprise's sustainable development, below is the main difference analysis form the management mode perspective.

(1) Organization structure: Chinese construction companies are all state-owned company, not private enterprises, the company's organizational structure of innovation system is formed based on the national and corporate strategic. Most of them are adopted with three-level innovation system, namely, the technical innovation organization management form level of national, provincial, and enterprises of special projects perspective. Like CSCE, CCCC and CMG (Figures 1-3). While the organization in CRC is different, it is a new innovation mode with four linkage pattern of technological innovation including headquarter administration, group companies, engineering companies and project department. The foreign large-scale construction enterprise adopts three-level innovation management system as well, like Vinci Group, its innovation organization is designed within the enterprise development based on the market demand instead of being assigned from the administration. The enterprise will set up a specific development company based on the project demand and directly report to the managing director.



(2)Technology innovation driving factors: technology innovation drive of foreign enterprise mainly comes from enterprise inner drive and market demands, most of innovation behaviors are market oriented. While for the innovation drive in Chinese construction industry, the dominated one is from the national development strategy, such as the national science and technology research plan, some of the drives are from market demand. The organization of R and D team or innovative projects is mainly structured based on the governmental strategy. But government function in the global international construction enterprise is not so obvious; the investments in R and D innovation are financed based on the market demand.

(3)Innovation organization management mode: the management mode in Chinese construction enterprise is similar with the traditional management mode. It has strict innovation organization chart, namely, the top level of policy making, management level of process control



and implementation level. Each level system has a clear command system. While the technology innovation management mode in the foreign construction enterprises are loosen and flexible. Such as the organization management mode in Vinci Group is very flexible, their management mission is to provide employees with good innovation environment by means of providing innovative city factory, regional innovation club and innovation forum like BBS, etc. to provide a free communication innovation platform and learning organization environment within the enterprises.

Incentive mechanism

Science and technology personnel is the key element of technology innovation, the effective incentive mechanism is the guarantee for the success of enterprise technology innovation. Enterprises are required to establish a set of mechanism of talents cultivation, employment, and evaluation and incentive instruments to ensure the technology innovation benefit and R and D personal interest, which is good to arouse their innovation enthusiasm in maxim. According to the technological innovation of the bidirectional interaction and incentives Lv Zhen-yong, Dang Xinhua [25], we compared the construction companies' incentive mechanism and found that:

(1)For the incentive method: The global foreign construction

companies not only provide employees with good welfare, comfortable office environment and generous bonuses, but also provide equity to the contracted staff of company. The company will publish their staff incentive data timely in their annual report. For instance, Fluor conducted an “Executive Performance Incentive Plan” to reward the personnel with outstanding performance on innovation or management. Some enterprises will set up special enterprise awards to encourage the innovative staff, such as Vinci announced Vinci Innovation Award to encourage the innovation contribution in all fields (e.g. the innovation of technology, management and service, etc.). While the employee innovation incentive policy of construction enterprises China focuses on short-term, direct material rewards, or encourage the employees to attend the contest, like National Science and Technology Progress Prize, Zhan Tian-yu Award, Lu Ban Prize, etc., then the company award the money according to the contribution. The incentives of employee stock ownership or equity just depends on the company actual situation. Some construction companies will consider the dividend for the outstanding talent.

(2)Company culture of innovation: both Chinese and foreign construction companies pay much attention on the cultivation of innovative culture. Like, CRG conducted a “five same” management mode in the company, namely, “leaning together, work together,

item	Company	Research institution or cooperative partnership
1	China State Construction Engineering(CSCE)	Set the company's direct operation design group with specialized technical center and experiment center
4	China Communications Construction(CCC)	With ten large design institute, two state-level technology center, seven provincial technology center, six key laboratory and post-doctoral scientific research workstation
2	China Railway Group(CRG)	With seven large design institute, two state-level technology center, seventeen provincial technology center, two national key laboratories, fourteen testing experiment center certificated by the national laboratory accreditation committee and four post-doctoral scientific research workstation
3	China Railway Construction (CRC)	With fourteen high and new technology enterprise, twenty provincial technology center, one provincial key engineering laboratory and four post-doctoral scientific research workstation
5	Vinci Group	Establish city factory innovation laboratory, Vinci-Paris technology R and D cooperative institution like Mines Paris Technology, école des Ponts ParisTech and Agro - Paris Tech engineering schools, regional R and D club, etc.
6	Bouygues Group	With particular enterprise innovation center, innovation laboratory, technology center and enterprise library
7	China Communications Construction(CCC)	With ten large design institute, five state-level technology center, twelve provincial technology center, five key laboratory, two post-doctoral scientific research workstation
8	ACS Group	With nearly fifty-nine research center in China and abroad, have cooperative relations with ninety-six universities and forty-two technology center; With seventeen institute, eighteen R and D centers and fifteen technology development center
9	Fluor Company	With several experimental research center, supply chain research center, project (safety) testing center and regional innovation factory or workshop in worldwide

Table 4: Global construction enterprises R and D institute and innovation cooperation mode summary (portion).

manage together, live together and same reward”. Fluor established an incentive system with the basis of creating value to replace its original incentive system. CCC hold the view of difference acknowledgement and fairness to form a culture of cooperation, collaboration, comfortable workplace and harmonious environment by implementation of management innovation and value concept through human resources, strategic planning, evaluation and control process(Dominic Barton and Clayton Deutsch [26].

Generally speaking, technology innovation incentive mechanism in above mentioned construction companies shows a diversification, the measures on the material incentive or spiritual are different. The construction companies from China emphasize the cultivation of the collective innovation and self-innovation spirit. While the foreign construction companies encourage the individual innovation, or offer motivation with flexible platform and work ambience.

Innovation cooperative mechanism

According to the endogenous economic growth theory, technological innovation is the source of economic growth [27]. It is a kind of activity with risks, the investment behavior on technological innovation enhances the risks [28]. With the business expansion in each of the construction company, the technological innovation mode is different as well. The innovation focus of construction companies may different because of the business scale. But for the construction engineering, infrastructure construction, the enterprise pays more attention on the elements of innovation, production technology and equipment. But for the innovation on products and equipment, it is better to implement the technical innovation with market and cost oriented.

Both Chinese construction enterprises and foreign international enterprises have the characters with independent innovation and external cooperation innovation. As the summary shown in Table 4, the investment from these enterprises in technology development realm is very big. Most of companies have their own technical design center and laboratory. But it still has slightly difference in the following two aspects:

(1) Besides the enterprise itself R and D tasks for company

development, Chinese construction companies still need to undertake their national technology research assignment. It is rare to see in the foreign construction enterprise whose business is operated with market based. The technology innovation demand for these enterprises is mainly determined by customers and market demand.

(2) Though both the Chinese construction enterprises and the foreign construction go the way with the university-enterprise joint innovation mode, their management mode is different. Chinese construction companies emphasized the joint technology development together with the institution or universities. They run the cooperation by establishing the doctoral research station or signing cooperative program with the school, but don't involve their institution administration. The foreign construction companies is different, they not only associate with the institution, but also directly engage in the construction of institution or universities. Such as, Vinci group directly invested the construction of Mines Paris Tech, école des Ponts Paris Tech and Agro-Paris Tech engineering schools. ACS group is similar with Chinese enterprise. It widely sets up different level of cooperation relations with professional universities, worldwide research institutions and technology centers so as to meet the need of enterprise technical innovation demand or make up the lack of technology innovation team.

From above exploration, the technology innovation mode in construction enterprises are different, some of them even are complicated and overlapping. A flexible and suitable cooperative innovation mode is very important to the company's development.

Difference Between Chinese Enterprises and International Companies

Although Chinese construction enterprises hold an absolute predominance among the construction enterprises in Fortune global 500 strong companies, based on the above exploration, particularly the contrastive analysis with the foreign construction company, the author found that Chinese construction enterprises still have certain gap in technological innovation management. Below is the key difference between Chinese construction companies and foreign construction companies.

(1) Technology innovation in Chinese construction enterprises has

big potential policy risk: The innovation within Chinese construction enterprise is mainly relies on the support of national key research projects or large scale engineering; the ability of independent research and development is not strong and lack of related market mechanism support. The enterprise's scientific and technological innovation needs a strong support from local government. It exist a big potential policy risk. While the science and technology innovation in the foreign international construction companies have just been oriented by the market demand, it has a stronger market operation mechanism on risks prevention.

(2) Rigid cooperation mode: the major technical research of Chinese construction enterprises takes a path of institution-enterprise joint or university joint mechanism, the conversion ratio of technological achievement is very low. While the foreign construction enterprises go with multi-level cooperation mode like university-enterprise cooperation or research institutions-enterprise mode. Meanwhile, they can directly invest the money to establish their own institute of technology to solve the enterprise's technology problem and cultivate the R and D talent.

(3) Low rate of R and D investment: The modern architecture enterprise has a strong consciousness of technology innovation. Most of the enterprises have set up the specialized R and D institution or technology development center, but the investment budget on science and technology development is still low compared to the other expense. The highest rate on R and D activity in CRCC just accounted for 2% of sales turnover, the lowest one is only 0.5% of sales turnover in CSCE. It has not exceeded 5% rate of sales turnover of Japan's construction companies, which is considered as a normal R and D investment rate internationally [29].

(4) Lack of technology innovation talents and with low internationalization degree: From the above comparative analysis, the technical personnel of construction enterprises in China sounds like share a big percentage of the total number of employees compared with foreign construction companies, but the real personnel engaged in scientific and technological innovation is still not enough. The foreign construction companies have a strictly definition of R and D personnel or experts from different regions. Moreover, the internationalization of foreign international company is very high, e.g. Vinci group, its foreign employees accounted for 96% of total staff, the employee of Fluor are from nearly 66 countries or regions worldwide, which account for 1.44% of the total employees.

(5) Both Chinese construction enterprise and foreign companies have the three-level innovation management system of organization structure but with difference. Chinese construction enterprises organization generally adopts the "pyramid" mode from the top to the bottom. While the foreign enterprise organization usually employs with a division or specialized project management mode, it has great flexibility among the innovation teams. Some enterprises even have the development in the project workshop, or arrange the innovation activities through the R and D innovation committee. Vinci is a typical example going through innovation workshop or committee method.

(6) Finally, from the perspective of technology innovation incentive mechanism, both the Chinese construction and foreign construction enterprises have emphasized the incentive and training to the technical personnel. The foreign construction enterprises pay more attention to the long-term training and motivation of the employees. But the Chinese construction just focuses on the short-term honor to

incentive to the employee.

To sum up, the technology innovation management construction industry still has certain gaps compared to the international construction enterprises, which limits its sustainability. Based on the analysis of above five innovation elements, below is the main reasons causing above differences:

(1) In accordance with the common three-level innovative system. The construction enterprises should response for their own innovation risk and cost in their own value-added chain respectively, which limits the technology innovation output in construction industry. The building product is a system with multi-technology integration but have different regional characters. It is in the discrete state in space; herein the implementation of technology innovation in construction industry is not replicable. It cannot enjoy the advantage economies scale like the general manufacturing industry. Besides the lack of enough and stable information exchange among the enterprises (such as the general contractor and the subcontractor), it leads the slow technology diffusion or produces "bullwhip effect", which restricts the overall technology enhancement in construction industry.

(2) The complexity of the engineering project in construction industry restricts the development of enterprise innovation ability, such as the complexity and durability of building materials, long period of construction. Plus the long technology diffusion cycle, it restricts the technology innovation as well in the whole industry.

(3) Due to most of Chinese construction companies are the "state" enterprises. The government's administrative control could influence the efficiency of technology innovation. For example, the bidding system of tendering and bidding process, and the provisions to the contractor and subcontractors, they seem have protected the rights and interests of the owners but ignored the rights and interests of the contractor who are the main participants of technological innovation. In the process of technological innovation, the contractor has to bear the most responsibility and innovation risks. This greatly limits their innovation enthusiasm. Moreover, the government regulation leads the more cost paid for the construction material supplier chain, which limits the development of the technology innovation.

(4) It has an information communication obstruction in the technical innovation organization management. The existing innovation system in construction industry is independent. The technical communication within the construction industry system is inadequate and unobstructed. Current construction industry technical communication is mainly arranged through the form of BBS or meeting assignment, but the real technical communication is often not enough and comprehensive, it need more channel to communicate with modern information technology.

(5) Finally, the internationalization of the Chinese construction industry also caused the expansion of technological innovation. Due to the system and management pattern is different. The innovation tasks in Chinese construction enterprise have been completed by the local Chinese engineers or researchers. They conduct the independent innovation strategy but with technology import as a complement. The thinking of "going out" has not been extended, which restricts the technology innovation achievements for construction industry.

Technology Innovation Management Improvement for Construction Industry

Through the review of the top 500 construction enterprises on

technological innovation management, we found that, although the Chinese construction enterprise dominated the leading position in the international construction industry, the technology innovation in Chinese construction companies has got much improvement, the engineering project complex characteristic and management mode difference restricts the further development of construction technology, it is imperative to continue the strength on technology innovation management China's construction industry thought below measurement to keep the enterprises sustainability:

(1) Accelerate the system innovation with market orientation. Because of the complexity and particularity of construction product in building industry, the industry admittance threshold is high; the investment of technology innovation can be solved through market mechanism. Through the enterprise system reform and innovation, accelerate the introduction of advanced technology and narrow the gap between the international construction companies based on the market economy orientation.

(2) Enhance the current three-level innovation management mode for Chinese construction enterprises and improve the relevant supporting facilities. It required to have a more flexible technology innovation management organization structure, such as to set up the particular agencies specialized in researches on innovation theory to improve the existing management mode and clear necessary institutional obstacles for technology innovation.

(3) Increase technological innovation investment continuously. The contribution brought by the scientific and technological innovation is obvious. The investment rate of enterprises' sales turnover in science and technology from Chinese construction companies is gradually increased, but the complexity of construction market causes some disorganizes business behavior, such as the phenomenon of undercut engineering price and embezzlement of public funds to undertake engineering task is often happened Ming Liang Yang [30], which caused the problem of capital returning and seriously impacted the normal investment in science and technology innovation. So the basic guarantee is to earmark a fund for the implementation on technological innovation

(4) Strengthen the personnel and incentive mechanism of technology innovation. In order to cope with the international standards of technological innovation for Chinese construction, it needs to strengthen the cultivation of technology innovation talents in construction industry. The personnel introduction of professional engineers with solid theory knowledge and rich practice is helpful to keep the enterprise international competitiveness. At the same time, it should increase the training for the staffs to improve their working quality as the whole.

(5) Deepen the integration of production, education and research, and establish technology innovation center in large scale construction enterprises. The existing cooperation between building enterprises and research institutes or universities has roughly formed a scale of China right now, the various enterprises has cooperative relations with domestic and international universities in different level. But the technology center of enterprises relatively weak. It needs to improve the abilities of research and development. To deepen the integration of production, education and research on technology innovation cooperation mode, and use the platform combined with the enterprise practice can close to the actual market demand for the enterprise R and D center.

Research Limits and Expectation

From the perspective of technology innovation management, this paper selected the top eight construction enterprises enlisted in Fortune global 500 companies of 2015 as an example and discussed their technology innovation status from five technology innovation elements like scientific research personnel, capital investment, organization management, incentive mechanism and cooperation mode of technology innovation management. A detailed comparison has been made between the Chinese construction enterprises and foreign construction companies. The study found that construction enterprises in the investment of technology innovation and management has some certain limitation and insufficiency. Based on the root-cause analysis for such difference, this paper puts forward the corresponding countermeasures on the improvement of technology management for construction enterprises.

Due to construction companies' information or data is not open enough, or the report emphasis each construction company is different for the public data. The data or analysis in this paper has leaves some limits and incomplete. This will encourage the author to continue the further research with a method of tracing study. Modestly, we think above exploration still can basically reflect the current management status of construction enterprises in technological innovation management. Especial for the Chinese construction enterprise, it could provide some management reference for the practitioners and enhance the international competitiveness of construction companies.

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