U.PORTO

FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

CIVIL ENGINEERING AND CONSTRUCTION IN CHINA – A ROADBOOK AND A BRIEF OVERVIEW

JOÃO PEDRO NEVES MONTEIRO

Dissertation submitted for the partial conclusion of the requisites of the degree

MSC IN CIVIL ENGINEERING — MAJOR IN BUILDING CONSTRUCTION

Supervisor: Professor Jorge Manuel Fachana Moreira da Costa

July 2015

MESTRADO INTEGRADO EM ENGENHARIA CIVIL 2014/2015

DEPARTAMENTO DE ENGENHARIA CIVIL

Tel. +351-22-508 1901

Fax +351-22-508 1446

✉ miec@fe.up.pt

Editado por

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Rua Dr. Roberto Frias

4200-465 PORTO

Portugal

Tel. +351-22-508 1400

Fax +351-22-508 1440

✉ feup@fe.up.pt

http://www.fe.up.pt

To my grandmothers, mother, father, aunt, sister and friends,

the foundations of my motivation

By three methods we may learn wisdom: First, by reflection, which is the noblest; Second, by imitation which is the easiest; and Third by experience, which is the bitterest.

Confucius

ACKNOWLEDGEMENTS

First of all, to Professor Dr. Jorge Moreira da Costa, coordinator of this work, for believing and understanding my proposal since the opportunity appeared and for the incredible capacity of enhancing this work to levels I didn't know were possible. Thank you for teaching me, for being my guide, and for the trust and esteem I felt during the last months.

To Alberto Carvalho Neto, without whom this work would not be possible. My guide and my godfather in China, for being a role model that I will always look upon with admiration. The time spent in China was of sheer experience and schooling adding value to my life at a measure I cannot quantify. May I always have you as a friend that always knows what to do at the right time, with the right amount of seriousness and professionalism.

To my grandmother, Maria de Lurdes, for being the person with the sharpest mind I know, for taking care of our family with so much sanity, wisdom and care. Thank you for warming my heart every time I think of you, and thank you for letting me look upon you for all my life to come.

To my mother, for being the person I hold dearest in my heart. For the unconditional love that motivates me every day to be a better man. Without your support nothing would be possible, the strength you give me is the fuel I need in my life. I am because of you and for you.

To my father, for being the engine of our family and for being the person that I most look upon in my life. The shape of my life and experiences is due to you and your vision. You are the man, thank you for that.

To my aunt and godmother, Manuela, for being without question my "second mother". Without your mark this work would not the possible, my education would not be the same, I would not be the same man. Thank you for believing in me on every moment of my life and thank for being the only person that never doubted of my capacities.

To my sister, Rita, for your peculiar personality that is getting shape. For the times that I feel your unquestionable love, for the times I'm able to see the pride you have on being my beloved sister. Thank you for looking at me as your older brother.

Finally, for the people that ultimately validate my existence and importance in this world, my friends. For making me feel that if anything happened to me, you would be there to hold me. For considering me, for validating my crazy ideas, for the relaxed times, for letting me cry, for not judging, for being there. The time I consider myself the luckiest person in the world is when I think of you, of how many you are, of the foundation you represent in my life.

ABSTRACT

Differences in the Construction Industry from the occidental world to the oriental world are a subject that is much debated on the current times of globalization and spreading of information.

The standing point for the research for this work was the idea of taking advantage of the three weeks I spent in China, inserted on an entrepreneurial mission. Therefore on a business environment. Combining this asset with the critical standpoint of a Civil Engineering student from FEUP the time spent in China originated a Roadbook and triggered the further research.

With the resulting investigations and literature review, the objective of this thesis is to shed some light on the Chinese Construction Industry with an approach that is understandable and usable for occidental construction professionals, for occidental academics and for anyone curious about the matter.

Alongside a Roadbook of the trip to China the investigation comprised a thorough study on the following matters:

- Comprehending basic education in China;
- Top China Civil Engineering Programs;
- Comparison of the Chinese Civil Engineering Programs with the Program at FEUP;
- Construction Industry market landscape;
- Top 5 construction companies in China;
- Advanced construction technologies used in China;
- Housing Industrialization in China.

A conclusion is set with a series of recommendations and concerns for China's construction industry, possible investors and Civil Engineering academics.

KEYWORDS: CHINA, CONSTRUCTION, EDUCATION, TECHNOLOGY, MARKET

RESUMO

As diferenças entre a Indústria da Construção no mundo ocidental e oriental são um tema muito debatido nos tempos correntes de globalização e propagação de informação.

O ponto de partida para a pesquisa deste trabalho iniciou-se com a ideia de usar a vantagem que o tive de estar 3 semanas na China incluído numa missão empresarial com vários empresários Portugueses interessados no mercado Chinês. Combinar esta mais valia com a visão crítica de um estudante de Engenharia Civil da FEUP foi o primeiro objectivo pelo que este trabalho começa com um livro de viagem numa perspectiva de encontrar tanto construção em curso como novas tecnologias.

Com a investigação resultante e revisão de literatura, o objectivo desta tese é dar conhecimento sobre a Indústria da construção Chinesa com uma aproximação que seja perceptível e de valor para profissionais da construção ocidentais, académicos e para curiosos na matéria.

Seguido do livro de viagem a investigação compreende um estudo geral nos seguintes aspectos:

- Compreender a educação base na China;
- Programas de Engenharia Civil em universidades de topo na China;
- Comparação dos programas Chineses estudados com o Programa de Engenharia Civil da FEUP;
- Panorama da Indústria da Construção na China;
- As 5 empresas de Construção de topo na China;
- Tecnologias e sistemas de construção avançados criados China;
- Industrialização da habitação na China.

A conclusão é feita tendo em vista uma série de recomendações para a China, para possíveis investidores e para alunos de Engenharia Civil.

PALAVRAS-CHAVE: China, Construção, Educação, Tecnologia, Mercado.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1
INTRODUCTION

1.1. CONSIDERATIONS

Throghout time different cultures always found a necessity to understand each others. With reasons that were triggered from business exchanges and relations to geopolitical strategies, the need was clear. Even though, civilizations developed a sense of community around themselves in order to achieve the objective of economical and geographical growth. Thus, the pace imposed by restrictions of technological/political/bellic nature showed to have great impact on every civilization economy and ability to grow.

An indicator that explains well these experiences is the concept of economic center of gravity introduced by Mckinsey&Company that comprehends a weighting of the national Gross Domestic Product (GDP) of each country since the beginning of the Common Era. The weight of each country pulls the economical center of gravity towards its own, with the combination of all the countries Mckinsey&Company was able to point the economic center of gravity of the world from 1 CE with a forecast until 2025. [4]

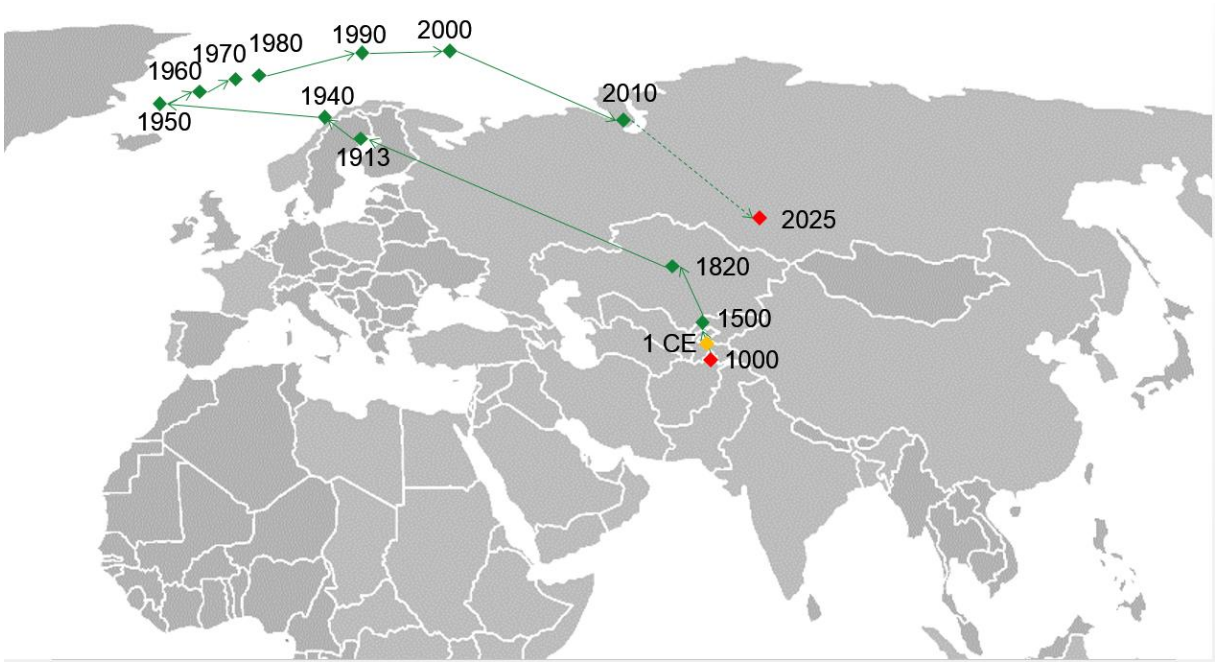

Figure 1.1 – Evolution of the earth's economic center of gravity, 1 CE – 2025, [4]

As it is easily understood, construction nurtured the feeling of greatness to all civilizations in the world and the role played by the industry takes different shapes and outputs from culture to culture, from one civilization to another.

The world is shifting, and among other factors, globalization is a key that makes geographical boundaries less important and less meaningful. Considering this, cultural differences continue well preserved in the personality of every place and every people. Combining these factors with a never seen before shift of the world's economic center, mainly due to an aggressive urbanization that is leading one thousand million people to enter the global consuming class by 2025 [4], and we have a cocktail that will defy global policy makers and industries.

Unquestionably, the sharing of information between countries starts to be a must for the survival of such an aggressive economical market. The next level is clearly understanding how the world can grow as a whole in order to diminish inequality while maintaining a sustainable urbanization growth. For that to happen we need to share information between cultures.

Having the opportunity to visit China for three weeks with a group of entrepreneurs from Portugal, and knowing the economical shift that the world is seeing towards this country lead to finding the opportunity to work on a dissertation. With the purpose of comprehending the duality and the difficulty of understanding another construction market.

Considering that China is colossal a thorough research would not be possible the academic research and information found is set mostly on tier one and two cities that are capital of a province or are at seaside.

Taking further the interest of understanding the Greater China Construction Industry, this work develops a search for the differences that exist inside the country, considering the Special Administrative Region of Macau (Macau SAR) and the Special Administrative Region of Hong Kong (Hong Kong SAR). Understanding the importance of the two late colonial sites was of the most importance due to the gateway they represent for international companies and workers to enter the Mainland China market.

1.2. OBJECTIVES

The aim of this thesis is to elevate the opportunity of visiting the country of China for three weeks already with the goal set to search points of interest that are not comprised in the western Construction Industry.

Knowing the valuable time that could be spent in China, the first goal was to have a critical and personal view of the Chinese construction industry from the standing point of a Portuguese Civil Engineering Student with the idea of creating a Roadbook.

With the mindset of finding what the country has best to offer in the broadest areas of construction, this work comprehends the understanding Civil Engineering education to and overview of the Construction Market acknowledging the top Chinese companies finishing on a search for the best practices and top technologies that the means of search lead to.

1.3. STRUCTURE OF THE WORK

This work is divided in six chapters. In the current chapter the first considerations about the theme are presented along with the motivation for the work. Besides this introductory chapter, this document is structured as follows.

Chapter two is a roadbook that comprises the experience gained during the time spent in China with the inclusion of my vision and critical standpoint, in the first person. It is important to note that one of the interests is to look at construction in China with the eyes of a Civil Engineering student from Portugal.

Chapter three is a study of the China's Civil Engineering Undergraduate and Graduate studies in China. Starting with an introduction about the elemental education and the entry requirement for universities. Programs from top universities were researched and a comparison was performed between a chosen program with the program endured at FEUP is done.

Chapter four starts with a market study of the most important economic figures on the Chinese Construction Industry followed by a study of the top Chinese firms in Revenue.

Chapter five is a consideration and explanation of the top technologies and construction concepts found in the country.

Chapter six closes the work and raps the chapters that come before with a comprehensive conclusion about the Chinese Construction Industry.

2

ROAD BOOK OF A TRIP TO CHINA

2.1. MOTIVATION, OBJECTIVES AND PLANNING OF THE TRIP TO CHINA

Early in the year of 2015 I was given the chance to travel to China integrated on an entrepreneurial mission organized by the Association of Young Entrepreneurs Portugal-China. The mission itself had the objective of introducing the Chinese market to Portuguese entrepreneurs with motivations to start or deepen business connections with partners in the country. The set of people that accepted the mission had the most diverse backgrounds, from software development, food & beverages, design, real estate development and green energy experts with emphasis on solar panels and wind energy.

The plan for my trip had 3 weeks of duration, starting on the 23rd of March and ending on the 13th of April with the following geographical distribution:

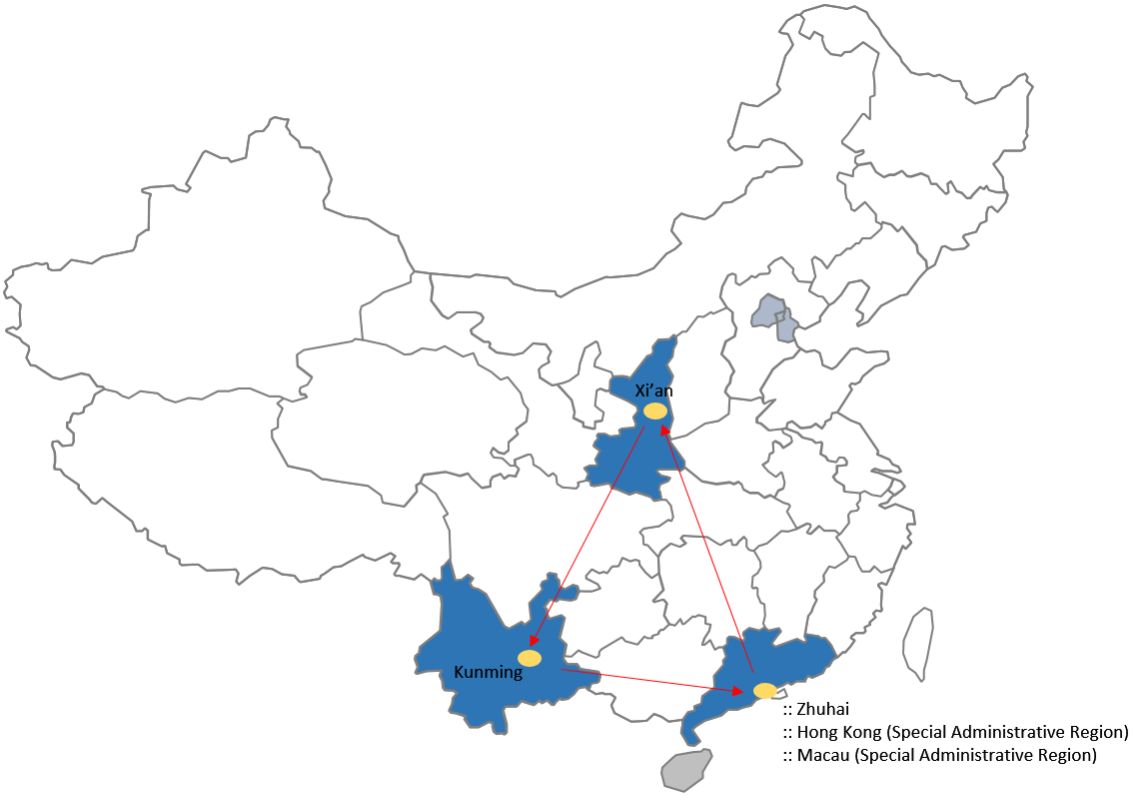

Figure 2.2 – Map of China

During the first week the main objective was attending MIECF in Macau. MIECF is the Macau International Environment Co-operation Forum and Exhibition which aims to develop environmental

business, technology and information exchange between businesses in southern China region and international markets. The main organization and hosting is by the Macau Special Administrative Region (Macau SAR) and with co-organization by several provincial/regional governments in southern China, namely, Fujian, Jiangxi, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan and Hong Kong. [5]

Throughout this time there was the chance to find new technologies focused on the environment and air quality for the construction industry and have a glance at the Macau construction scene that is peculiar with the crescent casino boom. There was time to visit to the Macau University where an interview was conducted in order to understand the education and construction scene both in mainland China and Macau.

The second week had planned a stay in Zhuhai with emphasis on meetings with local government officials and view of the dynamics of the free trade zone that are of extreme value for businesses that intend to export to China. During this week I had the opportunity to perceive life in Zhuhai, a city that is considered by many people one of the cities in China with the best life quality.

The third week was of travel through China, namely to Xi'an and Kunming where I stayed for one night in each city. The visits conducted gave the perception of how construction is developed differently in northern China and in Southern China where I focused my attention on differences between the construction found in the southern part of China and the north.

2.2. MACAU

2.2.1. SPECIAL AUTONOMOUS REGION OVERVIEW

Figure 3.2 – Macau Flag [6]

Table 2.1 – General Information of Macau Special Autonomous Region [6]

Area	30.3 Km^2
Population	552,503 Inhabitants
Population Density	21146 Inhabitants/Km^2
Border Control Activity	25 Million People/year
Govern	Macao Special Administrative Region of the People's Republic of China
Official Language	Portuguese and Mandarin

Macau was where my trip to Greater China started, with knowledge brought both from expectations about the Portuguese colonial time in Macau and from the recent buzz of Macau Casino Scene what I found met most of expectations.

Macau is a special Region of China where, in 1557, Portugal created its first Commercial warehouse in order to sustain and organize the large commercial transactions with Asia. In 20 of December of 1999 Macau was handled to the People's Republic of China Government as a Special Administrative Region, with its own Govern and large autonomy from China's Government. [7]

During the Portuguese governance the unique cultural organization was formed by 3 main groups, the Chinese as majority, the Portuguese and the Macanese (descendants from the miscellaneous between Portuguese and Asian people). Since the handling to the People's Republic of China the multiculturalist side of Macau became more present with the following distribution of the population, according to the 2011 Census: [6]

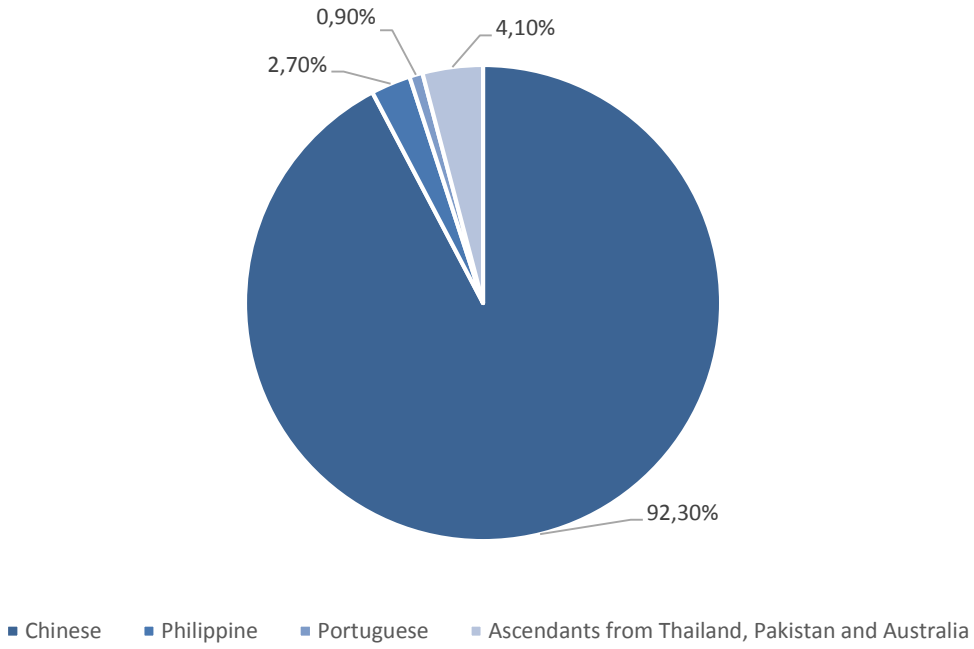

Figure 2.4 – Population distribution by ascendant [6]

Economically Macau is in a special location both in policies and geography. The special autonomous region of Macau is one of the regions with lower taxes while having a stable financial economy. Being a customs area with no cambial restrictions combined with a dynamical economy Macau creates the connection between international markets and Mainland China.

Before 1912 the size of Macau was about 11.6 km^2 which was not enough to meet the expectation of development towards today's era of urbanization, as so, the only method to increase the size of Macau was through land reclamation. [8] Macau started a process of land reclamation to the sea that increased its size by 250% from 11.6 km^2 to 30.3 km^2 in 2015.

2.2.2. Casino Construction in Macau

In the current days the casino scene defines Macau at some point. The region has developed itself in the coming years around the buzz that China boosted with incentives for casino construction, in figure 2.4 the gross revenue presented by gambling in Macau shows that there is no gaming hub in the world like it, in 2013 the Las Vegas strip had a gross revenue of 5.70 thousand million euros which is a fraction compared with the 43.95 thousand million euros that Macau counts. [9]

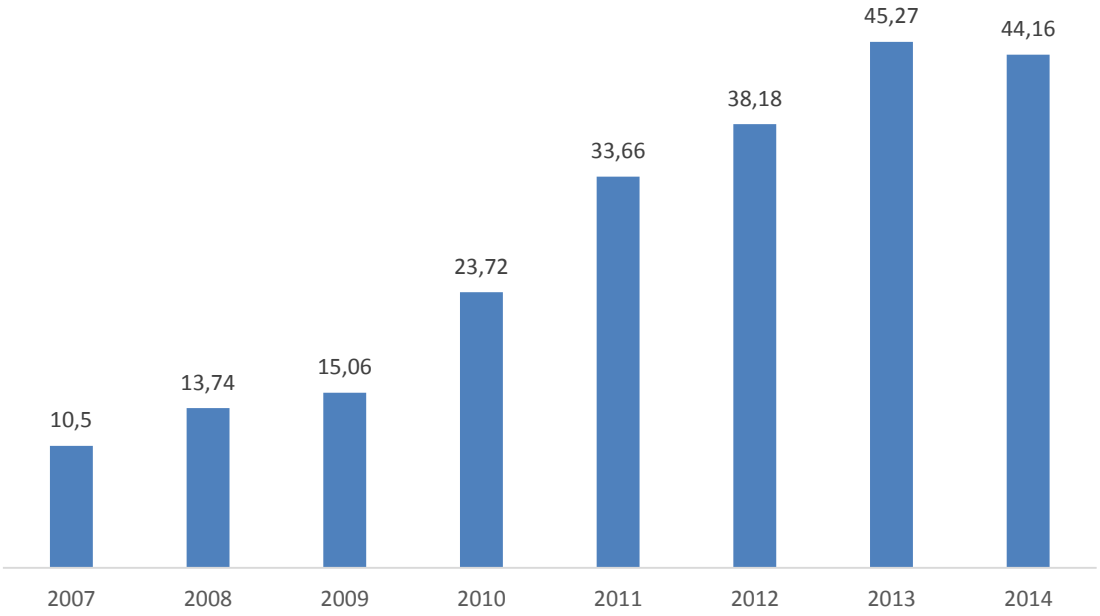

Figure 2.5 - Gross revenue from gaming and gambling in Macau (in thousand million euros) [10]

Construction in Macau is mostly defined by the Casino scene, thoroughly studied in chapter 5, that is happening since the current law of casino gaming was established in 2002. Macau has currently 33 casinos with the following being built until 2018 [11]:

- Galaxy Phase 2, 3 & 4:
- Hollywood Roosevelt;
- Lisboa Palace;
- MGM Cotai;
- Sands Cotai Central – St. Regis Tower;
- Studio City;
- The Parisian;
- Zaha Hadid Tower.

Figure 2.6 – Studio City Construction in Macau

2.2.3. THE LIGHT METRO OF MACAU

Besides the great construction value that the Casinos create there is another major infrastructure being built in Macau, the light metro of Macau, a project awarded to Mitsubishi Heavy Industries with a value of 6.69 Billion MOP (~79,300 Million Euros) for the first phase alone which account a 20 km line with 21 stations. The project is already delayed as it should be opening in the beginning of 2015. In figure 4 the delay of the Light Metro of Macau construction is evidentiated. [6]

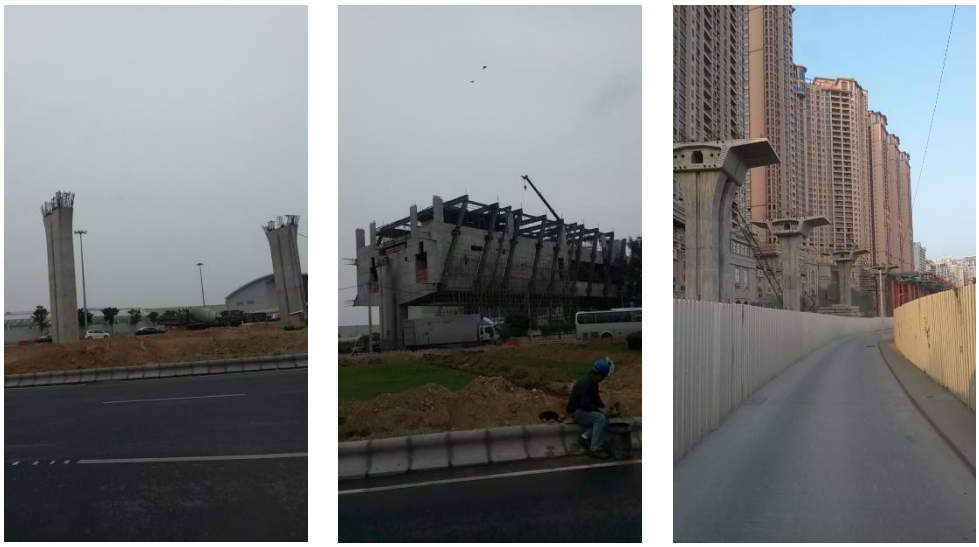

Figure 2.7 – Metro of Macau Construction

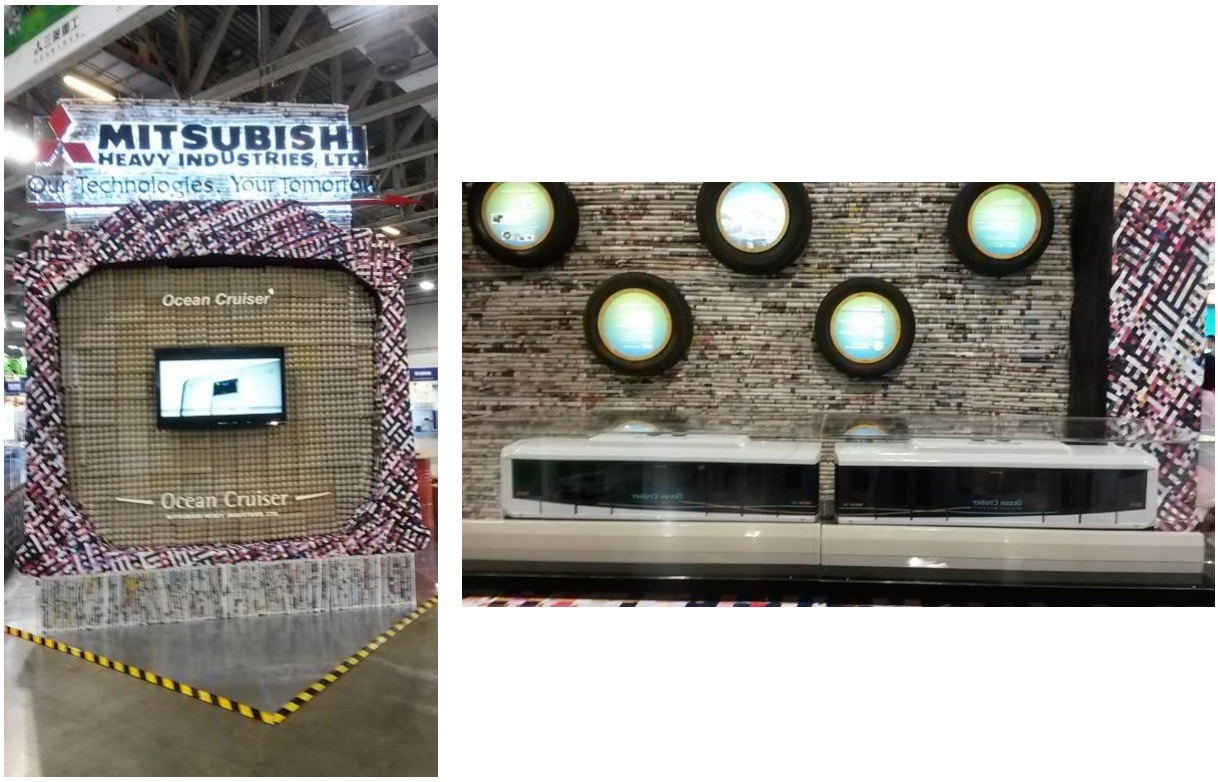

Figure 2.8 – The Mitsubishi booth at MIECF focusing on the new light metro of Macau

2.2.3. INTERVIEW AT THE UNIVERSITY OF MACAU

When I received the plan for my stay in China and got to know I would spend a week in Macau I was sure that it would be important for my search to visit the University of Macau and try to arrange an interview that could tackle the research on the following areas:

- Portuguese influences on construction in Macau;
- Chinese influences on construction in Macau;
- Understand the casino construction in Macau;
- Business environment of the construction scene in Macau;
- Have explained the Civil Engineering program at the University.

Figure 2.9 – University of Macau Department of Civil and Environmental Engineering

When arrived at the University campus, opened in 2014, the feeling was that the university was very well designed, with more green areas than building areas that comprised a lake, a silence and calm ambience that obviously enhanced the study and work environment.

Figure 2.10 – University of Macau Department of Civil and Environmental Engineering

The meeting conducted with Dr. Ao Ieong Tai Man (Raymond) of the Civil Engineering Department was of the most importance in the early stage of my search as it enhanced me to both enter the right path of search of the construction industry in China and demystify the construction scene in Macau.

When it comes to construction in Macau there is an obvious separation from the mega constructions of Casinos built by international contractors and the residential and not so impressive construction from the local contractors. The casino boom started upon the Macao reunification with the People's Republic of China that reset the legal system. The new laws introduced among other regulations the legal framework for competition in the gaming marketplace and the development of the casinos for the tourism, social stability and economy of Macau.

The other side of the construction of Macau is undertaken by the local contractors which are fighting for their place in the market. Local contractors do not have the size to concur for the Casino contracts so they stay as sub contracts for the big contractors from China and Hong Kong that usually manage these construction. As in Macau the legal framework for sub contracts is not developed the local firms are constantly pushing the government for fair proposals to be able to stay alive and competitive. There

is more construction in Macau than the Casinos but most of the attention goes to these constructions that are the drive of the economy of Macau.

During the interview the quality control of construction production was talked where Dr. Raymond explained that locally the regulations and practices were not among the most advanced. This was not the case of Hong Kong that is a pioneer in quality control of construction, with the example of the implementation of a performance assessment scoring system that evaluates if a contractor has the ability to deliver projects to a specified standard. In mainland China it is necessary to understand the difference from contractors that operate on big cities and small contractors that operate at a rural level, the first effectively follow the minimum ISO 9000 standards and the tendency is a growing number of enterprises that comply to the standards.

At the University of Macau, civil engineering students follow the Eurocode technical rules. In Macau, as there is no national regulation it is accepted the use of Eurocode, British and Chinese rules for contractors.

A topic of interest and that was tackled in the interview was the use of Prefabrication technologies both by Macau contractors and Chinese contractors. Locally, contractors don't have the necessary technology and knowledge to use Prefabrication technologies but top Contractors in Hong Kong and China use modular components on their enterprises in Macau.

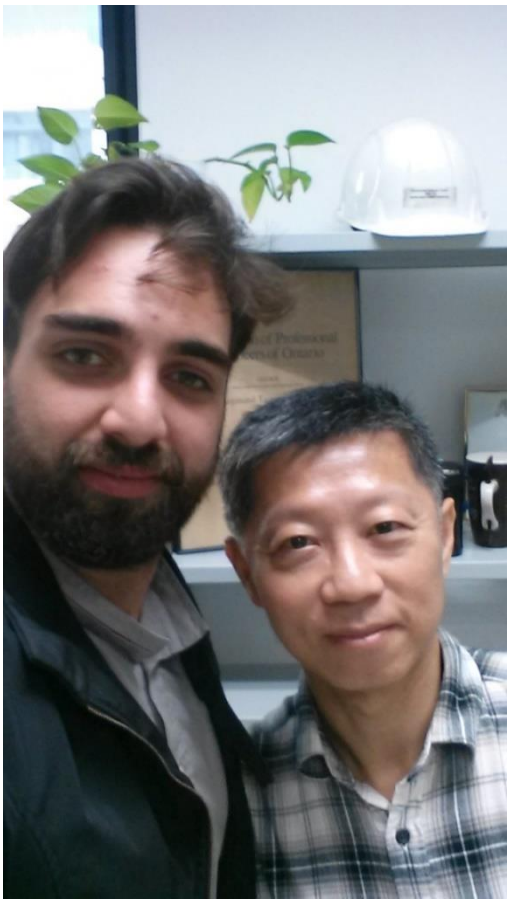

Figure 2.11 – A picture with Dr. Raymond AoIeong at the Civil Engineering Department of the University of Macau

2.2. MAINLAND CHINA

Figure 2.12 – People's Republic of China Flag [12]

2.2.1. ZHUHAI AND EXPLANATION OF THE CONCEPT "LOSE THE FACE"

Table 2.2 – General Information of the City of Zhuhai [13]

Area	1,724.32 Km^2
Population	1,562,530 Inhabitants
Population Density	906.2 Inhabitants/Km^2
Govern	People's Republic of China Government
Official Language	Mandarin, Cantonese accepted

Zhuhai is a city placed in the province of Guangdong that is, for its location, a strategic trade zone as it is connected by land with Macau SAR. The trade zone that Zhuhai represents is the key drive to create a city that is developed around the Gongbei area, which is the main crossing area to Macau SAR.

The region of Macau SAR, Zhuhai and Hong Kong SAR is so important that two measures were taken to enhance the connectivity between these three areas. First, the border is set to be opened 24 hours which never happened before, the reason for this is obviously the nightlife associated with Macau and the crossing of construction workers that work for Chinse companies and as there are no dormitories in Macau, in every turn shift they have to cross the border to Zhuhai. Second is the ongoing project of a bridge connecting Hong Kong- Zhuhai – Macau, a project that is set to meet the demand of passenger and freight land transport between the Mainland, Hong Kong and Macau. The bridge will have a three-lane dual carriageway across the sea for 42 kilometers that will cut the 4 hour time that the journey takes by ferry to forty-five minutes by car. The contractor is Bouygues Construction and the opening is set to be on 2016. [14]

During my stay in Zhuhai where I had no way to contact enterprises and professionals connected to the construction industry I was able to find 2 Portuguese Architects working in Chinese companies. Completely integrated in the Chinese environment as their employers and most of their co-workers are Chinese, Paulo Moreira and Maria Moura gave me their input on working at a Chinese company. I was able to have a feeling that has been told to me by many, that to work in a Chinese company, what Chinese entrepreneurs value the most are skills that they don't have access to and that we have as base in Portuguese Universities. When this is combined with a thriving will to work at an international level the opportunities appear.

With the time spent with Paulo and Maria for the first time I understood concepts of the Chinese way of working and concepts of the Chinese Real Estate organization. A curious fact that I learned was that in housing building as the government permits to build have a restricted area, builders are so eager to make this area worth the value in the apartments that they cut on having a second pane of wall in order to have the living area increased, this is widely accepted by the community because having a house with more square meters is a sign of well fair and good living conditions.

The concept of "lose the face" was firstly introduced to me, which is one of the most difficult social concepts to learn as there is no comparison with our way of acting and working. This concept is essential for any person that is working with people from China as it represents one of the basics of social relations in China.

In comparison with the Portuguese term "*saudade*" the term "face" in Chinese culture cannot be translated of defined. I will give a definition based on what I learned from Chinese people, from westerns working in China and from literature review. The definition of "face" is associated with western terms such as "prestige" of "reputation" but it goes even further with the fact that "face" represents the respectability and deference that a person can claim for himself from others. The two Chinese words that can be translated to "face" are "*lian*" and "*Mianzi*". *Mianzi* is associated effort, a reputation or prestige or status that rests on education, wealth and social position that can be achieved through effort. *Lian* is associated with moral integrity and social conduct that implies the respect for the righteous person regardless sex or social position. The connection between the two is implicit and a loss of *Mianzi* does not mean a loss of *Lian* as it the case of an impoverished righteous person but it is almost impossible to keep *Mianzi* once *Lian* is lost in the eyes of the Chinese society. [15]

In simple terms, if you lose face, you lose status and you aren't respected as much as you were before the situation. This creates some positive and more respectful social reactions but can also be a trigger for less improvement of oneself.

For example, a team manager that has a team member that performs below the expectation. In western culture exposing the failure to the person in question would be normal and accepted as a call to attention for the next time. In Chinese culture this behavior would be seen as making someone "lose the face" hence lose respect. An accepted behavior would be to relocate to a job that the person will be able to perform when distributing tasks next time. If this example is taken to the point where the failure is exposed to the team the person will feel even more losing the face.

Another example, where the concept of "lose the face" can lead to less improvement of oneself is when someone is learning to speak another language. A Chinese person will work hard to learn the language but may hold back from speaking to someone in that language because he thinks he will lose the face.

This basic sociologic event is a barrier that stopped business and friendship relationships between westerns and Chinese people so the understanding and respecting of these event will ensure a better work environment.

2.2.2. XI'AN AND THE BAMBOO SCAFFOLDING EXPERIENCE

Table 2.3 - General Information of the City of Xi'an [16]

Area	10,096.81 Km^2
Population	8,467,838 Inhabitants
Population Density	838.7 Inhabitants/Km^2
Govern	People's Republic of China Government
Official Language	Mandarin

Xi'an is a city located in the northwest part of China and is the capital of the Shaanxi province. The city is considered to be the beginning of the Silk Route which combined to the terracotta army creates a tourism buzz all around the year that the city is much proud of.

The region of Shaanxi is also one of the most culturally diverse cities in China with a representative community of Chinese Muslims that I was not aware existed before visiting the city.

The city of Xi'an was pointed on a report from the Economist Intelligence Unit as one of the 13 emerging cities in China. On that report the city is considered to become a Megalopolis, a type of city that is defined by a chain of adjacent metropolitan areas. The city is set to grow from 4.6 million inhabitants in 2000 to a total of 10.7 million inhabitants in 2020 which represents a compound annual growth rate (CAGR) of 5.7% between 2000 and 2010 and 3.1% between 2010 and 2020. An indicator that Xi'an is in need for more and better quality housing is the earning of the urban population and the rough conditions that are felt in the winter. In terms of income, in 2020 more than 70% of the urban population is expected to receive more than 4,380 Euros per year. In the year 2000 almost no one earned this amount of money. The forecast that we can take from this is that the so called housing boom will be alive in Xi'an for the years to come especially considering that Shaanxi is known for having better rates of earning equality than other seaboard provinces. [17]

The concept of Megalopolis is connected with a unification of city clusters that is happening with the cities Xi'an and Xianyang where two new urban districts are creating a connection between the two cities. [17]

During my visit to Xi'an I had scheduled to assist on a meeting that made me aware of a scheme that any entrepreneur can find when entering the country market on his own. In Chinese culture it is widely accepted that when business contracts are signed an exchange of valuable gifts is made, especially from the seller to the buyer, which can go up to 5% of the contract value.

Traditionally this exchange is made when the deal is closed but it is a measure of caution to only do it when the value is exchanged. I experienced a case where the buyers were a fake company with fake cards and a rented office that created all the conditions for the contract to be signed and in the end asked for the gift correspondent to the value of the contract. Aware of the succeeding no gift was given, therefore the group vanished from the place. This can happen in the form of a notary honorary that in order to validate the contract asks for a sum representative of a percentage of the contract value.

I had the opportunity to take photos of construction sites while in the city that validated some conceptions that we have of Chinese construction. The next photo is an example of a construction site where bamboo scaffolds are used, throughout my visit in China I saw bamboo scaffolds being used on all construction sites with the exception of the Studio City Casino construction in Macau. Scaffolding design is seen with seriousness on Chinese construction and there are people specialized on bamboo scaffolding design due to the fatal consequences that an error can make.

Bamboo is a natural and renewable feedstock material abundant in China. For my conception of safety the bamboo scaffolding looks flimsy but they are extremely tough and flexible with the adding that comes at a fraction of the cost of steel scaffolding. Yu-Hang, the director of Wui Fai holding from Hong Kong explained the example of a typhoon on a building that had both steel and bamboo scaffolding where the steel scaffolding collapsed and damaged the surroundings and bamboo scaffolding hold on and undertook the bending strain. As steel scaffolding are rigid and designed to hold strain from a vertical downwards direction they cannot support momentums on any direction which with a typhoon proved to collapse. The same did not happen with the bamboo scaffoldings and the wood is lighter and more flexible the structure was able to support the momentum and horizontal forces created by the typhoon.

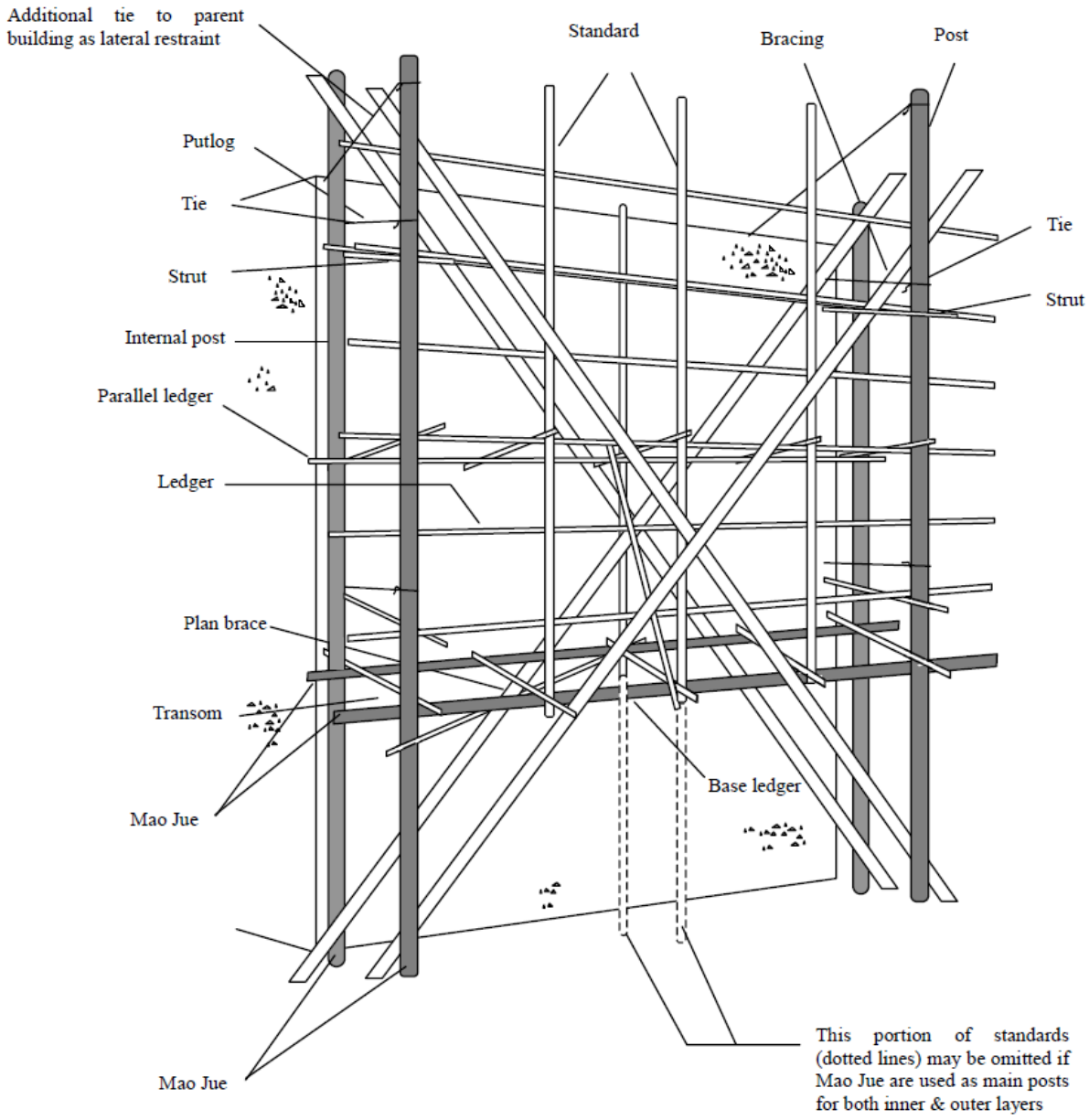

Figure 2.13 – Arrangement for double-layered bamboo scaffold [18]

The figure 2.12, above, shows an example of the basic arrangement of a double-layered bamboo scaffold that comes as a guideline from the Hong Kong Buildings Department. The inner layer is set at about 200-250 mm from the building surface while the outer layers is set at 600 mm from the inner layer, in between layers the working platforms are erected. [18]

An alternative arrangement and process that improves the strength of the bamboo scaffold and enhances the quality of the scaffold structure is the incorporation of metal elements. With this incorporation the scaffold retains the advantages of metal and bamboo scaffolding enhancing safety.

On the next picture a construction worker can be seen on top of a bamboo scaffolding. Representing both the art of bamboo scaffolding and the insecurity that the job represents.

Figure 2.14 – Construction site in Xi'an with bamboo scaffolding

Figure 2.15 - Construction sites in Xi'an

2.2.3. KUNMING

Table 2.4 - General Information of the City of Kunming [19]

Area	21,001.28 Km^2
Population	6,432,209 Inhabitants
Population Density	306.3 Inhabitants/Km^2
Govern	People's Republic of China Government
Official Language	Mandarin

Kunming is the city capital to the province of Yunnan in Southwest China. During the day I spent in the city I had scheduled a meeting and several walk-ins to companies that were targeted as possible partners to the Portuguese entrepreneurs I was with.

When arrived at the city the feeling could not be other than amazement when I realized the dimension of the city airport. The Kunming airport is and engineering and architectural feat that at first glance defied everything I ever saw before. Designed by SOM architects and ARUP Engineers the airport was approved during the 11th Five-Year Plan period from 2006 to 2010 with the investment of 3.3 thousand million euros. It also is the first airport in China certified by LEED as a "Green Airport". [20]

The terminal is now the biggest terminal in Greater China and is among the top five in the world, which is necessary for the development of a hub that is set to connect Asia and Europe being a gateway to South and Southeast Asia.

Figure 2.16 – Kunming Airpor Example 1

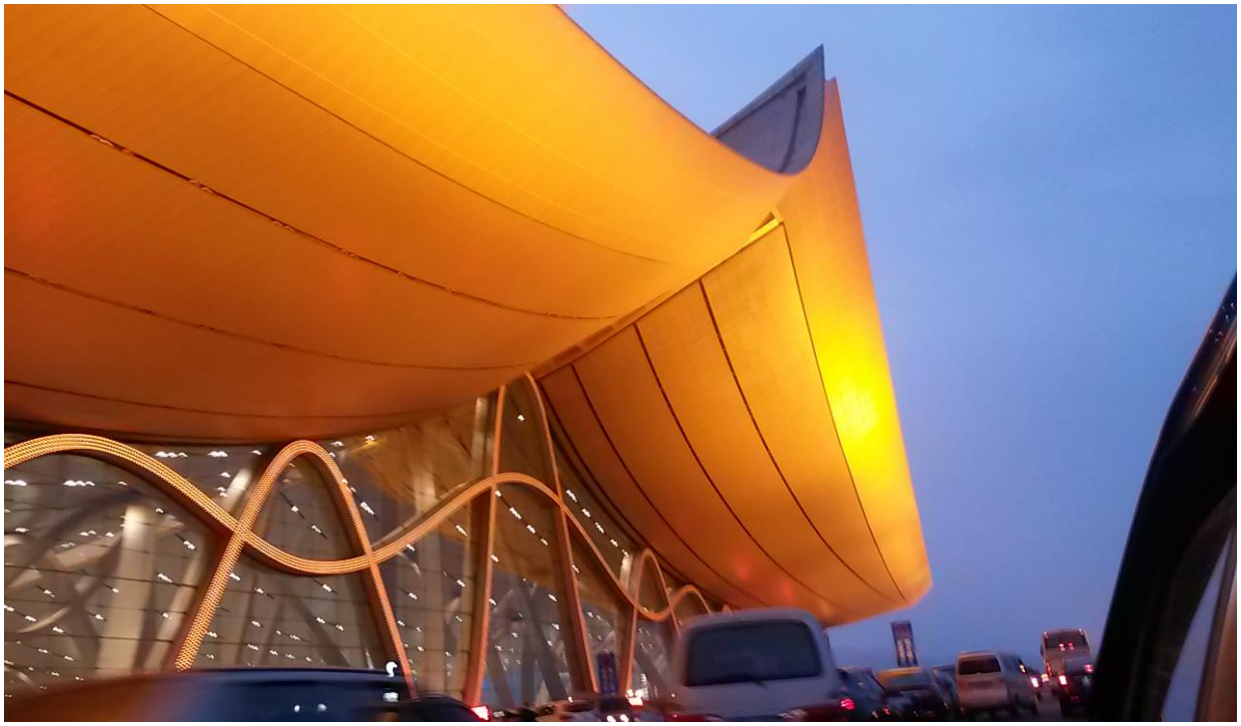

Figure 2.186 – Kunming Airport Example 2

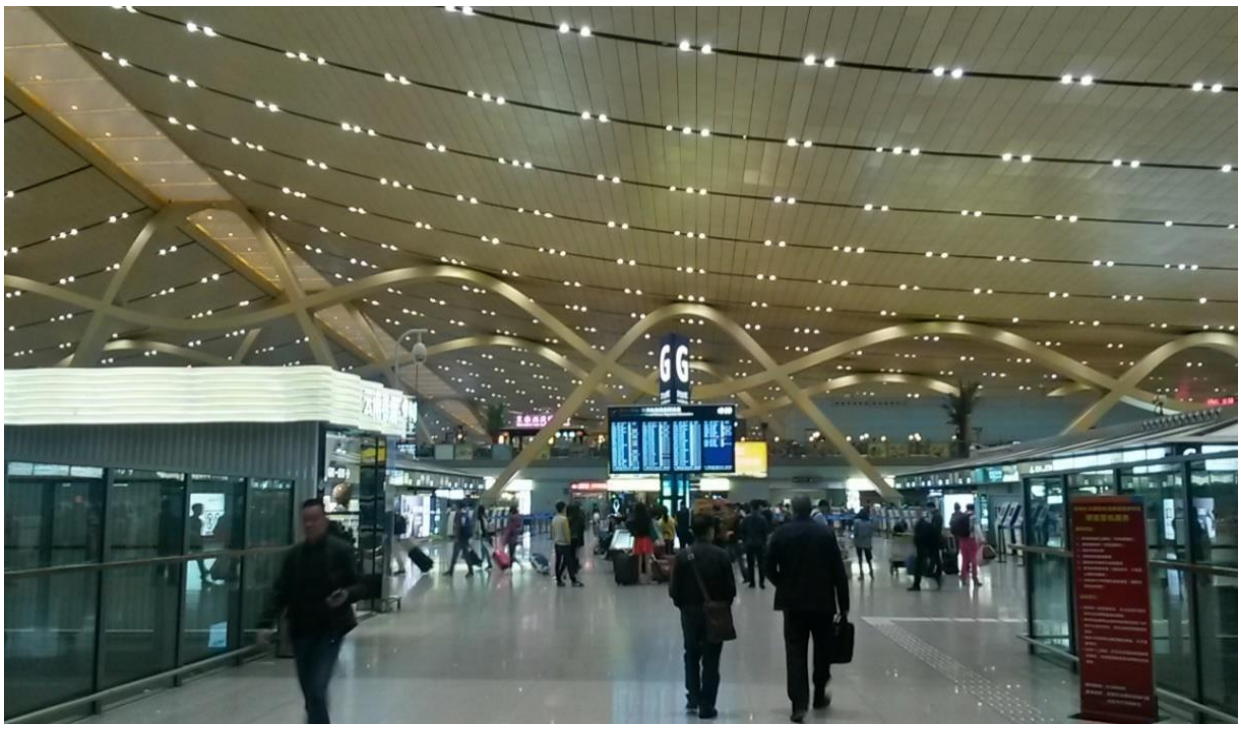

Figure 2.177 – Kunming Airport Example 3

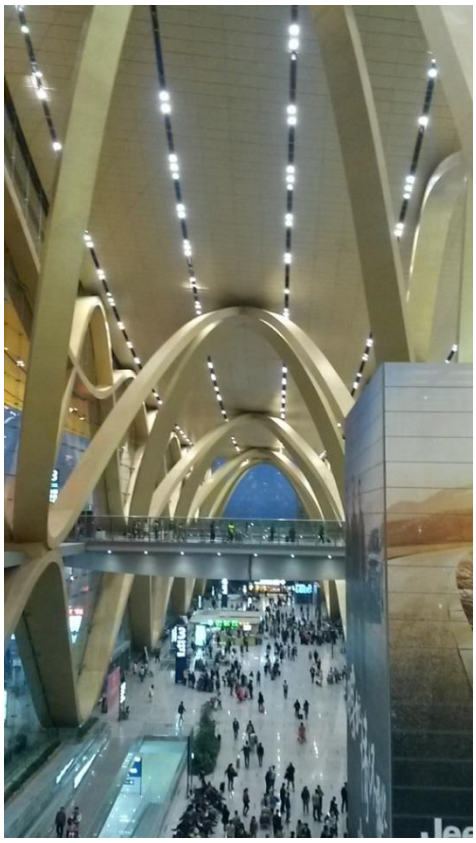

Figure 2.18 – Kunming Airport Example 4

2.3. HONG KONG

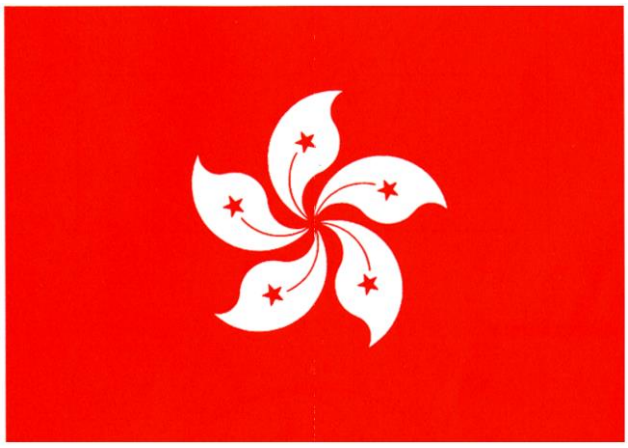

Figure 2.19 Hong Kong Regional Flag [21]

Table 2.5 – General Information of Hong Kong Special Administrative Area [22]

Area	1,104 Km^2
Population	7,264,000 Inhabitants
Population Density	6,544 Inhabitants/Km^2
Govern	Hong Kong Special Administrative Region of the People's Republic of China
Official Language	English and Mandarin

Hong Kong was the last stop of my journey through Greater China, the time I spent on the country was short but enough to have an idea of the construction wonders and urban planning of this particular place. Hong Kong moves around financial services and has one of the most important ports in Asia. The financial hub that Hong Kong represents creates a gateway for China for international companies doing business in Mainland China. The main motivations for this are the efficient regulatory frameworks, the low and simple taxation. The global free port thrives mainly on the free flow of goods, services and capital. With an economical view, Hong Kong is one of the most interesting places in the world.

The limited land available for construction obligated that the urban planning of the country to be dense, which can be validated by the population density of 6,544 inhabitants/km2. A direct consequence of the undergoing urban planning is transforming Hong Kong into the center of modern architecture that the region is showing to be. High-rises are the norm through the city center most of them serving as headquarters of major banks.

The influence from the colonial times of English ruling is clear and making a rough comparison Hong Kong took the best of this duality of cultures with a much better and enhanced law system, regulatory frameworks and construction rules when comparing to the scenery found in Macau. The outcome of this comparison is the fact that Casinos in Macau are built both by Hong Kong contractors and Chinese contractors.

Hong Kong companies have earned a reputation in rapid construction of quality high-rise buildings over the years with the adoption of specialized construction technics that make Hong Kong the regional leader.

Hong Kong breathes an infrastructure boost in the last decades and that was validated again in 2007 with the introduction of 10 mega infrastructure projects for the country. [23]

Transportation Infrastructure:

- West Island Line and South Island Line;
- Sha Tin to Central Link;
- Tuen Mun Western Bypass & Tuen Mun-Chek Lap Kok Link.

Cross-boundary Infrastructure Projects:

- Guangzhou-Shenzhen-Hong Kong Express Rail Link;
- HK-Zhuhai-Macao Bridge;
- HK-Shenzhen Airport Co-operation;
- HK-Shenzhen Joint Development of Lok Ma Chau Loop.

New Urban Development Areas:

- West Kowloon Cultural District;
- Kai Tak Development Plan;
- New Development Areas.

3

CIVIL ENGINEERING EDUCATION IN CHINA

3.1. INTRODUCTION TO CHINESE EDUCATION

In order to understand Chinese Education at a graduate level, it is compulsory to elucidate the effort needed to enter any top technical and undergraduate schools in this country. A description of the foundations of education is necessary due to the educational and cultural differences in occidental and oriental education and due to the competitive environment that exists to enter top universities. Government investment in education in China is relatively high; data shows that 4.3% of total GDP is allocated in Education. [24]

3.2. CHINESE COMPULSORY EDUCATION LAW AND THE CHINESE ELEMENTAL EDUCATION

Primary and Secondary education in China is divided in three stages:

- Primary;
  - 5 years
- Junior Secondary;
  - 4 years
- Senior Secondary.
  - 3 years

Compulsory by Law

The "Compulsory Education Law of the People's Republic of China" was issued by the government in 1986 and created the base for the 9 year compulsory education which represents the Primary and Junior Secondary (referenced in the 2nd article). The 5th article states the age entry for all children; according to this article all children shall start school activities at 6 years old and no later than 7 years old. [25]

Article 2: The State shall institute a system of nine-year compulsory education. The authorities of provinces, autonomous regions, and municipalities directly under the Central Government shall decide on measure to promote compulsory education, in accordance with the degree of economic and cultural development in their own localities. [26]

Article 5: All children who have reached the age of six shall enroll in school and receive compulsory education for the prescribed number of years, regardless of sex, nationality or race. In areas where that is not possible, the beginning of schooling may be postponed to the age of seven. [26]

Some attributes of Chinese education are of note due to the differences that any scholar from western colleges can feel when they are shown.

3.2.1. THE TEACHER AS THE CENTER OF THE CLASS

In China the tradition is that in class the teacher is the higher authority, in the merans that the words from the teacher are not to be questioned and students are not supposed to intervene in class of answer the teacher's questions. For this reason, most of the questions that are made are purely rhetorical. This dictates the connection between student and teacher where the respect that is meant to exist between student and teacher is known to create tension which does not let students to freely speak up. [27]

3.2.2. MEMORIZING METHODS AND CREATIVITY

Education in China in mainly based on learning and memorization from books focusing on classics and on the exams. There are monthly knowledge deadlines applied to teachers that often have to rush through books in order to meet those deadlines that may be examined. This creates a system that is equal throughout the country but makes students learn from memorizing facts rather than understanding them. As it is explained with an example in the next subchapter the exams put pressure on the students which leads them to memorize information in order to succeed. [27]

The education system in China seems to be set to produce the "perfect" student where actions that are out of the ordinary are seen as a sort of rebellion. The concept that some areas of knowledge are better or more respectable is the norm which discourages students to follow degrees in art or design.[27]

3.3. FROM THE GAO KAO EXAM COMPETITIVENESS TO THE TOP ENGINEERING COLLEGES IN CHINA

To understand China's education one has to recognize the importance of the Gao Kao exam. The Gao (High) Kao (Test) exam is the National Higher Education Entrance Examination (NCEE), this exam is considered the most important part of the educational life of Chinese graduating seniors. The exam is so important that the pressure and results that come with it have been referred as "separate the young people of China into two profoundly distinctive categories". [28]

On a social level the Gao Kao is for students from rural areas one of the two options that allow a desired escape from rural areas to the cities, join the army or pass the Gao Kao. [29]

Statistics from the Ministry of Education accounted for a total of 9.12 million students taking the exam in 2013 in a test that lasts 9 hours. [30]

Graduate opportunities are much different for students who attend a top 5 university compared to those who don't, as the entry rate to these top 5 universities comes as low as 0,2%. [28] In this dissertation consideration will go for the top 10 Engineering universities in Mainland China as well as Hong Kong University and Macau University.

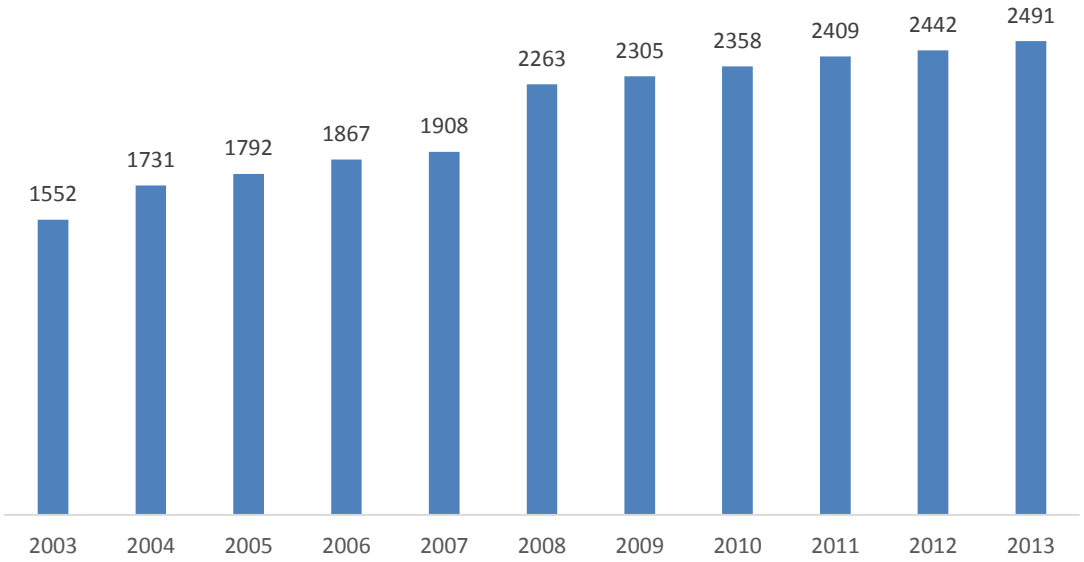

Figure 3.1 – Number of Universities in China [31]

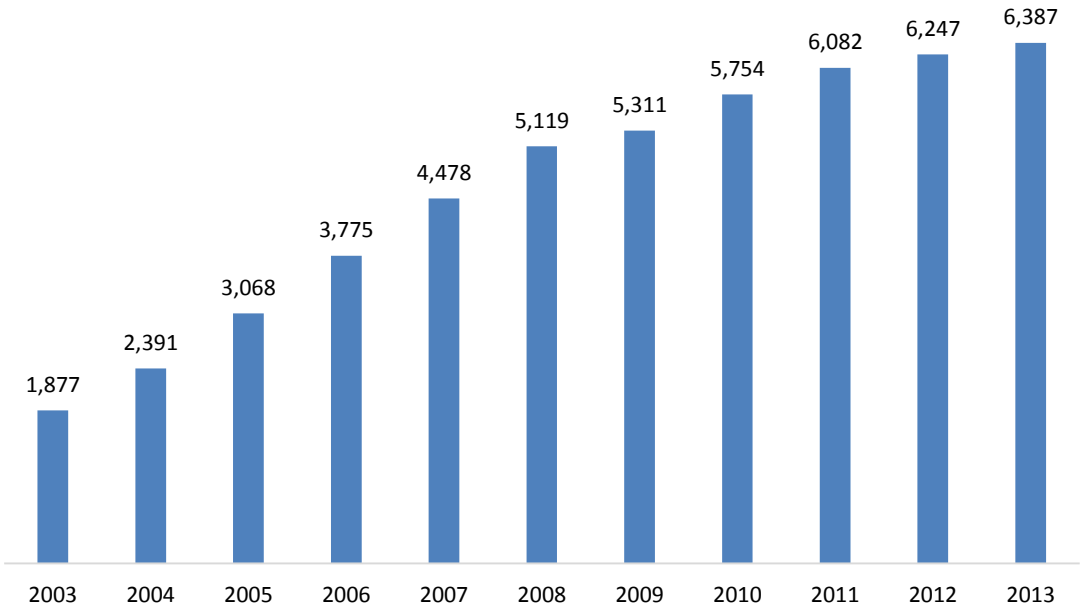

Figure 3.2 – Number of University Graduates in China [32]

Figure 3. and *Figure 3.* show that the number of universities in China is growing at a fast pace, between 2003 and 2013 a growth of over 60% is noted. Considering the same time frame for the number of university graduates the number in 2013 is almost 3.5 times larger than 2003. These numbers back the state of competition that students are brought to and indicates that there is a great challenge for education in China to provide higher education for those who seek it.

Table 3.1 – Student Enrollment on Higher Education Programs in Portugal and China in 2013 [33], [34], [35]

	Portugal	China
Total Number of Students Enrolled on High Education Programs	371,000	24,681,000
Total Population	10,723,000	1,360,720,000
Enrollment Rate	3.46 %	1.81 %

As can be seen in Table 3. even though there is a greater amount of people enrolling on higher education programs in China every year, when comparing with western countries like Portugal the figures show to be a fraction of the number of students that attend higher education programs.

3.4. OVERVIEW OF CIVIL ENGINEERING PROGRAMS OF TOP UNIVERSITIES IN CHINA

As stated above, elemental education in Mainland China leads to incredibly focused students with objectives and levels of effort that set the base for entrance in college.

Table 3.2 – Top 10 Universities for engineering study in China [36]

Ranking	University
1	Tsinghua University
2	Zhejiang University
3	Harbin Institute of Technology
4	Shanghai Jiao Tong University
5	Tianjin University
6	Dalian University of Technology
7	South China University
8	Beijing University of Aeronautics and Astronautics
9	Huazhong University of Science and Technology
10	Southeast University

Table 3.3 – The World University Ranking [37]

Ranking	University
5	Tsinghua University
7	Hong Kong University of Science and Technology
40	University of Macau
46	Zhejiang University
82	Dalian University of Technology
84	South China University

3.4.1. ZHEJIANG UNIVERSITY CIVIL ENGINEERING UNDERGRADUATE PROGRAM

Figure 3.3 – Zhejiang University Logo [38]

Table 3.4 – Zhejiang University General Information [38]

City	Hangzhou, Zhejiang
Leadership	Ministry of Education
Planned Length of Schooling	4 years
Minimum Graduation Credits	169
Awarded Degree	Bachelor of Science in Civil Engineering

Zhejiang University was founded in 1897 in the city of Hangzhou in the region of Zhejiang which is located in the eastern coast of China. The university follows the motto: "Seeking the Truth and Pioneering New Trails" in a broad set of knowledge fields such as philosophy, economics, law, education, literature, history, art, science, engineering, agriculture, medicine, management. The University accounts a total of 7 faculties and 36 colleges/schools. [38]

The education ambition of the Zhejiang University College of Civil Engineering Undergraduate Program is not only focused on the fields of Mechanics and Mathematics but also combines these fields with an education of Humanities and Sociology fundamentals. Zhejiang University located in the city of Hangzhou represents well this balance between knowledge areas.

Students of the Zhejiang University College of Civil Engineering undergraduate program are, during the degree, invited to independently select courses according to their own preferences and needs of development mainly in the fields of Architectural Engineering, Road and Bridge Engineering, Geotechnical Engineering, Engineering management and other fields.

Graduates in Zhejiang University are expected to acquire knowledge in mainly 4 topics: [38]

1. Fundamentals of theoretical knowledge in mathematics, mechanics and other natural sciences with preference for humanities and sociology. The knowledge areas are to be integrated with the ability for computer applications and foreign languages.
2. Mastery over basic theories about:

   - Mechanics;
   - Material Mechanics;

- Fluid Mechanics;
- Soil Mechanics;
- Engineering Geology;
- Engineering Graphing.

3. Mastery over special core civil engineering knowledge:

- Building materials;
- Structural principles and design;
- Computer analysis;
- Engineering design;
- Engineering Surveys;
- Engineering Economy;
- Project management;
- Engineering experiment.

4. Abilities for basic methods of literature search and data query.

Zhejiang University offers a set of Civil Engineering Master Degree Programs in order to specialize the students in different areas: [38]

- Geotechnical Engineering;
- Structural Engineering;
- Municipal Engineering;
- Disaster prevention and Reduction Engineering and Protective engineering;
- Bridge and Tunnel Engineering;
- Marine building and environment.

3.4.2. DALIAN UNIVERSITY OF TECHNOLOGY CIVIL ENGINEERING UNDERGRADUATE PROGRAM

Figure 3.5 – Dalian University of Technology Logo [39]

Table 3.6 – Dalian University General Information [39]

City	Dalian, Liaoning
Leadership	Ministry of Education
Planned Length of Schooling	4 years
Minimum Graduation Credits	165 + 3 optional specialized courses

Awarded Degree	Bachelor of Science in Civil Engineering

Dalian University of Technology (DUT), founded in 1949, is located in the Liaoning Province in the Northeastern part of China, in the city of Dalian. It is one of the key universities under the leadership of the Ministry of Education and is considered to be at the top of Technology Universities in China. The moto of the University is: "Unity, Enterprise, Realism and Originality". DUT has 14 colleges with 38 bachelor degree programs. [39]

When having an opportunity to look at the Civil Engineering curriculum, part of the Faculty of Infrastructure Engineering, it is clear that the focus is not only on Mathematics and Mechanics. Dalian Civil Engineering Faculty offers a set of compulsory courses focused on general knowledge, military, language, humanities and politics.

Table 3.7 – Main compulsory subjects of general education [39]

Subject	Duration (semesters)	ECTS
Basic Law	1	2.5
Military Training	1	3
Military Theory	1	0.5
Physical Education	4	4
Health Education	1	0.5
Chinese Modern History	1	1.5
Politics	2	6.5
Language	4	12

A total of 30.5 credits of compulsory courses are applied to areas not directly related with Civil Engineering practices. [39] This represents the value and effort the Ministry of Education of the People's Republic of China creates to form students with what they consider to be a broader education.

On a specialization level, the undergraduate program of Dalian University offers a full compulsory course program for the first and second academic year. On the third and fourth year there is a broader possibility for the student to choose between different specialties.

Main compulsory courses for the 3rd and 4th academic year: [39]

- Structural Mechanics;
- Soil Mechanics;
- Reinforced concrete structure;
- Steel structure;
- Elastic Mechanics & Fine Element Programming;
- Architectural Materials;
- Bridge Engineering;
- Building Architecture;
- Architectural Materials;

Main optional courses for the 3rd and 4th academic year: [39]

- Hydraulics;
- Structural Engineering;

    - Advanced material mechanics
    - Bridge Design and structure
    - Load and structure design Method
    - Engineering structure software
    - Design of composite structures
    - Qualitative structural mechanics
    - Earthquake-resistant structures
    - Wood structures
    - Pre-stressed Reinforced concrete construction
    - Large-span steel structures
    - Strengthening of structures
    - Steel bridge
    - Anti-seismic bridge construction
- Road Engineering;
    - Road surveying
    - Road Engineering CAD
    - Economy of road engineering
- Construction Management and safety;
    - Management of construction project
    - Principles of construction monitoring
    - Quota and valuation of engineering construction
    - Engineering economy and management
    - Construction safety
- Architecture;
    - Architectural instruments
    - Architectural structure
    - New architectural materials
    - Building architecture
    - Soil and Geo mechanics
- Geomechanics.
    - Engineering Geology
    - Treatment of soft soil foundation

3.4.3. TSINGHUA UNIVERSITY CIVIL ENGINEERING UNDERGRADUATE PROGRAM

Figure 3.6 – Tsinghua University Logo [40]

Table 3.8 – Tsinghua University General Information [40]

City	Beijing
Leadership	Ministry of Education
Planned Length of Schooling	4 years
Minimum Graduation Credits	177
Awarded Degree	Bachelor of Science in Civil Engineering

Tsinghua University was founded in 1911 in the city of Beijing and alongside with Peking University it represents Beijing top educational center. With the motto "Self-Discipline and Social Commitment" Tsinghua University offers a total of 74 Undergraduate programs distributed through 26 schools that tackle the most important fields of knowledge. [40]

With a similar knowledge distribution as the other Civil Engineering Undergraduate programs in China, Tsinghua University teaches students a broad set of fields that tackle both Social to Mechanical problematics. The program is divided in 4 categories, as described below. [40]

Main compulsory subjects of general education: (69 Credits)

- Politics Theory;
- Gym Lessons;
- Foreign Language;
- Humanity Culture;
- Nature Science;
- Computer science;
- Mathematics;
- Physics.

Main compulsory courses in the field of Civil Engineering: (82 Credits)

- Drawing for Engineering ;
- Mechanics;
- Structure;
- Communication and bridge construction;
- Introduction to Majors;

- Specialized Core Courses.

Practice Work: (22 Credits)

- Project;
- Internship;
- Practice Elective.

Dissertation on a selected field (15 Credits)

Tsinghua University offers a total of 5 graduate programs in the field of civil engineering:

- Structure Engineering;
- Disaster Prevention, Reduction and Protective Engineering;
- Hydrology;
- Geotechnical and Survey Engineering;
- Municipal Engineering;

3.4.4. SOUTH CHINA UNIVERSITY OF CIVIL ENGINEERING UNDERGRADUATE PROGRAM

Figure 3.7 – South China University of Technology Logo [41]

Table 3.96 – South China University of Civil Engineering General Information [41]

City	Guangzhou, Guangdong
Leadership	Ministry of Education
Planned Length of Schooling	4 years
Minimum Graduation Credits	147 + 35 = 182
Awarded Degree	Bachelor of Civil Engineering

South China University of Technology (SCUT) was founded in 1952 in the city of Guangzhou, with the motto: “Study Extensively, Enquire Accurately; Discriminate Clearly, Practice Earnestly “At the time it was established the University united several major institutes of technology around China by major force, such as the Tsinghua University in Beijing. In 1960 the university was considered by the state as one of the key universities in China. With over 60 years of teaching and creating knowledge SCUT, it is now a multi-disciplinary University combining: [41]

- Science;
- Engineering;
- Arts;
- Social Science;
- Business Management.

The School of Civil Engineering and Transportation (SCET) is one of the major Schools in South China University of Technology, as it combined the former Department of Civil Engineering with the School of Traffic Engineering. The undergraduate Civil Engineering Program is set and designed to enhance student knowledge, both practical and theoretical, in the field of Civil Engineering.

The program focuses mainly on the following skills:

- Design;
- Construction;
- Management;
- Research and Development.

The skills stated are then combined to lead the student to the understanding broad Engineering fields: [41]

- Civil Engineering;
- Bridge and tunnel engineering;
- Road and railway engineering;
- Geotechnical Engineering;
- Hydraulic and Hydroelectric engineering.

Main compulsory subjects of general education (81 credits)

- Ethics and Basics of Law;
- Chinese philosophy;
- Chinese History;
- Basic Tenets of Marxism;
- Current Situation and Policy;
- Language (College English).
- Physical Education;
- Military Theories;
- Higher Mathematics;
- College Physics;
- Linear Algebra;
- Probability and Statistics;
- Descriptive Geometry and Architectural Drawing;
- Fundamentals of Electrical Engineering;
- Computer Technology and Applications.

Main compulsory courses in the field of Civil Engineering (46 Credits)

- Introduction to Civil Engineering (bilingual);
- Civil Engineering Materials;
- Engineering Survey;
- Theoretical Mechanics;
- Materials Mechanics;
- Structural Mechanics;

- Fluid Mechanics;
- Soil Mechanics;
- Theories of Reinforced Concrete Structures ;
- Steel Structure Theories;
- Loads and Design Principles (bilingual);
- Civil Engineering Construction;
- Engineering Geology;
- Foundation Engineering;
- Project Management (bilingual);
- Construction Cost Management.

Main optional courses and specialty-related courses (Minimum of 20 credits)

- Construction Regulations;
- Elasticity Mechanics (bilingual);
- Themed Topics on Structural Mechanics;
- Engineering Economics;
- Design Principles for Composite Structures;
- Architectural Engineering Specialty Courses;
- Underground Structure Specialty Courses;
- Road and bridge Engineering Specialty Courses;
- Construction Management Specialty Courses;
- Urban and Municipal Specialty Courses;
- Reinforced Concrete Structure Specialty Courses.

South China University Civil Engineering Master Degree Programs

- Structure Engineering;
- Geotechnical Engineering;
- Bridge and Tunnel Engineering;
- Disaster Prevention and Mitigation and Protection Engineering;
- Municipal Engineering.

3.4.5. MACAU UNIVERSITY CIVIL ENGINEERING UNDERGRADUATE PROGRAM

Figure 3.8 – University of Macau Logo [42]

Table 3.10 – University of Macau General Information [42]

City	Macau
Leadership	Government of the Macau Special Administrative Region Education Bureau
Planned Length of Schooling	4 years
Minimum Graduation Credits	176
Awarded Degree	Bachelor of Science in Civil Engineering

The University of Macau was founded in 1981 and has been since the only public University in Macau. The motto of the university is: "Humanity, integrity, propriety, wisdom and sincerity". University of Macau offers a set of bachelor, master and PhD programs that are conducted mainly in English, Chinese Portuguese and Japanese. The University is divided in the following faculties: [42]

- Faculty of Arts and Humanities;
- Faculty of Business Administration;
- Faculty of Education;
- Faculty of Health Sciences;
- Faculty of Law;
- Faculty of Social Sciences;
- Faculty of Science and Technology;
- Institute of Chinese Medical Sciences.

The Department of Civil and Environmental Engineering of the Faculty of Science and Technology has an emphasis on Structural Engineering, Geotechnical Engineering, Construction Management, Environmental Engineering and Water Resources. Regarding the undergraduate program the focus is not only to lead students on technological fields but also introduce them to leadership skills and a good understanding in General Education.

When looking to the previous Program of the Bachelor of Science in Civil Engineering and comparing to the current one it is notorious that University of Macau is moving towards a program that resembles western education programs, much more focused on technical courses and leaving knowledge fields like

University Life, Visual and Performing Arts, Life Science and health conditions, World Histories and Cultures, Values Ethics and Meaning of Life.

Main compulsory subjects of general and preparatory education: (25 + 40.5 = 65.5 Credits) [42]

- General; (25 Credits)
    - English
    - Chemistry
    - Computer Science
    - Portuguese or Chinese
    - Introduction to Economics
- Preparatory. (40.5 Credits)
    - Mathematical Analysis
    - Linear Algebra
    - Physics
    - Numerical Methods & Computation
    - Probability and Statistics
    - Physics Laboratory

Main compulsory courses in the field of Civil Engineering (95.5 Credits) [42]

- Technical Drawing;
- Civil Engineering Drawing;
- Mechanics;
- Engineering Geology;
- Strength of Materials;
- Hydraulics;
- Surveying;
- Structures;
- Construction Materials;
- Environmental Engineering;
- Soil Mechanics;
- Electricity and Machines;
- Reinforced concrete;
- Construction methods, procedures & equipment;
- Engineering Planning & Management;
- Construction Management and Practice.

Five required elective courses from the list: (15 Credits) [42]

- Civil Engineering Hydraulics;
- Advanced Topics in Soil Mechanics;
- Advanced Mechanics of Materials;
- Advanced Structural Analysis;
- Structural Vibrations;
- Advanced Reinforced Concrete Design;
- Structural Systems and Analysis;
- Selected Topics in Geotechnical Engineering;
- Earth Retaining Systems;
- Application of Numerical Methods in Geotechnical Engineering;

- Introduction to Soil Improvement;
- Engineering Economics and Ethics;
- Construction Planning, Scheduling and Control;
- Construction Methods, Procedure and Equipment;
- Environmental Engineering;
- Essentials to Environmental Biotechnology;
- Wastewater Treatment Engineering;
- Traffic Engineering;
- Transportation Planning and Public Transport System;
- Special Topics in Civil Engineering;
- Intensive Industrial Training;
- Civil Engineering Internship.

Macau University Civil Engineering master degree programs:

- Structural and Geotechnical Engineering;
- Hydraulics and Environmental Engineering.

3.4.6. HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY CIVIL ENGINEERING UNDERGRADUATE PROGRAM

香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Figure 3.9 – Hong Kong University of Science and Technology Logo [43]

Table 3.11 - Hong Kong University of Science and Technology General Information [43]

City	Hong Kong
Leadership	Government of the Hong Kong Special Administrative Region Education Bureau
Planned Length of Schooling	4 years
Minimum Graduation Credits	126
Awarded Degree	Bachelor of Science in Civil Engineering

The Hong Kong University of Science and Technology was founded in 1991 with the objective to become an international research university, establishing relationships with global lead Universities and at the same time forging a strong connection with mainland China. The University offers a set of interdisciplinary studies in order to educate well-rounded students in the following schools:

- School of Science;
- School of Engineering;
- School of Business and Management;
- School of Humanities and Social Science.

The Department of Civil and Environmental Engineering of the School of Engineering of Hong Kong Science and Technology University aims to provide students skills in design, construction and management of civil engineering infrastructure with awareness in environmental sustainability. There are programs both for undergraduate and graduate levels. At the undergraduate level the program lasts 4 academic years and includes Structural, Geotechnical, Construction Materials and Hydro systems as the main specialty courses. Each semester comes with a University Core Course that can be conducted in different fields.

Hong Kong University of Science and Technology Core Course Areas: (32 Credits) [43]

- Arts;
- Chinese Communication;
- English Communication;
- Healthy Lifestyle;
- Humanities;
- Quantitative Reasoning;
- Science and technology;
- Social Analysis.

Main compulsory subjects of general and preparatory education: (45 Credits) [43]

- Calculus;
- Accounting Calculus;
- Multivariable Calculus;
- Matrix Algebra & Applications;
- General Physics;
- General Chemistry;
- Technology Communication;
- Introduction to Computers;
- Statics;
- Discover Civil and Environmental Engineering;
- Modeling systems with uncertainties;
- Fluid Mechanics;
- Infrastructure systems Engineering & Management;
- Mechanics of Materials;
- Environmental Assessment and Management.

Main compulsory courses in the field of Civil Engineering: (49 Credits)

- Construction Materials;
- Structural Analysis;
- Reinforced Concrete Design;
- Geotechnical Analysis & Design;
- Foundation of Geotechnics;
- Hydro systems Engineering;
- Construction Management;
- Traffic & Transport Engineering;

- Civil Capstone Design Projects;
- Technological Communication;
- Final year Project/Thesis.

Hong Kong University of Science and Technology Civil Engineering Master Degree Programs:

- Civil Infrastructural Engineering and Management;
- Environmental Engineering and Management.

3.5. CIVIL ENGINEERING PROGRAM AT FEUP AND COMPARISON WITH CHINESE UNIVERSITIES

The comparison undertaken in this chapter does not intend to make a comparison between the whole picture of Civil Engineering Education both in China and Portugal. In both countries the educational programs vary between universities so the intent of this comparison is to discern differences between the top Universities in China, from the rankings stated above and the Civil Engineering program of the Faculty of Engineering of the University of Porto.

3.5.1. FACULTY OF ENGINEERING OF THE UNIVERSITY OF PORTO CIVIL ENGINEERING PROGRAM

Figure 3.10 – Faculty of Engineering of the University of Porto Logo [44]

Table 3.12 – Faculty of Engineering of the University of Porto General Information [44]

City	Porto
Leadership	Public University
Planned Length of Schooling	5 years
Minimum Graduation Credits	300
Awarded Degree	Integrated Master Degree in Civil Engineering

University of Porto is a Portuguese Public University founded in the year of 1911. U.Porto is considered a benchmark institution for higher education and scientific research in Portugal and Europe. [45] Combining high quality education that focuses individual vocations and talents while answering the market needs with the claim of being the greatest birthplace of science in Portugal. [45]

U.Porto counts a range of 15 different schools and over 50 research centers that motivate the country's highest ranked students. With a highly qualified scientific and teaching staff and a growing number of

international students, teachers and researchers U.Porto guarantees an optimal academic experience. [45]

The 15 schools that are part of U.Porto create a broad set of knowledge fields that guarantee the highly qualified training: [45]

- Architecture;
- Arts and humanities;
- Engineering and technology;
- Exact Sciences;
- Natural Sciences;
- Health Sciences;
- Social Sciences;
- Sports;
- Law.

The faculty of Engineering is the biggest school of U.Porto with a total of 8200 students enrolled in the year 2014/2015. Civil Engineering at the Faculty of Engineering of the University of Porto offers an Integrated Master Degree with a total of 300 ECTS with the option for a Bachelor in Engineering Sciences – Civil Engineering with the duration of 3 years and 180 ECTS.

Table 3.13 - Main Compulsory Courses for the Bachelor of Civil Engineering [44]

Subject	Duration (Semesters)	ECTS
Computation	1	6
Technical Drawing	1	6.5
Algebra	1	7
FEUP Project	1	1.5
History of Civil Engineering	1	2
Mathematical Analysis	3	19.5
Mechanics	1	13
Topography	1	6
Numerical Analysis	1	6
Economics and Management	1	4
Strength of Materials	2	16
Engineering Geology	1	6
Environmental and Social Assessment	1	4.5
General Hydraulics	2	11.5
Physics	1	5
Statistics	1	6.5
Architecture	1	5.5
Construction Materials	2	11
Operational Research	1	5
Physics of Constructions	1	6
Structural Analysis	2	14
Territorial Planning	1	5.5
Technology of Construction	1	5.5
Hydrology and Water Resources	1	6.5

Table 3.14 – Main compulsory courses on the first year of the Master's Degree [44]

Subject	Duration (Semesters)	ECTS
Project Management	1	3
Roads	2	12
Environmental and Urban Hydraulics	1	6.5
Soil Mechanics	2	13
Structural Concrete	2	16
Construction Management and Safety	1	4.5
Urban Environment and Transport Planning	1	5

Students are enrolled in a program that is strict for the first 4 years with a broad education in the main scientific and technical civil engineering domains which can be chosen for specialization in the 5th year:

- Material Construction Processes;
- Structures;
- Geotechnics;
- Building Construction;
- Planning;
- Transport infrastructures;
- Hydraulics.

The fifth year of specialization is comprised with subjects during the first semester strictly in the field chosen. The second semester is strictly for the purpose of writing and presenting a Dissertation, during which no other classes can be attended.

3.5.2. COMPARING FEUP PROGRAM TO PROGRAMS IN CHINA

When comparing two different education realities it is important to state that the concept of education is different and not to be discussed in the matters of this dissertation. Focus will be in comparing key features comprised in the Civil Engineering teaching with notes for the general education courses that Chinese programs have.

A distinction must be made as inside China realities may differ, from Mainland China to Macau, and to Hong Kong. Chinese Mainland universities are under the leadership of the Ministry of Education while Hong Kong and Macau follow their own special administrative region governments. Dr. Ieong Raymong from Macau University stated in an interview that Macau University share for the most part Chinese Mainland programs, which can be confirmed in the program studies above. As Hong Kong University ranks as one of the top 25 top Engineering Universities in the world (TIMES, 2015) we can say that it follows its own program and culture with proven success.

The following topics will be checked and compared:

- General Education inclusion;
    - Social education
    - Humanities
    - Physical education
    - Language education
- Key specialties in Civil Engineering;
- Comparison of a selected course.
    - Class Hours
        - Theoretical
        - Practical
    - Advised time spent per week on studies

3.5.2.1. General Education Inclusion

In terms of general education the difference between the programs from Chinese universities and the program from FEUP is clear. From the Chinese point of view, general education is considered as of the most important in all universities with some having more compulsory courses than others. The standard compulsory obligation for a Chinese student comprises physical education, politics theory, Chinese philosophy, foreign languages and humanity culture. The General Education compulsory courses take place mainly on the first two years of the program due to the growing specialization on civil engineering subjects. On the other hand, FEUP offers from the beginning a very strong base education on math and physics, economy and computational sciences. FEUP program admits that general education was taught with success in secondary school which in some cases proves to not be enough. With this assumption, the concept of college learning in Portugal does not give incentives for foreign language learning, which creates a challenging ability to perform in an ever growing international market that requires both social and technical English language skills. In terms of lifestyle and health it is clear that with no direct incentives or compulsory courses on university students at FEUP the lack core areas of healthy living like sports or physical education.

3.5.2.2. Key Specialties in Civil Engineering

When it comes to who has the broadest civil engineering areas covered through the years of the program, FEUP differentiates from all other schools. When looking at Chinese schools, none of the universities studied offers a program that tackles such a broad set of specializations at a Master Degree standard. Structural, Geotechnical and Building Construction can be seen in all of the studied schools, the same cannot be said for Hydraulic, Planning and Material Construction Processes. This may be due to the separation of studies in Engineering courses, given the example of Maritime Engineering which studies hydraulics, even though, the bases of structural design and construction materials are connected and needed for specialization in this areas.

3.5.2.3. Comparison of a key selected course

Concrete is one of the main materials in construction and represents one of the core fields of study for any Civil Engineering program.

The comparison will be made between concrete studies between Dalian University of Technology and FEUP. Considering the comparison with FEUP an assumption was made, for the Dalian University concrete program the working time on class (practical and lecture) and the working time out of class were considered to be the same.

Table 3.15 – Structural Concrete courses in FEUP [44]

FEUP	Structural Concrete I	Structural Concrete II
ECTS	8	8
Practical (hours per week)	2	2
Lectures (hours per week)	3	4
Working time out of class (hours per week)	5	5
Weeks	15	15
Total Hours per course	150	165
Total Hours	**315**	

Table 3.16 – Structural Concrete courses in Dalian University [39]

Dalian University	Reinforced Concrete Structure I	Reinforced Concrete Structure II	Reinforced concrete structure design (1,5 weeks)	Prestressed Reinforced Concrete Construction
ECTS	2,5	2	1,5	2
Practical (hours)	0	4	0	32
Lectures (hours)	40	32	64	0
Working time out of class (hours)	40	36	0	32
Total Hours per course	80	72	64	64
Total Hours		**280**		

It is clear that in the Dalian University case, even though concrete studies are divided in 4 different semesters the amount of time spent in this subject is less than in FEUP. In FEUP every week there are theoretical and practical classes while in Dalian University there is clearly more focus on lectures throughout 4 semesters. Practical studies in Dalian University mainly occur during a 1.5 weeks intensive course. The division between lecture and practical classes on Dalian University shows that emphasis goes to the theoretical education of reinforced concrete structures with the practical side being taught almost exclusively in the area of pre-stressed reinforced concrete.

4

CONSTRUCTION IN CHINA: MARKET LANDSCAPE

4.1. INTRODUCTION TO THE CHINESE CONSTRUCTION MARKET

As one of the oldest civilization in the world China's culture and history has many distinctive construction evidences that reminisce the dynasties that ruled each period of the country's history. Each of this constructions show distinctive character and architectural influences.

However, in recent history China has only been growing at a better pace since 1980. After a century with many struggles for the whole culture China is again showing economic success and re-establishing its position in the world. Figure 4.19 and Figure 4.20 show the growth of the Gross Domestic Product (GDP) and the Gross Domestic Product per Capita from 2005 to 2014. China's GDP during the years studied (1995-2014) climbed impressively showing a Compound Annual Growth Rate (CAGR) of 13.1%. Indicators show that in the forthcoming years this level of growth will slow down with the Economist Intelligence Unit (EIU) forecasting the Real GDP Growth in 2018 to be 6.0% [46] and OECD long-term Forecast showing that by 2060 this growth will only be 1.55%. [46]

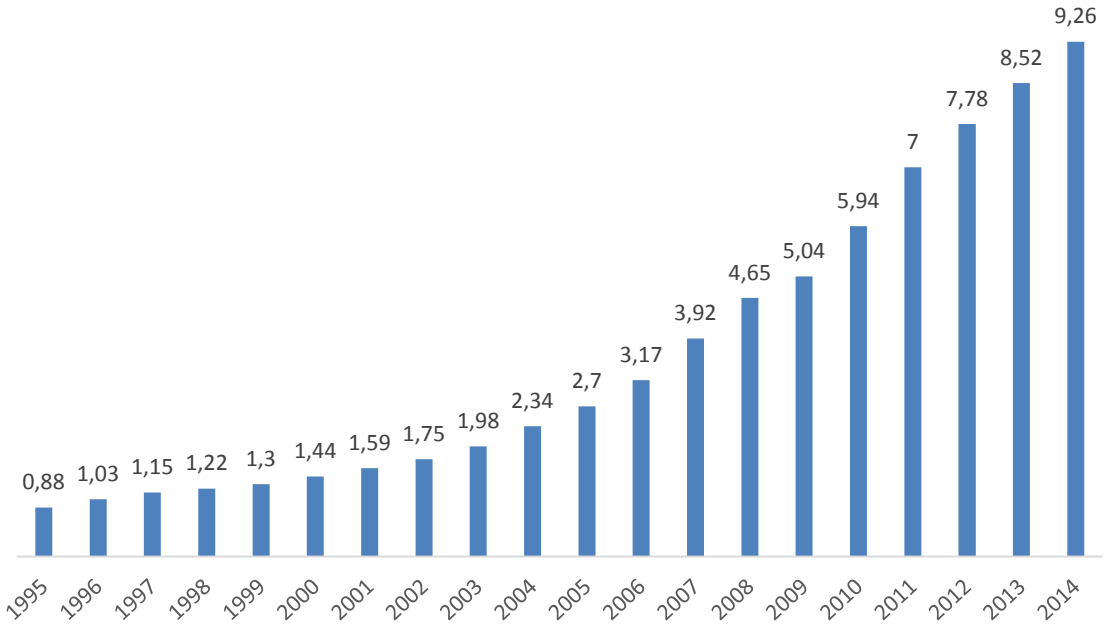

Figure 4.19 - Gross Domestic Product (GDP) Growth in China (Thousand Billion Euros) [33]

Even though the coming years will be of slowdown in growth pace it is important to note that when compared to other economies China will continue to show impressive growth with what can be considered endless opportunities for a diversity of markets and industries in the years to come. Construction Market, as we will see, is one of them.

In terms of Per Capita Gross Domestic Product, shown in Figure 4.20, the Compound Annual Growth Rate (CAGR) has a figure of 12.4% which is in line with the GDP growth of the country. With a population of 1.347 billion people in 2014 [33] this growth represents an economy where people start having the power to buy. Which combined by the increasing urban population that is set to grow by 26.1% between 2011-2020 [47] is likely to show a boom in housing where Residential Flooring space must grow exponentially.

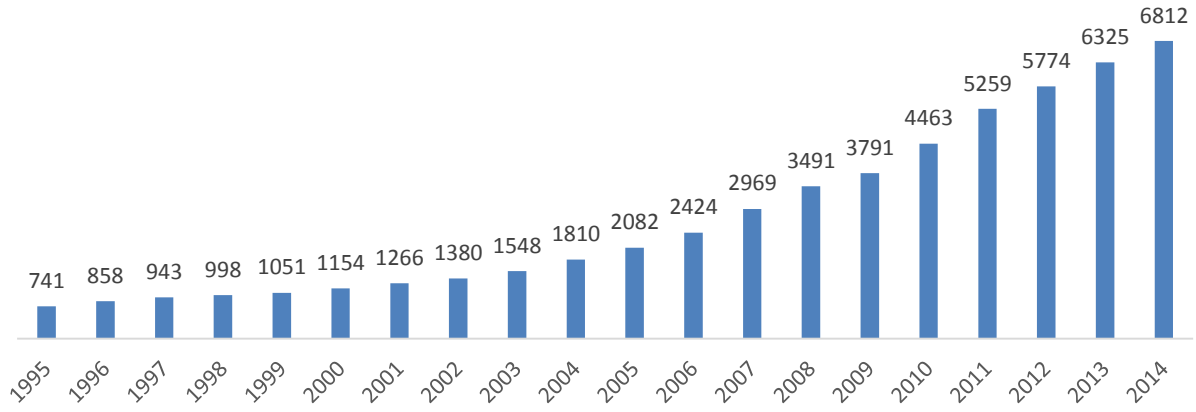

Figure 4.20 – Gross Domestic Product per Capita in China (Euros) [33]

China's construction industry is showing to be a major force behind the nation's rapid economic growth since the government enhanced the industry as one of the key points of the national modernization agenda in the 1980s.

The Gross Output Value in construction for the year 2014 was 9.26 thousand billion euros and represented 27.9% of the Gross Domestic Product. The growing tendency In China Construction is mainly separated in 3 sectors, Residential, Non-Residential and Infrastructure.

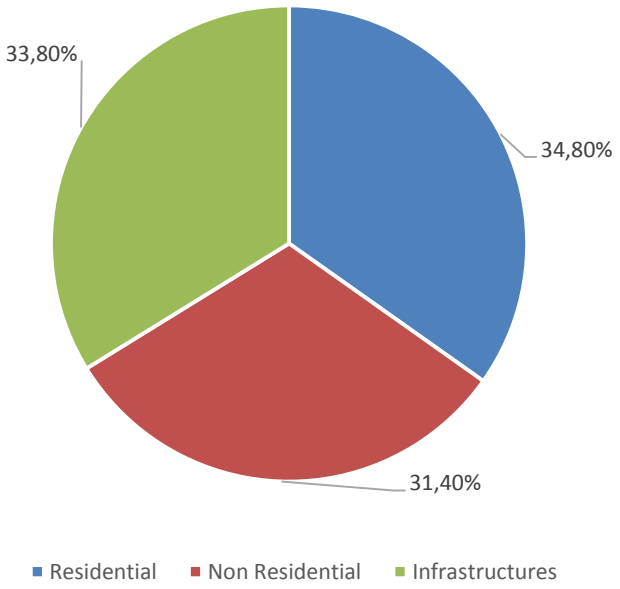

Figure 4.21 – Distribution of construction sectors in China for 2012 [33]

A balance is seen between the 3 main sectors where in 2012 Residential accounted for 34.8% of the industry, Non Residential, 31.4% and Infrastructures, 33.8%. During the government's 12th 5 year plan from 2011-2015, 511 thousand million euros were allocated for railway construction alone which boosted the infrastructure figure. On a Residential level the key point to be considered is the growing urbanization of the population. The Economist Intelligence Unit tackles the figures accurately on the paper "Building Rome in a Day" with the following: "Between 2011 and 2020, we expect China's Urban population to increase by 26.1% or over 160m people, while urban per head disposable incomes will increase by 2.6-fold to 7,491 euros. Residential floor space per hear in Urban Areas will increase from 30 square meters (in 2008) to 41 square meters by 2020".

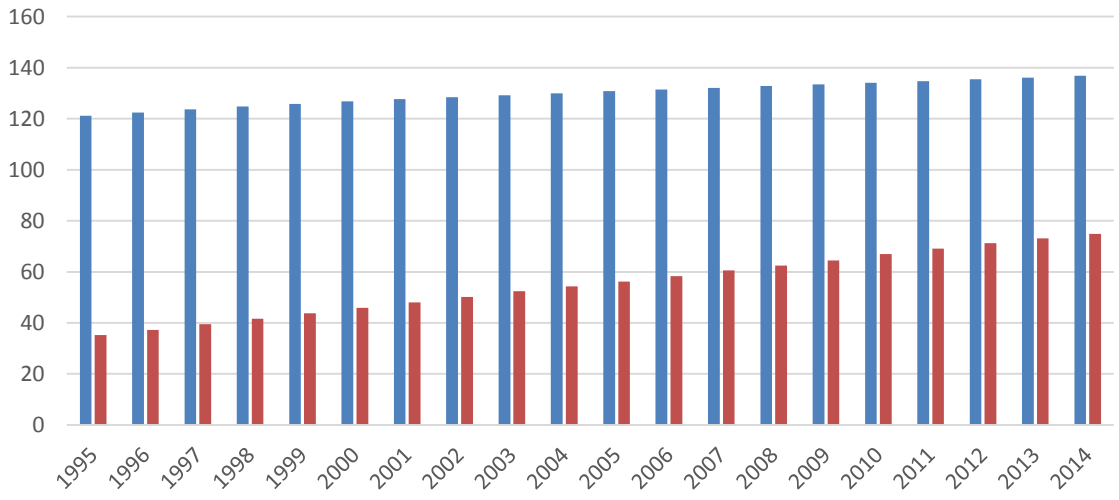

Figure 4.22 – Comparison between Urban Population and Total Population (100,000,000 people)

Considering the country's income level, the average living space per head is impressive. On Table 4.6 – China Railway Construction Corporation General Information [2]Table 4. comparison with India, a country in fast development, the floor space set side by side with the personal disposable income is representative of the Chinese housing boom of the last years.

Investment in Residential buildings in 2014 accounted 1.09 thousand billion euros which is experiencing a steady growth. In 2005 the total investment in Residential Building was 224 thousand million euros, the CAGR between for the 9 years in between is 19%. As stated above, the growing urbanization of China is the main responsible for this growth and forecasts point that it continues during the 2020's. [17]

Table 4.1 – Comparison of floor space and personal disposable income between India and China [47]

	India	China
Residential floor space per capita ($m^{2)}$	10.5	31.0
Personal disposable income (per capita, euros)	1,006	1,695

Combining the rising urbanization of cities in China with a clear effort from the government on infrastructural construction, with the creation of the Asian Infrastructure Investment Bank in 2014 which is mostly backed by the Chinese government the percentage of construction on the total GDP will not only continue to increase but will play a major role on Chinese economy. Figure 4.23 notes this trend as a combination of the above mentioned investment on Residential, Non-Residential and Infrastructure areas.

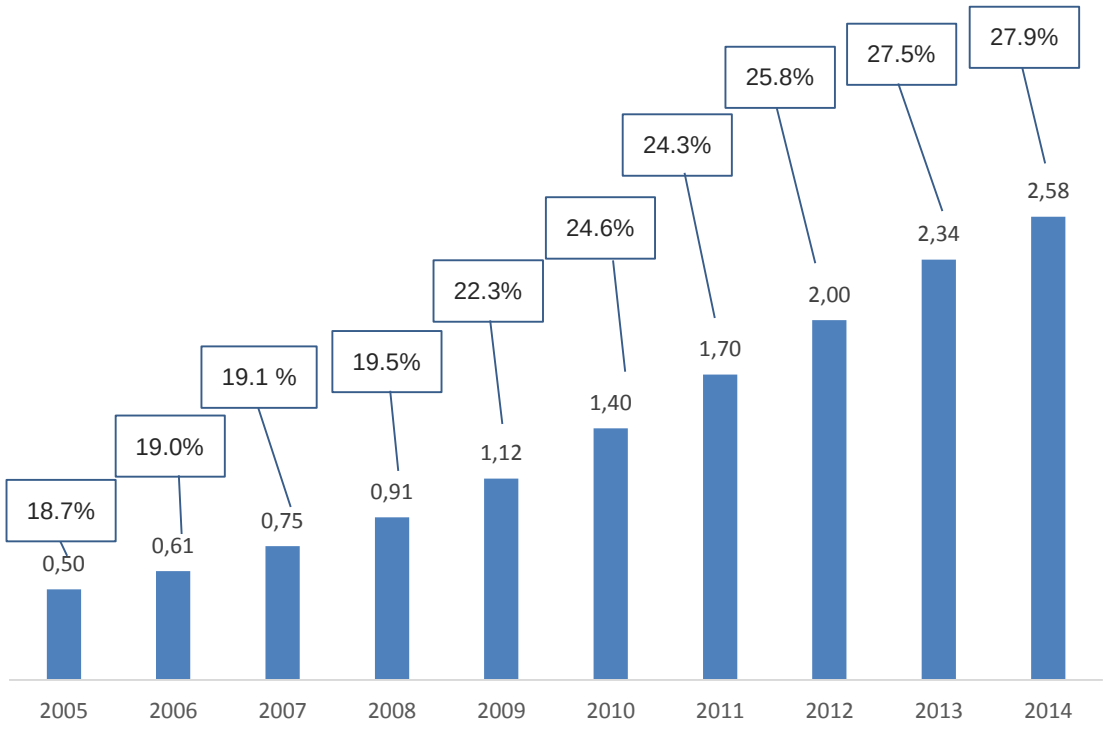

Figure 4.23 – Gross Output Value of Construction in China (thousand billion euros) [33] and percentage of Con struction value in total GDP

4.2. CONSTRUCTION FIRMS AND CONSTRUCTION EMPLOYMENT

4.2.1. CONSTRUCTION FIRMS AND CONSTRUCTION EMPLOYMENT OVERVIEW

As the whole industry rises the work power needed grows steadily too. The number of persons employed in construction enterprises is growing, just in 2014 3.6% of the population was employed by construction enterprises. As is stated later, most of the persons employed in construction work on rural and local enterprises that make the most part on the distribution of the construction companies in China.

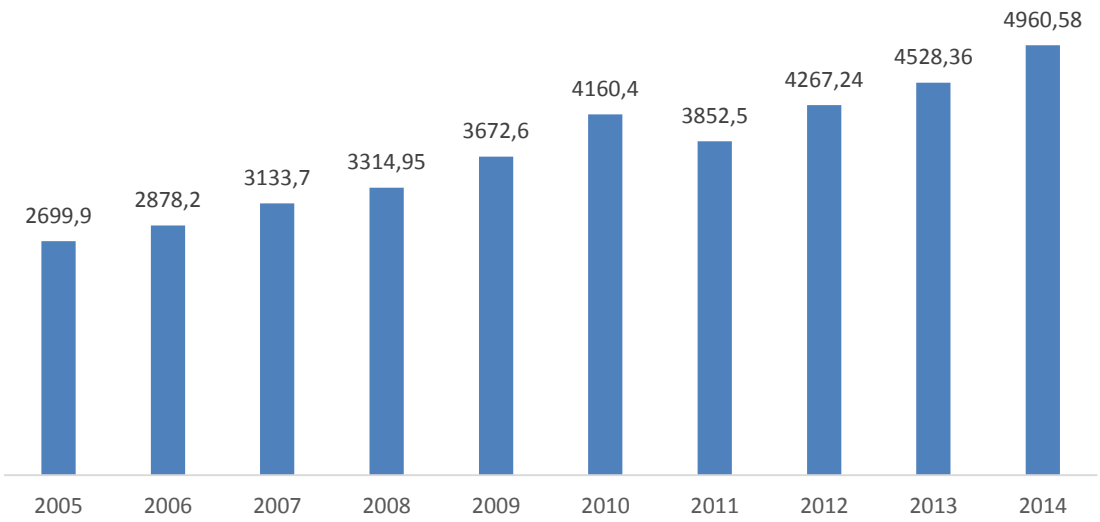

Figure 4.24 – Number of Persons Employed in Construction Enterprises (10,000 persons) [33]

The total number of construction enterprises for 2014 in China is 79,528. The next chart shows this distribution where the biggest stake falls in the area of “others”. Even though the most impressive of Chinese construction enterprises are public they are not the norm, nor do they employ the most people. The clear winner in terms of employment and market stake are small contractors that operate at a local level.

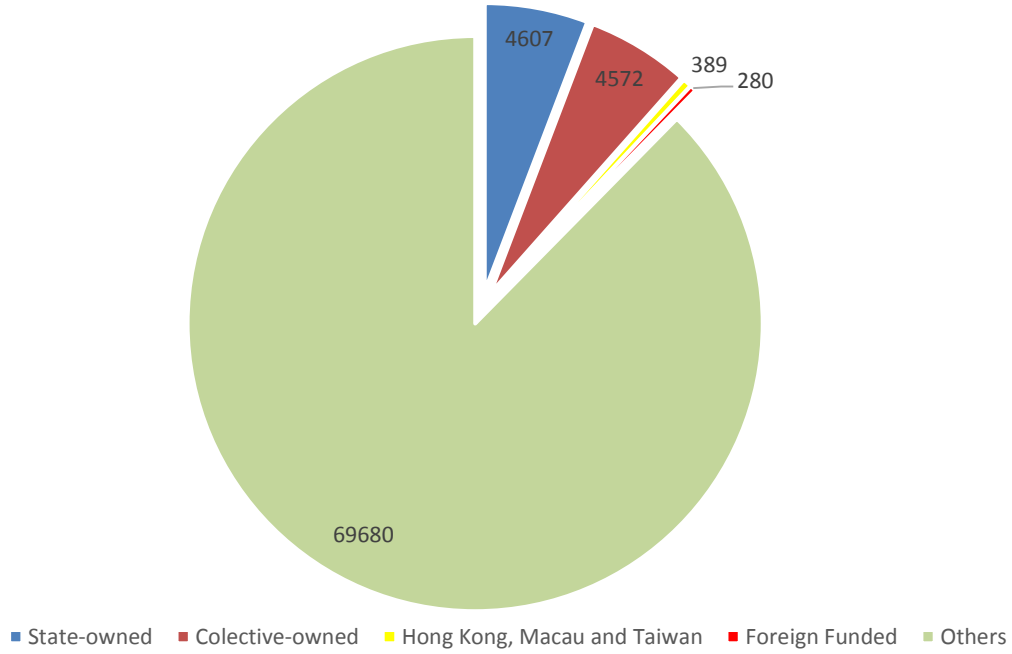

Figure 4.25 – Distribution of Construction companies ownership for 2014 [33]

4.2.2. Legal Framework of Construction firms in China

In terms of legal framework and management of the construction industry in China, the most important law is called the *Construction Law of the People's Republic of China*. The document comprises 8 chapters and 85 articles where the following frameworks can be found: [8]

- Building permit system;
- Contract management;
- Construction supervision system;
- Construction safety;
- Manufacture management;
- Construction quality management.

Chinese contractors and players have to fill the qualification requirements in order to be able to engage their activity in the industry. The legal framework on qualification has also a grading system that separates players and enhances competitiveness on the industry and is divided in four parts. [8]

- Comprehensive regulations;
- Administration of qualifications;
- Standard level of qualifications;
- Administration of qualification for foreigner contractors.

It is important to state that these frameworks are applied to all contractors obtaining construction works in China. No differences are made between local and overseas contractors or private and public companies. The only exemption made is for state-operated construction enterprises, these don't need to be included in the contractor grading system. [8]

On the grading system applied contractors in China are divided on different levels were the lowest possible is Labor Contractor of Level 3.

Table 4.2 – Contractors Grading system in China [8]

Tyoe	Levels
Main Contractors	1,2,3
Specialist Contractors	1,2,3
Labor Contractors	2,3

4.3. TOP 5 CHINESE CONTRACTORS AND CIVIL ENGINEERING COMPANIES

To understand the magnitude of the top 5 Chinese contractors and Civil Engineering companies it becomes crucial to understand the level of construction realized by the top contractors of the world. As we can see in Figure 7, in total revenue, both national and international wise, 4 out of the 5 biggest contractors in the world are Chinese. As all of the companies listed are owned by the government a statement can be called, that in terms of total revenue, the Chinese Government is currently the biggest contractor in the world.

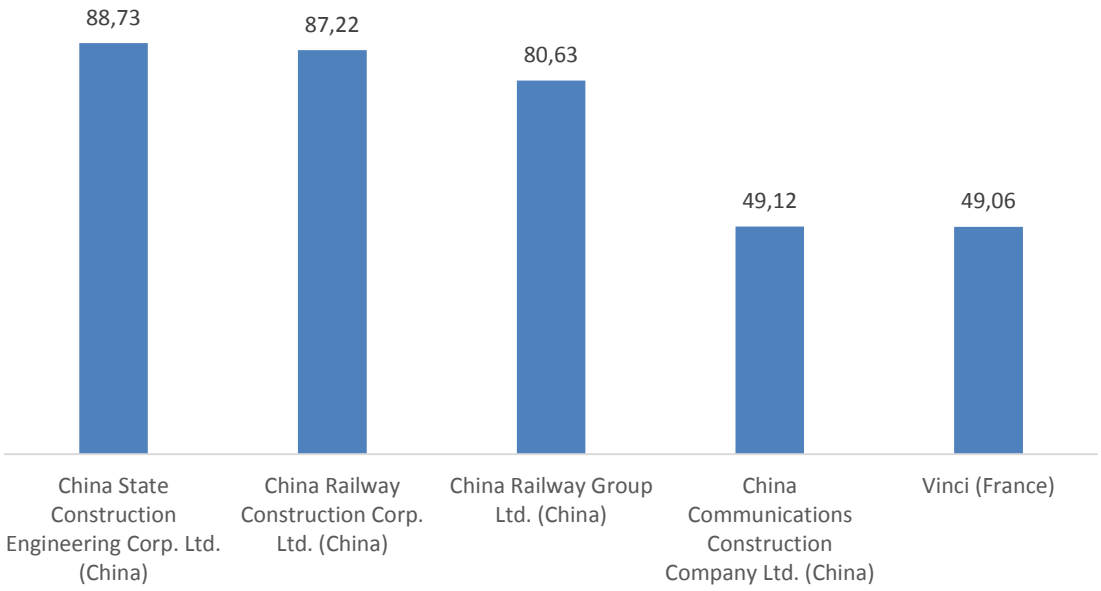

Figure 4.26 – Total Revenue World's Top Contractors 2013 (thousand million euros) [48]

As we will see during this subchapter, what makes Chinese contractors such players in the worldwide scene is not only the projects underdone in China. There are projects done by Chinese contractors in almost all emerging countries, like Brazil and India. There is however a continent that has clearly more influence from Chinese contractors, a lot due to the fast urbanization that its countries are going through, Africa.

China is not only providing manpower to fuel the quick urbanization of African cities but also it is exporting its own version of urbanization with cities and economic zones that resemble Chinese ones. [49]

The west has been trying to develop and help Africa for many years, something that China is being able to do with the economic interests that go along. The difference is that China instead of focusing on aid is focusing on business development which is shaping the many economic zones of Africa with various notes of influence from China.

The reasons are mainly due to the resemblances between China and Africa. The speed of urbanization is similar to the Chinese in the last 30 years.[50] Plus, the level of entrepreneurship and ambition for progress in African and Chinese cities is comparable. [50]

Chinese contractors are clearly taking advantage of this happening and it is important to note that the state-owned companies comprised in this chapter are not only undertake projects in Africa but also shaping African cities and economic zones.

For this reason, the data shown in this chapter comprises a combination of projects underdone in Chinese soil and internationally too.

4.3.2. CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD.

Figure 4.27 – China State Construction Engineering Corporation Ltd. Logo [51]

Table 4.37 – China State Construction General Information [51]

Leadership	Government
Total Revenue (2013)	88.63 thousand million euros
Founded	1957
Headquarters	Beijing

China State Construction is China's largest construction and real estate company with the biggest asset of underdone building works as a contractor since its foundation. In Greater China the company's business is spread all over except in Taiwan and internationally it operates in more than 20 countries. [51] Now being the largest international contractor the company was the first to launch international contracting in China. [51]

There are two sub-brands worth mentioning that tackle the real estate market, "China Overseas Property" and "China Construction Property". Both companies stand in position to offer an of contracting and property development.

As a contractor, China State Construction carries its business operations on the following main areas:

- Building Construction;
- International Contracting;
- Real Estate Development and investment;
- Infrastructure construction;
- Infrastructure construction and investment;
- Prospecting and design.

Table 4.4 – China State Construction Key Projects in Mainland China [51]

Key Projects in Mainland China	City	Year of Conclusion
Shanghai World Financial Center	Shanghai	2008
CCTV Building	Beijing	2012
National Swimming Center	Beiing	2008
Shenzhen Airport Expansion	Shenzhen	2011
Kunming Airport	Kunming	2011
World Trade Center Phase 3	Beijing	2010
Guangzhou International Finance Center	Guangzhou	2010
Wuhan Greenland Center	Wuhan	Under Construction
Shenzen Ping'an Financial Center	Shenzhen	Under Construction

Table 4.5– China State Construction Key Projects Overseas [51]

Key Projects Overseas	Country	Year of Conclusion
Terminal for Hong Kong International Airport	Hong Kong	2008
Cairo International Conference Center	Egypt	2012
Boumediene International Airport	Algeria	2007
RAMA VIII Bridge	Thailand	2002
Russian Federation Tower	Moscow	Under Construction
Republic Polytechnic of Singapore	Singapore	2007
The Palm Islands	UAE	Under Construction
Doha Tower	Qatar	2006
Nº1 National Highway	Republic of the Congo	2014

4.3.3. CHINA RAILWAY CONSTRUCTION CORPORATION LTD.

Figure 4.28 – China Railway Construction Corporation Ltd. Logo [2]

Table 4.6 – China Railway Construction Corporation General Information [2]

Leadership	Government
Total Revenue (2013)	87.22 thousand million euros
Founded	1948
Headquarters	Beijing

China Railway Construction Corporation is a company devoted to infrastructures in the fields of railways, highways, bridges, tunnels and urban rail traffic carries its business operations on the following main areas: [2]

- Project Contracting;
- Survey Design Consultation;
- Industrial Manufacturing;
- Real Estate Development;
- Logistics;
- Trade of goods and Materials;
- Capital Operations.

Table 4.7 – China Railway Construction Corporation Key Projects in Mainland China [2]

Key Projects in Mainland China	City	Year of Conclusion
Haikou Meilan International Airport	Haikou	2013
Nº1 Terminal Building of the Capital Airport	Beijing	2008
Head Office of China Construction Bank	Beijing	2008
Qinghai – Tibet Railway Extension	-	Under Construction
Beijing Zhonggang Building	Beijing	2008
Guangzhou–Shenzhen High-speed Railway	-	2007
Beijing – Tianjin High-speed Railway	-	2008
Guangzhou–Wuhan Passenger Railway Line	-	2010

Zhengzhou – Xi'an Passenger Railway Line	-	2010

Table 4.8 – China Railway Construction Corporation Key Projects Overseas [2]

Key Projects Overseas	Country	Year of Conclusion
Khoms – Sirte Railway	Libya	2008
Metro of Mecca	Saudi Arabia	2009
Football Stadium for F.C. Internazionale Milano	Italy	Under Construction
Hong Kong West Rail	Hong Kong	2003
Construction and Maintenance of Nigeria Railway System	Nigeria	2003
Macau Parliament Building	Macau	1999
East Wing Venetian Casino	Macau	2007
Algerian East-West Expressway	Algeria	Under Construction
Istanbul – Ankara Railway Reconstruction	Turkey	Under Construction

4.3.4. CHINA RAILWAY GROUP LTD.

Figure 4.29 – China Railway Group Ltd. Logo [52]

Table 4.9 – China Railway Group General Information [52]

Leadership	Government
Total Revenue (2013)	80.63 thousand million euros
Founded	2007
Headquarters	Beijing

China Railway Group is owned in majority by China Railway Engineering Corporation, a state-owned company founded in 1950. The company focuses on the following core areas: [52]

- Infrastructure Construction;
- Surveying;
- Designing;
- Consulting Services;
- Engineering equipment and component manufacturing;
- Property development.

China Railway claims an impressive amount of infrastructures built in China, where the company built approximately two thirds of the total operation length of railways in China. [52] It is responsible for approximately 95% of of electrified railways. [52] Overseas where the company provided construction-related services for more than 230 projects. [52]

Table 4.10 – China Railway Group in km of infrastructures built [52]

Electrified Railways	22,660 km
Bridges	4,230 km
Tunnels	3,900 km
Expressways	3,400 km
Metropolitan Railways	566 km

Table 4.11 – China Railway Group Ltd. key projects in China [52]

Key Projects in Mainland China	City
Qinghai - Tibet Railway	-
Datong – Qinhuangdao	-
Beijing – Kowloon	-
Beijing Railway Station	Beijing
Nanjing Railway Station	Nanjing
Lhasa Railway Station	Lhasa, Tibet

4.3.5. China Communications Construction Company Ltd.

Figure 4.30 – China Communications Construction Company Ltd. logo [53]

Table 4.12 – China Communications Construction Company General Information [53]

Leadership	Government
Total Revenue (2013)	49.12 thousand million euros
Founded	2005
Headquarters	Beijing

China Communications Construction Company is a state-owned company devoted to the construction of transportation infrastructures in the following main areas: [53]

- Port Terminals;
- Road;
- Bridges;
- Railways;
- Tunnels,
- Civil work design and construction;
- Capital Dredging;
- Reclamation Dredging;
- Container Cranes;
- Heavy Marina Machinery;
- Large Steel Structures;
- Road Machinery Manufacturing;
- International Project Contracting;
- Import and export trading services.

Though the areas of core business cover a large set of specialties the company is considered to be specialized in Dredging, Port Construction, Port Machinery, Steel Bridges and Railway Construction.

Table 4.13 – China Communications Construction Company Key Projects in Mainland China [53]

Key Projects in Mainland China	City	Year of Conclusion
Dock Project of COSCO Logistics	Dalian	2005 - 2008
Shenzen Yantian Port	Shenzhen	2005 - 2008
Jiangsu Rongsheng Dock	Nanjing	2008
Huanghua Breakwater	Huanghua	Not Found
Beiliang Hydraulic Structure and Silo	Dalian	Not Found
Xi'an – Hefei Expressway	-	Not Found
Beijing – Tianjing – Tanggu Expressway	-	Not Found
Shanghai – Nanjing Expressway	-	Not Found
Runyang Bridge	Nanjing	2005
Junshan Yangtze River Bridge	-	2001
Nanjing Third Yangtze River Bridge	Nanjing	2005
Shanghai – Hangzhou High-speed Railway	-	2010
Dredging of navigational channel of GuangZhou Port	Guangzhou	Not Found

Lang Formation Project of Yangshan Deepwater Port	Shanghai	Not Found
Dredging of Yingkou Port	Yingkou	Not Found
Navigational Channel of Zhanjiang Port	Guangzhou	2005
Manmade Island of Jidong Oilfield	Bohai Bay	2006

Table 4.14 – China Communications Construction Company Key Projects Overseas [53]

Key Projects Overseas	Country	Year of Conclusion
Mombasa – Nairobi Railway	Kenya	Under Construction
Manmade Island of Macao International Airport	Macau	1995
Container berth project of Sudan Port	Suddan	Not Found
Repair of Tajikistan – Uzbekistan Highway	-	Under Construction
Addis Abada Ring Road	Ethiopia	2004
Hong Kong New Airport Platform	Hong Kong	Under Construction
Dry Dock of Malta	Malta	Not Found
Gwadar Deepwater Port in Pakistan	Pakistan	Under Construction
The Friendship Port of Mauritania	Mauritania	Under Construction

4.3.6. SHANGHAI CONSTRUCTION GROUP CORPORATE LTD.

Figure 4.31 – Shanghai Construction Group Corporate Ltd. Logo [54]

Table 4.15 – Shanghai Construction Group General Information [54]

Leadership	Government
Total Revenue (2013)	22.50 thousand million euros
Years in Business	50 years +
Headquarters	Shanghai

Shanghai Construction Group is a tier 1 construction company from China. The company integrates various fields of investment, construction and operation of urban infrastructure in the following areas: [54]

- High-rise buildings;
- Large Bridges;
- Light Railways;
- Public culture and sport facilities;
- Large Industrial plants;
- Major Environment Protection Projects.

Table 4.16 – Shanghai Construction Group Key Projects in Mainland China [54]

Key Projects in Mainland China	City	Year of Conclusion
Pudong International Airport	Shanghai	2015
National Grand Theater	Beijing	2008
Shanghai Center Tower	Shanghai	2015
Canton Tower	Guangzhou	2010
Dalian Greenland Center	Dalian	Under Construction
Shanghai World Financial Center	Shanghai	2008
Zifeng Tower	Nanjing	2010
Dalian International Trade Center	Dalian	Under Construction

Table 4.17 Shanghai Construction Group Key Projects Overseas [54]

Key Projects Overseas	Country	Year of Conclusion
Faleolo International Airport Terminal	Samoa	Under Construction
National Performance Center	Trinidad and Tobago	2009
Chinese General Consulate in New York	U.S.A	2003
Park East Condominium in New York	U.S.A	2007
SCG Plaza I in New York	U.S.A	2015
Galaxy Resort and Casino	Macau	2011
Pakistan-China Friendship Center	Pakistan	2010

5

CONSTRUCTION TECHNOLOGIES AND INDUSTRIAL HOUSING IN CHINESE CONSTRUCTION INDUSTRY

5.1. INTRODUCTION AND MOTIVATION TO CHINESE CONSTRUCTION TECHNOLOGIES STUDY

When searching through the immense construction scene of China different sets of construction traditions and technologies can be found. On the interview with the Architect Mr. Jorge Teixeira it was emphasized that in tier 1 and 2 cities modern techniques were applied, mostly on the construction of high-rise building, while on less developed provinces mud bricks are still widely used to answer construction demands. This creates the feeling that was presented before in this work that China's construction scene is so large that one cannot look at the industry as a whole.

This chapter accentuates the fact the country has a wide range of construction technologies being used with its aim at finding the best solutions on construction technologies on the country. Most of these comprehend particular findings of pure entrepreneurship that are in the forefront of the world's best construction technologies.

One of the biggest motivations for new construction technologies is the fast urbanization of the country, therefore in the last subchapter industrial housing systems are tackled and checked for suitability to answer China's housing needs.

5.2. THE PARTICULAR CASE OF BROAD SUSTAINABLE BUILDING CONSTRUCTION COMPANY

Broad Sustainable Building Construction Company (BSB) was established in March 2009 under the name BROAD SUSTAINABLE BUILDING CO., LTD which is a fully owned subsidiary of the BROAD Group. Established in the capital of the Hunan province, Changsha, Broad Group is focused on enhancing unique technologies with a clear sustainable vision of preserving and optimizing human life and the environment as a whole. The BROAD Group CEO, Zhang Yue was pointed one of the world's top 25 Eco-Innovators by Fortune magazine, for his vision that China's urbanization can be more sustainable. The Sky City project along with the energy efficient cooling system were the main factors that lead to the nomination. [55, 56]

The group provides services and products of different natures, all based on sustainability. These services include non-electric central air conditioning powered by natural gas as well as waste heat, which the

company claims to be 2 times more energy efficient than traditional central air conditioning. There is a branch focused on air quality alone, which supplies heat recovery, fresh air machines that filter 99% PM2.5, mobile air quality monitors, air purifiers and central air conditioning terminal products. [56] Fine particulate matter (PM2.5) is an air pollutant that is harmful for people's health when levels in the air are high, the standard for air quality in America is in for long-term exposure 15 micrograms of $PM_{2.5}$ per cubic meter of air. [57] Another branch focuses on energy services by providing CHP (cool-heating-power) operation services and promoting energy-efficient project designs. [56]

BROAD Sustainable Building Construction Company is, as seen above, part of a bigger picture. The Construction branch is aimed at providing factory-made sustainable buildings with groundbreaking and impressive technologies and methods. Many construction professionals and enthusiasts from the occidental world had their first contact with Chinese construction by watching the reality-defying videos of buildings being raised in record times using impressive pre-fabricated technologies. [56, 58] It is important to state that the technologies described in this chapter are outliers when considering the majority of construction projects and enterprises.

BSB is aiming to build the tallest building in the world. With 838m of height built in 7 months, the Sky City will be on the edge of innovation when it comes to the Chinese construction scene.

In a nutshell the main goals of BSB are [1]:

- To build with 90% pre-fabricated components;
- Be 5 times more energy efficient;
- Improve PM2.5 filtration up to 99%;
- No collapse under a 9 magnitude earthquake, in Richter scale;
- Material Saving;
- Reduce land area per capita

By Reading the BSB CEO interview with Mckinsey&Co, [55] the social intention of the Sky City clearly goes back to the architectural experiment and concept of Le Corbusieur, La Cité Radiseuse. In 1945, the French Minister for Urban Planning and Reconstruction, Raoul Dautry, proposed to Le Corbusier the project Unité D'Habitation. Le Corbusier worked alongside with Portuguese architect-painter Nadir Afonso for the creation of the Unité d'Hábitation of Marseille. [59] The architect accepted the proposal with the condition to be free from any regulation. Completed in the year of 1952 in the city of Marseille, France, the social purpose of this building was to, along with 337 apartments, to incorporate local retailing spaces, sport, medical and educational facilities, a hotel as well as a gastronomic restaurant. [59] Le Corbusier believed that the project was the solution for rehousing families that had been displaced during the Second World War, creating a high rise building with the intent to create spacious city homes with the same feeling of a typical street.

Figure 5.32 – La Maison Radieuse [60]

Without a negative background, the concept of the Sky City took this architectural philosophy even further, not only in size but in the construction methods applied.

In contemporary construction, when considering super skyscrapers, the expectation is that these particular constructions are both expensive and built for commercial use. Sky City is set to be different, with a pragmatic multi-use at a medium price and available to the middle class population. This creates a drastic cut in land area per capita, with the added benefit of sparing individual transports, which is set to reduce 20,000 cars in the city. [1]

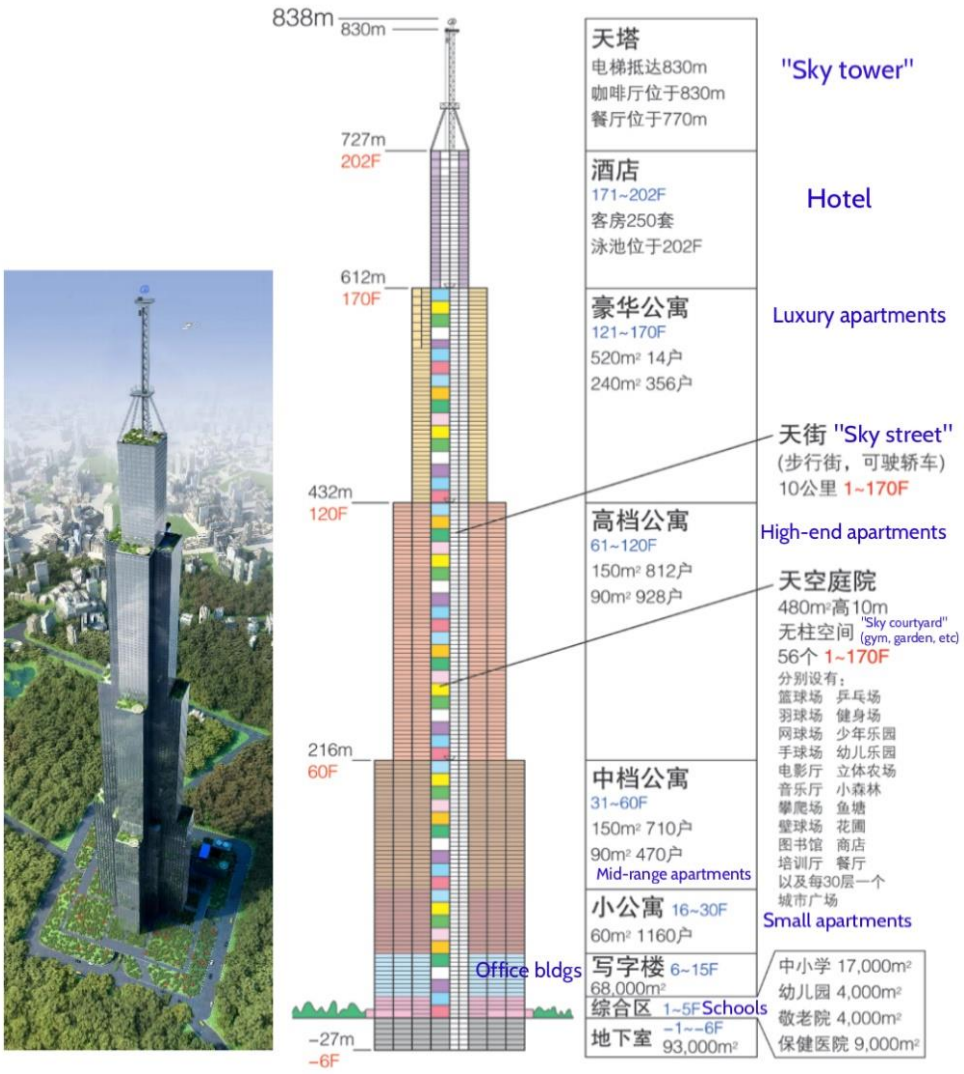

Figure 5.33 - Sky City Organization [1]

Table 5.1 – Sky City in Numbers [1]

Height	838 m
Lifts	93 (up to 830 m)
Building Area	1.05 million m^2
Facilities Area (School, Hospital, Office)	100,000 m^2
Residents	30,000
Hotel Rooms	250
$PM_{2.5}$ elimination	99%
Thermal insulation walls	20 cm
Apartments with 60 m^2	1160

Apartments with 90 m^2	1398
Apartments with more than 90 m2	1892

After foundation is laid, Sky City only needs 7 months to be completed, considering 4 months of factory work plus 3 months of local assembly. This is only possible with a modular assembly system, where 90% is factory made and only 10% relies on conventional construction work.

Flooring, ceiling, water supply, electricity supply and HVAC are fitted in a 60m^2 module. Walls, windows and doors are stacked on top of the module to be assembled later.

Figure 5.34 presents a truck where the two 60m^2 models are fitted, the metallic slabs are at the bottom of and on top of each the different components of each model, doors, windows, walls, sewage and water supplying pipes are stacked on top of each slab to ensure that the components are not lost in transportation. [1]

Figure 5.34 – Two 60m^2 modules on a truck [1]

Foundations are considered separately from the rest of the building. China Construction 5th Engineering Division will ensure that Foundation is complete in 6 months before the start of the assembly.

The building structure is made of steel. The choice of material is justified by the pre-fabrication method applied, and the longevity the material has. Even though in China there is no regulation or codes stipulating the grade of steel to use, BSB is importing steel from Luxembourg in order to assure further quality.

In terms of safety the building is designed to endure a Magnitude 9.0 earthquake. This protection is ensured by a symmetrical pyramidal structure where all steel columns are wrapped in ceramic fiberboard with a minimum of 4 hour fire retardation.

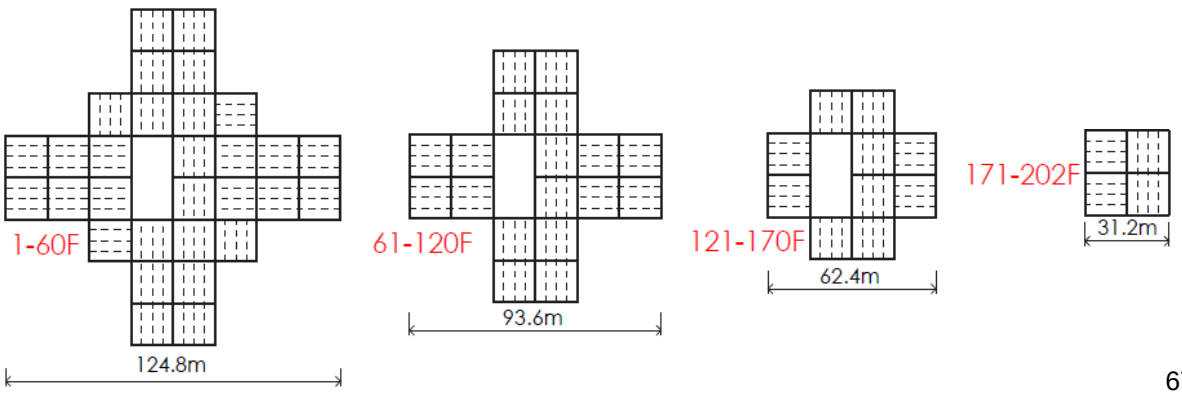

Figure 5.35 – Floor Distribution of Sky City [1]

On Figure 5.35 the floor distribution of Sky City is comprised showing the symmetry that the building requires. The clear are on Figure 5.35 up to the 170 floor is a walking street that exists in order to develop a sense of city and community to the project.

China is a country that expects a growing urban population for several decades to come. Changing the concept through which cities are developed is needed. BROAD Sustainable Building Corporation is clearly a top player that strives to take Chinese urbanization, minimizing land usage and urban environmental pollution.

5.3. TOP LEVEL TECHNOLOGIES THROUGHOUT CHINESE CONSTRUCTION INDUSTRY

Being a country that is striving to change the world's perception from "made in China" to "created in China" the effort shown by Chinese construction entrepreneurs is crucial but it needs to be backed and enhanced by a clear effort from the Government. The cases shown in this chapter show the force of the entrepreneurial net in China but are not the norm nor ordinary throughout the country.

5.3.1. 3D Printed Houses by Winsun Decoration Design Engineering Co.

Winsun is a company devoted to change the way the general public perceives construction. This company is highly engaged with research and development while maintaining successful market applicability in a forward thinking area. Winsum is considered to be the world's first company to print houses, holding a total of 98 national patents for new construction materials and counting with the world's biggest 3D house printer (150(L) x 10(W) x 6.6(H) m). [3]

Figure 5.36 – 3D Printed Construction Details [3]

Figure 5.37 – 3D Printer by Win Sun [3]

In order to enhance the use of recycled construction waste, the Winsun team created an innovative printing "ink" that uses a mixture of Recycled construction waste, glass fiber, steel, cement and other additives. WinSun expects that the use of recycled construction waste will dramatically cut cost for construction companies to build while maintaining sustainability.

The printer uses CAD design templates so that the computer controls a mechanical extruder arm to lay down concrete. The mechanical arm carefully spills the mixture layer by layer, which are treated with special hardeners to ensure that each layer is strong enough to support the next one. The pieces that derive from the printer are joined together on the construction side. The printing can also take into account the several installations that are needed such as insulation materials, plumbing, electrical linins and windows.

On 2014 the company printed 10 houses, each measuring 200 square meters. In January 2015 the company presented their new product line, a 5-storey residential house and a villa, both to be the first of their kind, proving that 3D printed houses are a reality with demonstrated success. [3]

Figure 5.38 – The First 3D printed 5 storey building and Villa by WinSun [3]

Winsun has caught the attention of foreign investors and it is now in a promising joint venture with an American company, developing a new 3D printer for Egypt in order to establish 12 Factories in the desert.

5.3.2. INTELLIGENT EXTERNAL RESPIRATORY DOUBLE SKIN CURTAIN WALL

In order to explain the Intelligent External Respiratory Double Skin Facade, it is important to first explain the concept of Double Skin Facade. Historically the Double Skin Facade was explored and tested by the Swiss-French architect Le Corbusier, but not until 1980's any commercial and big scale buildings were made using this technology. This system is acclaimed for being a sustainable and "green" technology that, due to its high cost, is mostly used in high profile buildings, where consultants are hired and a sustainable profile is needed. [61]

The technology in question sits on the idea that exterior walls respond dynamically when ambient conditions vary, making it possible to incorporate several integrated systems, including sun-shading, natural ventilations, thermal insulation and acoustic insulation. The interior layer acts as insulation, leaving the air corridor in the middle of the layers of glass to act as insulation against temperature variation, wind and sound. [61]

Examples of the Double skin Facade system are seen in famous buildings throughout Europe, with examples like the 30 St Mary Axe (The Gherkin) in London, by Foster + Partners and the One Angel Square Building in Manchester.

Figure 5.39 – 30 St. Mary Axe by Foster + Partners [62]

Figure 5.40 – One Angel Square Construction [63]

The Intelligent External Respiratory Double Skin Facade is a Chinese innovation which comes as an extent of the original Double Skin Curtain Wall. Based on a system that controls matching technologies of the building, such as warming and cooling and electricity, combined with the effective utilization of the curtain wall and solar energy, the intelligent curtain wall efficiently regulates indoor air, temperature and light through a software that integrates all the components and manages the different systems. [64]

The wall consists of the following parts: [65]

- Double skin curtain wall;
- Ventilation system;
- Sun-shading system;
- Air conditioning system;
- Environmental monitoring system;
- Intelligent control system (Key Component).

The intelligent control system is the key component of the Intelligent External Respiratory Double Skin Facade, the system gathers information from the different systems to control the different modes and command the transmission mechanism. Multiples factors are taken into account including the measurement of: [65]

- Weather;
- Temperature;
- Humidity;
- Air freshness;
- Luminous intensity;
- Data from the operation of heating;
- Data from the operation of ventilation;
- Data from the operation of air conditioning;
- Data from the operation of the sun shading system.

5.3.3. China State Construction Modular Building

One company with enough power and drive to enforce modular housing in China is certainly China State Construction Engineering Corporation. Stated as the biggest contractor in the world on subchapter 4.3.2. the company endures projects that require levels of quality and efficiency that no other contractor in China endure.

During the visit to MIECF in Macau the booth of China State Construction showcased the modular housing system that the company is implementing on its projects.

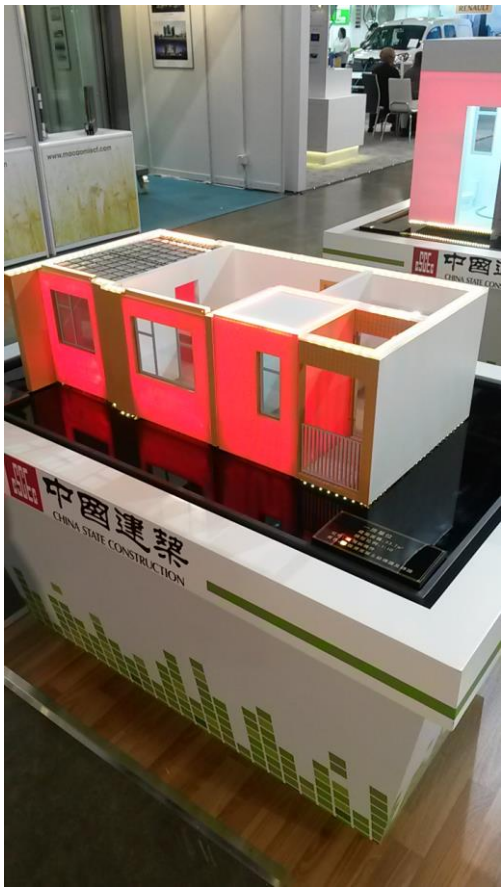

Figure 5.10 – China State Construction Modular Housing Example 1

Figure 5.11 – China State Construction Modular Housing Example 2

On figure 11 it is shown an example of the apartment the company is building with modular technologies. The components highlighted in red are all fabricated offsite and only after assembled onsite. The prefabricated elements are non-structural walls and complete bathroom compartments that aim to reduce time and cost of these elements.

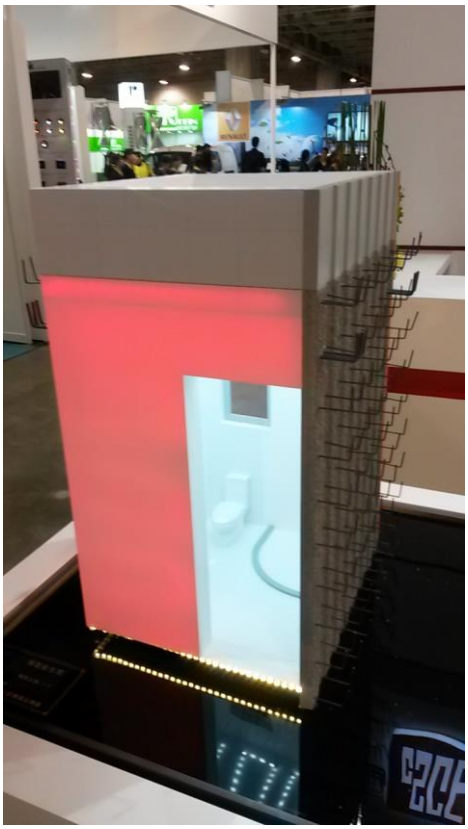

Figure 5.12 – China State Construction Modular Housing Example 3

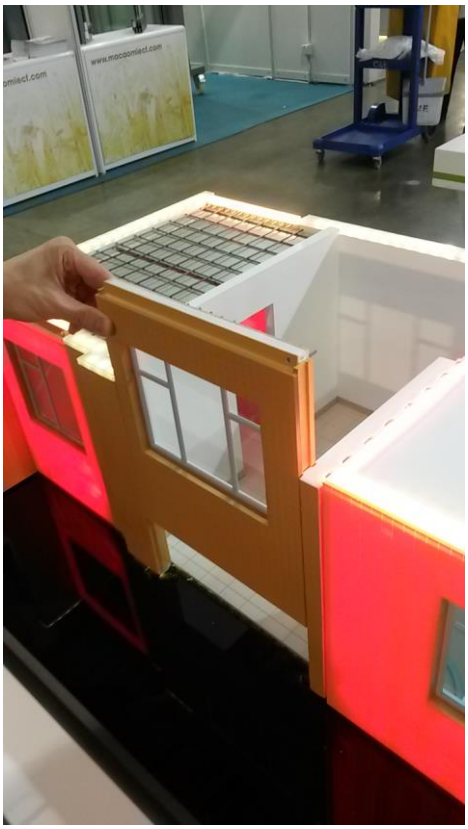

Figure 5.13 – China State Construction Modular Housing Example 4

Figure 5.41 – China State Construction Modular Housing Example 5

For the biggest contractor in the world, prefabrication at a structural level is representative both of the difficulty of applying integrated modular systems to all components of a building and the inability of the top Chinese contractors to answer to the great demand and expectation for this technology.

5.4. INDUSTRIALIZED BUILDING SYSTEMS IN CHINA

Industrialized building is first of all a concept of building that can incorporate different systems and technologies with the common objective of having more planned, standardized, optimized and simplified construction process. The concept can incorporate the assembly of a building considering factory produced components, structural and non-structural, application of systematized methods of design, production planning and control. In industrialized building manufacturing processes and supply chains are of upmost importance, both of these concepts win with standardization and simplification of the processes.

Being a general concept, different variations come along with industrialized building, considering prefabrication building, modular housing, supply management, lean construction, scheduling and standardization of processes. [66]

The United Nations defined industrialized building as "a continuity of production implying a steady flow of demand; standardization; integration of the different stages of the whole production process; a high degree of organization of work; mechanization to replace manual labor wherever possible; research and experimentation integrated with production." [67]

As industrialized building comes along with the concept of prefabrication, the United Nations defined this concept as "the transfer of saving propositions of the operations of manufacture from the building site to factories or workshops, which may be independent of the site or associated with it" [67]

The industrialized building system has a set of main features: [68]

- Most building elements are prefabricated offsite;
- Large prefabricated assemblies, where various works are incorporated with minimum work onsite;
- Mechanized onsite work, considering most materials and component handling;
- Planning and coordination of design, production and onsite erection, considering all of these part of an integrated process;
- Automation on assembly and processes in order to reduce human involvement, improve quality and minimize errors.

As Tam et al. [69] cited, as prefabrication is one of the main features in industrialized housing, it can have various forms. There is a classification considering different models of prefabrication:

- Semi-prefabricated non-structural elements, such as windows, ceiling, facades, and partition walls;
- Comprehensive prefabricated units containing structural prefabricated elements, such as columns, beams, floor or roof sheathing, slabs, load-bearing walls, and staircases, most of which are completed in the factory prior to assembly;
- Modular buildings that are wholly completed offsite as a one-stop system.

5.4.1. INDUSTRIALIZED BUILDING IN CHINA OVERVIEW

An example of industrialized building in China is the project T30 Tower Hotel (amongst other successful projects) conducted by BROAD Sustainable Building Company. This hotel has 30 stories as well as a helicopter pad, which took only 15 days to be assembled on-site. Foundations were finished within 40 days, time by which most components were already finished.

Although the case of the T30 Tower Hotel and the creation of projects like the Sky City are impressive cases, they are not the norm in China's construction industry. Prefabrication systems have not been widely used by Chinese builders, especially in the field of high-rise residential buildings. One of the top real estate companies, Vanke Real Estate Company, conducted one of the first experiments of high-rise residential building with the Xinlicheng Project in Shanghai. The concept of Prefabrication used was towards Semi Prefabrication with non-structural external walls, precast stairs and balconies and other precast components. [70]

As referred in the interview with Architect Jorge Teixeira, China's construction industry still relies mostly on traditional methods of construction. The main advantage of China's construction industry is the capacity of organization and the respect to the hierarchy that creates the possibility for fast development and implementation of industrialized methods.

It is obvious to consider importing technology from developed countries to progress industrial building in China. This possibility doesn't come easy as there are obvious problems from importing industrialized building systems. Either because of economic and social benefits or environmental issues regarding local conditions, the approach of importing industrialized building methods results in expensive and inappropriate constructions. Development in China, for the most companies and projects is going toward two streams, prefabrication of small-middle components and partial prefabrication. [71]

5.4.2. PEOPLE'S REPUBLIC OF CHINA INCENTIVES TO BUILDING INDUSTRIALIZATION AND DEVELOPMENT OF SMART CITIES

Since the house booming in China began, the Government has proposed innovative strategies to tackle the problem of poor construction quality as well as the waste and environment affect the traditional methods have on the Chinese population and quality of living. The way to do so were the above mentioned Five-Year Plans created by the Chinese Government. [72]

The 12th Five-Year Plan, between 2011 and 2015, released a statement on Green Building and Ecological Urban Community development in China, where particular emphasis was placed on promoting the construction industry to embrace prefabrication technologies in order to improve efficiency, higher quality and better environmental performance. As no actual and practical policies were implemented thus far, the government's initiatives to promote off-site innovation lagged behind expectations and were only validated by a small number of companies and projects. [72]

Citing Don Johnson, "The most far reaching effort, however, is led by the Ministry of Housing and Urban and Rural Development (MOHURD). Last year, MOHURD selected 193 local governments and economic development zones as official smart city pilot project sites, making them eligible for funding from a ¥100 billion (14.5 thousand million euros) investment fund sponsored by the official China Development Bank. Investment from local government and private sources has also been growing fast: There's no standard definition of the sector, but some estimates foresee ¥2 trillion (290 thousand million euros) of investment into smart city development projects over the next 10 years." [73]

The citation above shows the compromise that Chinese Government is making with enhancing cities that have a base to enhance a sustainable quality of life to its inhabitants. This happening and the

subsequent flood of new projects will represent a challenge to the MOHURD in order to discriminate the projects to embrace and encourage.

5.4.3. Main events in Mainland China enhancing industrialized building

In China a great amount of value and innovation is found on fairs and other events alike that focus not only on showing the development of R&D in China but in finding foreign technologies and companies that can add value to the Chinese path on Industrialized Building. A list is provided with the annual events of interest. Dates are provided as reference as the day and month traditionally stay the same from year to year.

Table 5.2 – Main events for Industrialized Building in China [74]

Event	City	Reference Date
PMMHF 2015 - The 5th China Prefab House, Modular Building, Mobile House & Space Fair	Guangzhou	05/09 - 05/11
IEHI 2015 - The 14th China International Exposition of Housing Industry & Products and Equipment's of Building Industrialization	Beijing	09/09 - 09/11
ICSCE 2015 - 2015 International Conference on Sustainable Civil Engineering	Chengdu	09/19 - 09/20
BICES 2015 - The 13th Beijing International Construction Machinery Exhibition & Seminar	Beijing	09/22 - 09/25
BIC 2015 - 2015 Shanghai International Building Industrialization Exhibition	Shanghai	11/04 - 11/06
Shanghai International Integrated Building & Light Steel Housing Expo 2013	Shanghai	08/15 - 08/17
2015 Smart City China Expo & Congress	Shanghai	11/04 – 11/07
SIBT 2015 - Shanghai Intelligent Building Technology 2015	Shanghai	09/23 - 09/25

5.4.4. Challenges and Recommendations to Industrialized Building in China

When considering the application of industrialized building systems in China, many factors must be taken into account. The challenges detailed here refer to challenges that Mainland China, from the least developed regions to tier 1 cities, may face when applying these methodologies.

Importing industrialized building technologies from overseas

A strategy is the approach of directly importing industrialized housing technologies from developed countries which may involve challenges due to the differences that separate those countries. It is clear that when introducing industrialized housing technologies in developing countries there should be considerations to the characteristics of the following natures:

- Technological;
- Social;
- Economical;
- Political.

The characteristics mentioned to be taken in consideration will ensure a system that can meet the local demands. [71]

Constructability of industrialized building technologies in Chinese context

Constructability by definition is the understanding and opportunity to apply integration of construction knowledge and experience in planning, engineering, procurement and operations in the building process with the agreement of the various projects and environmental constraints. Chinese construction practitioners have several challenges; starting with the ‘design-bid-build” approach referred above in this dissertation. The constructability of industrialized building projects requires a high level of communication, coordination and integration through all the construction chain, from developers to builders. In favor of the Chinese construction is the adaptability that the companies show to new projects and the fast adaptability of companies. [75]

Architectural performance challenges

In general, for industrialized building technologies to be implemented it is necessary a design based on standardized, repetitive and modularized designs. Until now, studies made with Chinese practitioners show that the architectural considerations linked to industrialized construction were not fully understood and therefore the advantages attached were not noted. [75] In order to have industrialized construction as the norm practitioners need to understand the benefits on the long-term and be aware of the initial effort as a necessity for more sustainable housing.

Noting the cost efficiency gains of industrialized construction

Industrialized construction related costs are referenced to have higher initial costs, higher capital costs and a longer capital payback period. These economic parameters usually are seen with importance when it comes to decide which process to select for a building construction. As most of the economic benefits by industrialized construction are associated with labor, time, material and maintenance savings the level of awareness of the Chinese builders to these issues takes an important role. The amazing manufacturing capacity and low cost of labor work both in favor and against industrialized building. [75]

Supply chain considerations

The network of parties involved in the different processes and activities, through upstream and downstream linkages, adding value in form of products, resources or services to a certain costumer, is one of the most practical challenges that a building project faces. Therefore management of the supply chain relies mostly at three levels, cooperation, coordination and collaboration between parties. In China, traditionally, integration and coordination in construction industry have arguably very poor standards, examples of disjointed relations between architects and contractors, contractors and manufacturers, homebuyers and developers are the normal in Chinese construction industry.

Traditionally, Chinese culture has a good sense and understanding of hierarchy that occidental cultures struggle to understand and follow. Thus the large number of parties involved in construction may benefit from diagrams that explain how they shall react to different situations and a guide to good practices on supply chain management. [75]

Final considerations

Learning from and encouraging Chinese companies that are contributing towards industrialization processes, most of them focused on prefabrication methodologies, is a must for the success of a sustainable urban growth. A thoughtful separation from the Ministry of Housing and Urban and Rural Development on which projects are of value and which are of no value to the industry will be essential in the next years where so much economical effort will be put in the development of smart cities where industrialized building is included.

In sum, the residential industrialization launched by China government will make possible the correct development of industrialized building, mainly towards prefabrication. This will be possible if research institutes and enterprises continue to increase both investment and effort on the evolution of industrialized housing technologies. [71]

6
CLOSURE AND CONCLUSION

The objectives of this thesis are illustrated on the subchapter 1.2 and aim to set a base for the development of the work in consideration.

When developing a conclusion for this work opinions from the researchers and construction professionals are covered as well as my own opinions on the Chinese construction industry and civil engineering education.

Composing the Roadbook of a 3 weeks trip to China inserted on a business environment lead to understanding both the Chinese construction industry and the way business is developed in the country which can be of the utmost interest for professionals of the construction industry that have an interest in the country. The expectation of expanding internationally for the first time, either as an individual or a company, can lead to several mistakes and errors that can cost the entire effort of internationalization.

That being said, first it is important to perceive the cultural diversities and understand that working in a Chinese environment shall lead to changes both in management and behavior. Example of the conception of "lose the face" and the perception of building relationships are important for anyone considering working in China. It is recommended that either the first time is guided by an experienced professional or it is performed a deep study of the China's economic and cultural profile.

An important factor is the gateway that both Macau SAR and Hong Kong SAR represent for occidental professionals to enter the market. Focusing on Portugal, Macau still has a strong Portuguese influence with opportunities for both sides and can serve as the entry to the mainland China market.

The feeling caught on the construction sites that were visited was that there are few buildings being rose with less than 30 stories in the cities visited at the moment. This is a statement that comes alone from my experience at the country and of the cities I've visited which comes in line with the brutal urbanization of the country. One of the cities the I've seen more building being rose was Xi'an where for the 20 km of highway between the airport and the city the scenery was flooded with new construction all around.

In terms of education the clear first result of the research carried is the care for general education that is given at most universities at the undergraduate level. Subjects such as political theory and physics education are the norm at the universities considered in the Mainland China. The quality and hours spent studying the subject compared, concrete structures, that is one of the core subjects in civil engineering did not fall far behind the reality at FEUP. In terms of specialization and diversification of subjects no other university comprised in this work had such a broad number of specialization compared to FEUP which is key for students that may be interested in different areas of civil engineering.

Cooperation agreements between FEUP and the Universities considered in this study may be of importance to elevate the sheer purpose of this study that is to understand differences between cultures and understand how construction in China is developed.

It is of notice that the conclusion of this study about education in China comprised only the universities considered to be the top in the Country, the universe that goes beyond this study, in terms of education, is not questioned.

The Chinese Construction Market where a view of the economic outlines was shaped and the biggest contractors were pointed gave rise to a conclusion that the government is an intrusive player. The policies chosen in the 5 Year Plans create the base for development in the Country and the level of control of the companies, where the biggest contractors have all public investment, is a serious issue that leads to a control of the market. This theme may be of controversy if we're pointing the positive and negative aspects of the government inclusion on the market but some points are clear. Urbanization, enhanced by the government, is a coin of two sides as it vanishes population cultural aspects which are not to be taken lightly but ultimately continues to create the economic buzz that has been seen in the las years. China is now growing at a not so impressive level and the measure to keep that growth for the years to come may lead to not desired consequences like the disappearance of cultural identity. In sum, urbanization will continue with 160 million people being driven to urban areas until 2025 which will create opportunities for construction professionals from around the world. The creation of the Asian Infrastructure Bank, highly enhanced by the Chinese government is a way to buzz Chinese construction market where great infrastructures projects are set for the long-term, which will fall on the same contractor stated in this work if the liberalization of the market is not well regularized.

One of the objectives of this thesis was to find construction technologies that were used in the Chinese construction industry. Before the research the perspective was that for such a great amount of high rise buildings being constructed there would need to be advanced technologies to back the fast urbanization of the country. The findings did not lead to that conclusion, it is true that there are advanced and top of the line findings both in terms of technology and planning but they are what we can call a drop in the ocean that are mainly driven by entrepreneurs that strive to take construction to the next level.

The conclusion on the construction technologies used in China leads also to an understanding that the country is so immense that a profile can be made where technology is completely behind any notion of industrialization in some areas while in others, tier 1 and 2 cities, are well developed and in line with the most developed areas of the world.

In general terms, we can speak of a disruption between the occidental and oriental reality. The differences are craved in the construction industry and go from cultural levels to the consideration of cutting edge technologies. That being said, the years to come will be of opportunities for both the occidental and oriental world, where China plays the leading role in construction. Considering the enhancing of globalization and the desire of China to import know-how from countries considered to be more developed the construction boom may be backed with sustainability and an economic growth that comprises more equality for the population.

BIBLIOGRAPHIC REFERENCES

1. Broad, *Why Sky City?* 2013.
2. Corporation, C.R.C. *http://english.crcc.cn/*. [cited 2015 28/07/2015].
3. Winsun. *http://www.yhbm.com/index.php?m=content&c=index&a=lists&catid=77*. 2015 [cited 2015 15/07/2015].
4. Mckinsey&Company. *http://www.mckinsey.com/insights/urbanization/urban_world_cities_and_the_rise_of_the_consuming_class*. 2012 [cited 2015.
5. MIECF. *http://www.macaomiecf.com/miecf2015/en/general-information/about-miecf*. 2015 [cited 2015 27/06/2015].
6. Government-Macau. *http://www.gcs.gov.mo/*. 2015 [cited 2015.
7. Monteiro, A.N., *Macau e a presença portuguesa seiscentista no Mar da China. Interesses e estratégias de sobrevivência.* 2012.
8. Chung, P.I., *Feasibility Study of Grading System for Contractors and Construction Companies in Macau*. 2010, University of Macau.
9. Forbes. *http://www.forbes.com/sites/greatspeculations/2015/01/07/trends-in-the-casino-industry-a-shift-from-the-las-vegas-strip-to-east-asia/*. 2015 07/21/2015].
10. Statista. *Gross revenue from gaming and gambling in Macau from 2007 to 2014*. 2014 07/21/2015].
11. New-York-Times. *http://www.nytimes.com/2014/03/26/business/international/macau-rides-high-on-new-round-of-casino-construction.html*. 2014 [cited 2015.
12. Government, C. *http://www.gov.cn/test/2005-05/24/content_18247.htm*. 2013 07/21/2015].
13. Citypopulation.de. *http://www.citypopulation.de/php/china-guangdong-admin.php*. 2010 [cited 2015.
14. Bouygues. *http://bouygues-construction.com.au/project/hong-kong-zhuhai-macao-bridge/*. 2015 [cited 2015.
15. Weidmann, D. *http://www.qualitative-research.net/index.php/fqs/article/viewArticle/915/1998*. 2001 [cited 2015.
16. Citypopulation.de. *http://www.citypopulation.de/php/china-admin.php?adm2id=6101*. 2010 [cited 2015.
17. Economist, T., *Supersized Cities China's 13 megalopolises a report from the Economist Intelligence Unit.* 2012.
18. -Department, H.-K.-B., *guidelines on the design and construction of bamboo scaffolds* 2006, Hong Kong Building Department.
19. citypopulation.de. *http://www.citypopulation.de/php/china-admin.php?adm2id=5301*. 2010 [cited 2015.
20. airport-technology.com. *http://www.airport-technology.com/projects/kunming-changshui-international-airport/*. 2012 [cited 2015.
21. Government, H.K., *Regional Flag and Regional Embleme Ordinance*. 1997.
22. Government-Hong-Kong. *http://www.censtatd.gov.hk/hkstat/sub/bbs.jsp*. 2015 [cited 2015.
23. Government-Hong-Kong. *http://www.policyaddress.gov.hk/10-11/eng/pdf/projects.pdf*. 2007 [cited 2015.
24. World-Bank. *http://data.worldbank.org/indicator/SE.XPD.TOTL.GD.ZS* 2015 [cited 2015.

25. Chanieducenter. *http://www.chinaeducenter.com/en/cedu/psedu.php*. 2015 [cited 2015.
26. Government, P.s.R.o.C., *http://www.china.org.cn/government/laws/2007-04/17/content_1207402.htm*. 1986: china.org.cn.
27. Lin, J., *The difference between Western and Eastern education - Education system in need of change?* 2008.
28. Economist, T. *http://www.economist.com/blogs/analects/2012/06/university-entrance-exams%20*. 2012 [cited 2015.
29. Goldstick, W., *The Gaokao Examination: A Shadow behind China's educational system.* S. l.: Nanjing University, 2010.
30. ChinaDaily. *http://www.chinadaily.com.cn/china/2014-06/04/content_17562178_2.htm*. 2013 [cited 2015.
31. Statista, *Number of Universities in China between 2003 and 2013*. 2014: http://www.statista.com/statistics/226982/number-of-universities-in-china/.
32. Statista, *Number of University Graduates in China between 2003 and 2013 (in thousands)*. 2014: http://www.statista.com/statistics/227272/number-of-university-graduates-in-china/.
33. China, N.B.o.S.o., *National Bureau of Statistics of China*. 2015: http://data.stats.gov.cn/english/easyquery.htm?cn=C01.
34. PORDATA, *Alunos matriculados no ensino superior: total e por sexo - Portugal*. 2015: http://www.pordata.pt/Portugal/Alunos+matriculados+no+ensino+superior+total+e+por+sexo-1048.
35. OECD, *Population Demography*. 2015: https://data.oecd.org/pop/population.htm.
36. Shulian, W. *Top 10 Universities for engineering study in China*. 2013 20/07/2015].
37. Reuteurs. *The World University Rankings*. 2015 [cited 2015 20/07/2015].
38. University, Z. *Zhejiang University*. 2015 [cited 2015 22/07/2015].
39. Technology, D.U.o. *Dalian University of Technology*. 2015 [cited 2015 2/07/2015].
40. University, T. *Tsinghua University*. 2015 [cited 2015 22/07/2015].
41. University, S.C. *South China University* 2015 [cited 2015 22/07/2015].
42. Macau, U.o. *University of Macau*. 2015 [cited 2015 22/07/2015].
43. Technology, H.K.U.o.S.a. *Hong Kong University of Science and Technology*. 2015 [cited 2015 22/07/2015].
44. Porto, F.o.E.o.t.U.o. *Faculty of Engineering of the University of Porto*. 2015 [cited 2015 22/07/2015].
45. Porto, U.d. *Universidade do Porto*. 2015 [cited 2015 22/07/2015].
46. Knoema, *China GDP Growth Forecast 2015-2020 and up to 2060, Data and Charts*. 2015: http://pt.knoema.com/loqqwx/china-gdp-growth-forecast-2015-2020-and-up-to-2060-data-and-charts.
47. Unit, E.I., *Building Rome in a day: The sustainability* 20155.
48. Statista, *Total Revenue World's Top Contractors 2013* 2013: http://www.statista.com/statistics/279942/the-largest-construction-contractors-worldwide-based-on-total-revenue/.
49. Quartz. *African cities are starting to look eerily like Chinese ones*. [cited 2015 20/08/2015].
50. Michiel Hulshof, D.R., *Facing East.* more-architecture, 2015.
51. Ltd., C.S.C.E.C. *http://english.cscec.com/*. 2015 [cited 2015 22/07/2015].
52. Ltd., C.R.G. *http://www.crecg.com/tabid/173/default.aspx*. [cited 2015 25/07/2015].

53. Ltd., C.C.C.C. *http://en.ccccltd.cn/*. 2015 [cited 2015 22/07/2015].
54. Ltd., S.C.G.C. *http://www.scg.com.cn/en/index.html*. 2015 [cited 2015 25/07/2015].
55. Yue, Z., *Rethinking Conventional Construction*, M. Company, Editor. 2014.
56. Broad. *http://en.broad.com/*. 2013 21/07/2015].
57. State, D.o.H.o.t.N.Y. *https://www.health.ny.gov/environmental/indoors/air/pmq_a.htm*. 2011 [cited 2015 10/06/2015].
58. Alter, L., *A Close Look at Broad Sustainable Building's PreFab Hotels.* 2013.
59. Corbusier, F.L. *http://www.fondationlecorbusier.fr/corbuweb/morpheus.aspx?sysId=13&IrisObjectId=5234&sysLanguage=en-en&itemPos=58&itemCount=78&sysParentId=64&sysParentName=home*. 2015 [cited 2015 08/07/2015].
60. Buczek, M. *http://www.mariabuszek.com/ucd/ModernDesign/Exam2_gallery3.htm*. [cited 2015 20/07/2015].
61. al., T.M.B.e., *Understanding the General principles of the Double Skin Facade System.* 2003.
62. Homedit. *http://www.homedit.com/london-gherkin-an-unusual-eggshaped-building/*. 2010 [cited 2015 28/07/2015].
63. Commons, W. *https://commons.wikimedia.org/wiki/File:Co-op_Building_construction_7_Dec_2011.jpg*. 2011 [cited 2015 20/05/2015].
64. Qingdao AEON Glass Co., L.-. *http://aeonglass.en.made-in-china.com/product/kXtnoOWbLhce/China-Innovative-Facade-Design-and-Engineering-Intelligent-Respiratory-Double-Skin-Glass-Curtain-Wall.html*. 2015 [cited 2015 13/06/2015].
65. Jangho. *http://en.jangho.com/html/chanpinyujishu/jianzhumuqiang/2013/0304/28.html*. 2012 [cited 2015 13/06/2015].
66. Zhang, X. and M. Skitmore, *Industrialized housing in China: a coin with two sides.* International Journal of Strategic Property Management, 2012. **16**(2): p. 143-157.
67. Dietz, A.G.H. and L.S. Cutler, *Industrialized building systems for housing*. 1971: MIT Press.
68. Arif, M. and C. Egbu, *Making a case for offsite construction in China.* Engineering, Construction and Architectural Management, 2010. **17**(6): p. 536-548.
69. Tam, V.W.Y., et al., *Towards adoption of prefabrication in construction.* Building and Environment, 2007. **42**(10): p. 3642-3654.
70. Liu, Z. and H. Ying. *Prefabrication construction in residential building of Vanke real estate company China*. in *Management and Service Science, 2009. MASS'09. International Conference on*. 2009. IEEE.
71. Pan, Y.-h., *Application of industrialized housing system in major cities in China: a case study of Chongqing*. 2007, The Hong Kong Polytechnic University.
72. Zhai, X., R. Reed, and A. Mills, *Embracing off-site innovation in construction in China to enhance a sustainable built environment in urban housing.* International Journal of Construction Management, 2014. **14**(3): p. 123-133.
73. Johnson, D., *http://www.chinabusinessreview.com/smart-city-development-in-china/.* 2014.
74. ChinaExhibition. *http://www.chinaexhibition.com/trade_events/list-0-82-0-Building_Construction.html*. 2015.
75. Zhai, X., R. Reed, and A. Mills, *Factors impeding the offsite production of housing construction in China: an investigation of current practice.* Construction Management and Economics, 2014. **32**(1-2): p. 40-52.