DETERMINANT of SKYSCRAPER

HEIGHT

P5 REPORT

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Preface

This is a master thesis under the Graduation Laboratory of Management in the Built Environment in TU Delft, with the theme of real estate management. The process of real estate development connects to different aspects, including urban economic, stakeholders, and many others, which is a complicated system. This research chooses to focus on skyscrapers, which narrow down the scope and increase the possibility to understand the topic more.

Skyscraper is a building typology that provides a large amount of supply of space to a location. It connected to the urban development and capacity of a city to house population and companies. And height is one of the major features that provide the characteristic of a skyscraper. Thus understanding height determinant of a skyscraper could provide an understanding of the construction decision process of these buildings, also tell us if these building affected city skyline and if they are constructed efficiently.

In my own perspective, city increase in urbanization rate, more skyscrapers are constructed around the world. I live in Asia for most of my life and seen many skyscrapers constructed in the past ten years. City skyline started to be determined by these tall structures. Amount of skyscraper in cities grows rapidly and become a building typology that you are surrounded by. Currently there is an increase in skyscraper construction around Asia, but there is not much study done on the relationship of skyscraper with city urban development, thus this research focuses on study of skyscraper development, to provide more empirical evidence that could be used to understand the previous development, and could be used to improve future skyscraper development.

The result of this research found a strong relationship of skyscraper height with function, construction material, design aspect, also spotted distribution pattern of skyscrapers across China. This research also has proven again the connection between skyscraper construction and economic status of the location. There are also some interesting finding regarding height competition and buildings efficiency. Most buildings in China are constructed around 200 meters, which suggested that these are constructed according to the demand for space rather than competition. This topic is an emerging field, I believe that there are more to study, but this research also provided new findings regarding skyscraper development.

I received a lot of help throughout the process, especially from my mentors, Ilir Nase, and Peter DeJong. They widen up my understanding of the topic and suggested all different perspective that I could look into the topic. They also answer all of the questions I have regarding statistical analysis and research possibilities. Through the process, I started with minimal understanding towards statistic into able to understand regression analysis results. I would like to thank them for all the help and support they provided throughout the process.

Tzu-wen Chiang
Delft, June 24

Executive Summary

This research aims to investigate the height pattern and height determinant factors of Chinese skyscrapers. A skyscraper is a habitable structure that is taller than 150 meters, with more than 50 percent of the space occupiable (CTBUH, 2019). It is a widely used building typology around the world, especially in countries and areas with rapid economic growth. This is due to the ability of skyscrapers to accommodate a large amount of the population and activities in a single location, where it is also an efficient building design for areas with high demand in land, and locations with high land prices. Building tall is one of the characteristics of a skyscraper, and Height could be used as a tool to allocate city population and improve city efficiency. Thus Skyscraper distribution and height pattern is important to understand for city development

Problem statement

With urbanization and efficient building technology, cities grow rapidly in size and density. To accommodate the population, many cities, especially in developing countries start the construction of high rise building for both commercial and residential uses. A skyscraper boom has occurred in China in the past twenty years, the amount of buildings keeps on rising and the height continuously increases. Due to the unique characteristics of skyscrapers, it could bring major changes to the city context. However, researches on construction decision making of skyscrapers is an emerging field. Especially with the focus on China, many questions related to height pattern and height determinants remain unanswered. This study may give us a better understanding of the reasons behind the construction of these skyscrapers in China and find out the main trigger that leads to the continued construction of taller buildings. The aim is also to provide a statistical base for municipalities to set up further development plans.

Research Question

Based on the problem statements, the research question and sub-questions are listed as follows:

"What are the height determinants of Chinese skyscrapers and to what extent do these height determinant factors affect Chinese skyscraper height patterns?"

Sub-questions

- How does the height pattern of skyscrapers above 200 meters vary across China?
- What is the factor that causes the specific height pattern across the country?
- To what extent does each height determinant factor affect the height pattern of skyscrapers in China?

Research Scope

The research focuses on skyscrapers above two hundred meters that are completed in China, excluding Hong Kong and Macau due to the different political system. With a timeframe from 1990, when the first building over two hundred meters have been built in Guangdong until 2017 (CTBUH, 2019).

Research Method

The research process is divided into five steps. Step one looks into previous studies on a related topic to define theories that stated potential height determinant factors. These factors could be classified into four major aspects, including urban development, economical aspect, Design, and construction aspect and competition aspects. The four major topics are classified into city level and building level height determinants factors. Building level factors are factors that affect the urban space as a whole, including demographic changes, city economic situation, and city development direction. Building level factors are based on the decision making process of each building, including the choice of material, building shape and personal perspective of the designer.

Step two identifies variables that could be used to measure and represent each aspect listed in the previous paragraph. Step three collect data from the available source, in this case, CTBUH for data related to skyscraper development, and NBS for statistical data related to cities in China. After obtaining a database of selected variables, an overview of the data distribution will be provided to answer the first research question "How do height pattern of skyscraper varies across China". Regression analysis performed using the database would provide an understanding of the relationship between variables and height, which will answer the second research question on "what are the factor that causes the specific height pattern". Lastly, the variables that are proven to have a significant effect on skyscraper height will be included in a linear regression model that expresses the extent each height determinant factors affect the height of the skyscraper in China.

Results

In general, from the results, one infers that building height does not have a significant relationship with city-level height determinants. Looking into the height distribution around the country, skyscrapers in China mostly cluster around 200 meters, this, on one hand, shows that "building higher" is not the main focus regarding most of the construction in China. On the other hand, it also shows that lands in the urban area are not used efficiently. This is also proven by a wide range of height and the expansion of cities in China. According to the theory stated in the literature review, skyscrapers are first designed to provide more space in a location due to high land prices and a limited amount of land, but China has large amounts of empty land around. This may be the reason why there are more skyscraper development projects that stay around 200 meters.

As stated above city-level factors does not show a significant relationship with height, while most of the building level determinant factors have a strong relationship with skyscraper height. Building function, material, and type of finishing are significant in all the models. This shows that building level height determinant, in general, has more influence on skyscraper height compare to the city level one. The only variables under city level height determinant that shows significant with height are city GDP. This result aligns with other studies, stated that skyscraper construction highly correlated with the economic situation of a location. There are some situations where cities with low economic growth constructed buildings over 400 meters, for example, Changsha IFC (figure 4.16 in appendix). This shows that a small number of cities in China did use skyscraper as an advertisement to attract companies and population, with the goal to improve the economic situation of the city, but this is not the majority.

In terms of location and time, there is no significant pattern that could be spotted from the data. This shows that the average skyscraper height is around the same across different cities and time period. There is mainly an increase in the amount of skyscraper constructed each year, rather than average height. The only significant variable is cities in Pearl Delta urban cluster under city fixed effect. This shows that there is a higher average height in these cities. The coefficient shows that it has 3.8% more height which is around two more floors more than the other cities. Which is a lot more space in cities like Shenzhen and Guangzhou, due to a large number of skyscrapers located in these cities.

Some of the results in this research show similarity to previous research, including the connection between skyscraper development and economic situation; there are also results that contradict the previous research results, including height competition and location-specific factors. This shows that skyscraper development in each country could be different due to many reasons. Some Specific characteristic could largely influence the construction pattern. Also, skyscraper development connects with height and also the number of buildings. This research focuses on height, the results derived also from the perspective of height, so more studies could be done on the connection between the amount of skyscraper and height.

1. Introduction

Cities over the world are growing vertically, along with the increase in the amount of global cities. Major cities in Asia, including Shanghai and Beijing developed into global cities with rising economic power (Trujillo & Parilla, 2016). Through the process of city development, numerous Asian cities promote themselves by developing large amounts of skyscrapers. Especially in China, cities developed skyscrapers that clustered around a specific location. Shanghai and Shenzhen have more than twenty skyscrapers, with a height above two hundred meters, clustered around nearby blocks (CTBUH, 2019). This raises the question of what the reasons are that cause these developments and distribution patterns.

Currently, china continuously proposes new skyscraper development projects in major cities. Shanghai proposed a new construction over one kilometer tall, with three hundred floors, while Guangzhou and Wuhan proposed buildings taller than eight hundred meters. Height does not only provide inhabitable space but also symbolic qualities (McNeill, 2005). Cities develop skyscrapers higher and higher to compete with other global cities and also with cities within their nation. The Shanghai tower with 632 meters and Ping An Finance center with 555 meters are both record-breaking buildings, The Shanghai tower is completed in 2015 and is the tallest building to date in China. The Ping An Finance center in 2017 is the tallest in Shenzhen (CTBUH, 2019). With news reporting certain projects becoming the next tallest building in the area, it raises the question of what determines the height of skyscrapers.

This research aims to investigate the height pattern and height determinant factors of Chinese skyscrapers. A skyscraper is a habitable structure that is taller than 150 meters, with more than 50 percent of the space occupiable (CTBUH, 2019). It is a widely used building typology around the world, especially in countries and areas with rapid economic growth. This is due to the ability of skyscrapers to accommodate a large amount of the population and activities in a single location, where it is also an efficient building design for areas with high demand in land, and locations with high land prices.

The fundamental function of constructing skyscrapers for housing as many businesses and people in the same location as possible (Barr, 2012), to enhance the agglomerating economies. However, efficiency is not the only advantage of skyscrapers. Tall buildings also have a symbolic quality due to their height, and a have large connection with social and economic context of a location (Gottmann, 1966). Cities use skyscrapers to display their economic strength (Gluckman, 2003) and also as a sign to show that they are ready for more investments (Barr, 2018). These are factors that are strongly connected to the development of a city. While the efficient height decision of skyscrapers could enhance a city agglomeration effect, inefficient skyscraper height may not push the city towards its full potential. On the other hand, bringing too much of the population and of certain activities into a city could lead to diseconomies of scale. Thus, the distribution of skyscrapers and their height pattern is important to understand how city development evolves.

Several studies have proven the connection between economical height determinants. These researches focus on cities like Chicago and New York City. Cities that go through the process of large amounts of skyscraper development. China also goes through the process of city development with skyscrapers as the main typology (Barr, 2010; 2012; 2016). However, the process of development in each country differs from each other due to diversity in culture, development possibilities and government intervention. Thus, the focus of this research is to study skyscrapers above 200 meters in China, to provide empirical evidence that explains the mechanism of skyscraper development in China. And where these results could be used as a base to make decisions on future development, and if possible provide a base for urban development policies.

1.1 Motivation

As one of the fastest growing countries in terms of economy growth, China also is the fastest growing country with regard to the amount of skyscraper construction. More than half of buildings over 200 meters constructed in 2018 are located in China. The speed of this construction has a connection with the efficiency of construction technologies. It also has a lot to do with the support of the municipality. Skyscrapers in China start to grow exponentially in the past ten years, after the land reform that started around 1940. Excluding Hong Kong, due to the different legal system, looking at cities in mainland China, Shenzhen with 2050 km2 of land area is packed with 217 skyscrapers to accommodate a large amount of population growth. 48 skyscrapers are planned to be built in the next years. Other cities including Chongqing and Guang Zhou also have more than 190 skyscrapers within each city. Although skyscrapers in China are currently growing rapidly in amount and height, still only a limited amount of studies have been performed on the incentives of building skyscrapers over 200 meters. More studies could be done on this topic.

1.2 Problem statement

With urbanization and efficient building technology, cities grow rapidly in size and density. To accommodate the population, many cities, especially in developing countries start the construction of high rise building for both commercial and residential uses. A skyscraper boom has occurred in China in the past twenty years, the amount of buildings keeps on rising and the height continuously increases. Due to the unique characteristics of skyscrapers, it could bring major changes to the city context. However, researches on construction decision making of skyscrapers is an emerging field. Especially with the focus on China, many questions related to height pattern and height determinants remain unanswered. This study may give us a better understanding on the reasons behind the construction of these skyscrapers in China and find out the main trigger that leads to continued construction of taller buildings. The aim is also to provide a statistical base for municipalities to set up further development plans.

1.3 Research Questions

Based on the research motivation and problem statements, the research question and sub-questions are listed as follows:

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Sub-questions

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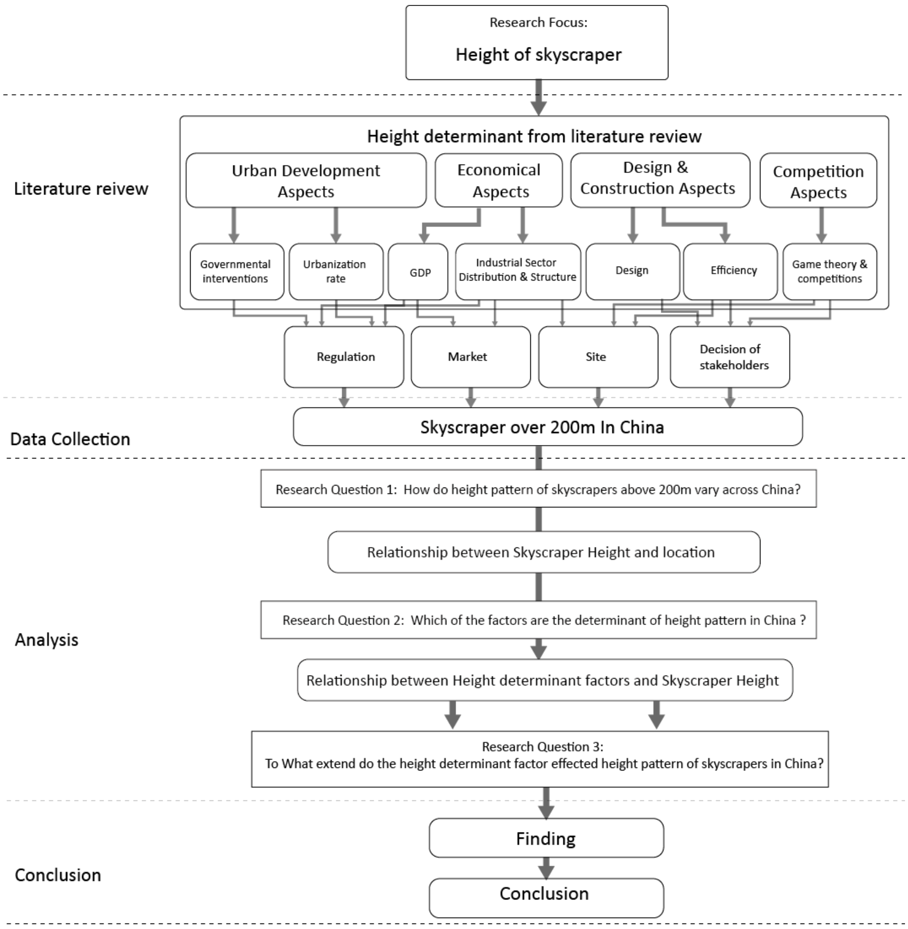

Figure 1.1: Concept diagram

1.4 Research Scope

The research focuses on skyscrapers above two hundred meters that are completed in China, excluding Hong Kong and Macau due to the different political system. This is done in the timeframe from 1990, when the first building over two hundred meters has been built in Guangdong until 2017 (CTBUH, 2019). China is an interesting location for research because of the fast growing economy and the fast growth in skyscraper construction. More than half of the buildings above 200 meters are constructed in 2018, and there are more proposed constructions until the year 2024 (CTBUH, 2019). The height and design of skyscrapers, and the predicted completion year changes over the construction period. Therefore, the cases chosen for this study are the completed constructions. This results in a total number of 665 observations.

1.5 Relevance

This section explains the relevance of the research. Scientific relevance defines how this report fills up the knowledge gap from previous studies done by other researchers. Societal relevance describes the potential of the study result and the possible benefit the outcome could bring.

1.5.1 Scientific relevance

This research addresses the existing research topics on economic and development of skyscrapers. As a modern construction typology, high rise buildings are first designed and constructed in 1885 (Douglas, 2004). The development of construction technologies has improved rapidly; it has pushed the height from 42 meters to over a kilometer within the past hundred years. With the possibility of building higher, countries over the world use this advantage to construct a large amount of these international style architectures.

Early studies of high rise buildings focus on efficiency and urban development aspects, including minimizing transportation costs, and doing calculations on the most efficient height and agglomeration. As skyscrapers continue to develop and spread, studies focus more on design aspects and strategies behind the decision making and construction. However, efficiency is not the only reason for building taller. The objective of this study is to fill up the knowledge gap in skyscraper development patterns, height patterns and more suggested reasons that lead to fluctuation in skyscraper height.

The research uses existing theories as the foundation. Many previous studies have focused on skyscraper height, but due to the refinement of the study topic, it is lacking a comprehensive overview and a study that links each theory together. Thus, this research uses prevailing theories of skyscraper height and a database from China to further understand possible factors that determine skyscraper height, development patterns and trend in China. It also improves knowledge on skyscraper development and quantify how these factors affect height, which is still missing in previous researches.

1.5.2 Societal relevance

The concept of "skyscraper height" shows city status, power, economic conditions and have importance for urban development aspects. In a world where skyscrapers are one of our familiar building typologies, we could easily take it for granted that skyscrapers are what a city should contain and how its skyline should look like. Yet different from the other building types, skyscrapers bring a large number of space into the local supply, changes people's behavior, have the tendency to promote more economic activities, changes the social geography and is architecturally designed and used differently compared to other building designs (Pawson, 2008). Skyscraper development created a new city structure and has a large effect on the future arrangement of firms and activities in an urban context (Liu, 2018). Although the cities rapidly expand vertically, not many pieces of research have been done to understand the mechanism of high rise development.

China is a good place to study due to the concentration of tall buildings. However, because of rapid growth, it leads to urban planning problems. Local government sets policies on construction height and the zoning plan, with a minimal amount of research data and results that can support the decision of the municipality. There is a lack of quantitative research on skyscrapers that the government could use as a base to construct their policies. This can potentially lead to regulations that bring negative effects (Barr, 2018). The idea of this report is to improve understanding of skyscrapers and develop a suggestion for further development and government regulations.

1.6 Report structure

The report consists of five chapters, including introduction, theoretical underpinning, method, empirical research and conclusion. Chapter 2, theoretical underpinning, look into the prevailing theories related to factors that effected skyscraper height and basic situation of skyscraper development in China. Chapter 3, Method, explains the research process, the variables used and the expected results. Chapter 4, empirical research reports the finding of the research and the last chapter, conclusion summaries the finding and provide suggestion on further skyscraper development.

2. Theoretical Underpinnings

This chapter discusses the mechanism of skyscraper development that effected decision in skyscraper height, along with by general and location specific determinant of height. Section 2.1 discussed general theories related to concepts of height that have the ability to explain skyscraper construction, and height. Section 2.2 goes through theories on skyscraper height determinants. Section 2.3 explained situations in China and connected it to theories related to skyscraper development decision on height.

2.1 Height determinants

This section goes through theories related to factors that potentially influences decision on skyscraper height. To classify and understand possible influence delivered by each of the factor, section 2.2.1 explain the concepts and terms use for height. Section 2.2.2 explains the determinants that have influence from the city level and 2.2.3 discuss factors from building level.

2.1.1 Height Composition

According to the definition from council of tall building and urban habitat there are many concepts behind skyscraper height. Each of these terms defines different height component, and could have different factors that poses influence on the final decision of these heights.

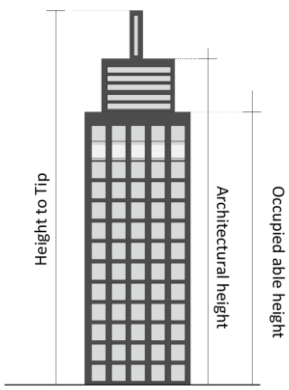

Figure 2.1: Height composition

Height could be explain using different terms, including height to tip, architectural height, occupied able height and vanity height (Figure 2.1). Height to tip refers to the distance between the lowest point of a building above ground, up on till the highest point of a building, including elements of antennae, flag poles and other technical facilities. Different from height to tip, architectural height does not include elements of antennae, flag poles and other technical facilities. Compare to height to tip, architectural height expresses the cost and value of height decision more precisely. Therefore, this will be the definition of height for this research.

Other terms that is used to describe height includes, occupied able height refers to height that provided usable space, and could perform the functional value the construction, and vanity height, which is the height of un occupied able space in the building, architectural height minus occupied able height. This unusable space normally located on the top of the building in order to increase the height of the buildings without providing any functional value to the construction. There are also other concepts of height that is discuss in other papers, but will not be the focus of this research, for example the economical height of return (Clark, 1930; Barr, 2012).

2.1.2 Height determinant factors from "City level"

This section looks into the height determinant factors that have an influence from the city level. These factors are originated from city development directions, and could have influence on individual decisions of the developers.

Urban development perspective

Vertical development plays a significant role in city transformation, construction of urban landscape and city competiveness (Lin, Huang, Chen, & Huang, 2014). Through the process of city developed, labor forces migrated into the area to improve job opportunity and standard of life. Especially in China, with decrease of state control, raises the amount of rural-urban migration (Seeborg, Jin, & Zhu, 2000). As population and company increases, the demand of space located in and around city center rises accordingly. To house large amount of residents, many Chinese cities started the process in horizontal development leading to urban sprawl (Yaping & Min, 2009). Through the process of horizontal expansion, city reach limitation of development lands, this triggers vertical development (Lin et al., 2014).

As city expanded horizontally, distance between points increase, this process rises transportation cost and time (Pawson, 2008). Vertical development provides a solution, with the advantage of offering more space in one location. High rise developments in one hand decrease inconvenience in transportation, on another hand increase supply of space. As height increase, amount of space for economic activities increased relatively. This set up the conditions for agglomeration, increase in city competiveness and efficient level.

To construct city with higher urban efficiency level, studies have been done on city horizontal expansion, however, in modern cities, vertical development have more effects on shapes city skyline, citizen lifestyle and possible development in urban economic (Lin et al., 2014). This makes height an important variable to study under the context of city planning and building. In situations of urban diseconomies, height and city size is also a municipal tool to balance city competiveness and social environment (OECD,2010). FAR and height regulations could be used to allocated city population towards an efficient city (Shanghai Municipality, 2012).

Perspective from City Economic development

Economic growth has strong relationship with the process of urbanization (Barr, 2018). As explains in the previous section, labor pooling increases competiveness of a city and have potential that leads to city growth in size and also economically (Barr, 2018). In this case, constant economic growth, could forecast a growth in population and city clustering. Which effected the amount of demand in space, thus, triggers developers to construct more buildings to increase supply.

Ability in skyscraper development is also related to city economic power of a location (Barr,2018). GDP growth possibility combine with regulation effected the amount of investment that flow into the local market (Wu & Chen, 2016). China as a country with strong economic growth attract many investors which increase the capability in companies and firms to develop new office spaces and also many of these investment goes into real estate investment. Some cities generate 20-30% of their GDP through real estate industry (Sina news, 2018).

Economic development combine with regulations and city planning are the reason behind migration of labor and it explain rationale behind construction of skyscraper in general. These aspects poses influence the decision of developers in building level, which will be explaining in the next chapter

Government focus and regulation on city level

Currently Skyscraper height have a lot to do with government regulations and city plans. Buildings need to be construct according to zoning plans. Although there are fix regulations on land use possibilities, but there is still negotiation possibility with the municipality. Looking at regulation on city level, different focus of the government frame possibility in development. Mostly in China, government focus on GDP growth, as it is one of the criteria for evaluating performance of the mayor. Government officials tends to make decision according to the economic benefit it could bring into the city.

2.1.3 Height determinant factor from “Building level”

In the previous section we discussed the effect that economic condition and urban development of a city has significant effect on development decisions, capabilities and possibilities. In this section we will look at other factors that affect skyscraper height and construction from the perspective of developer’s decision making in building level.

Theories related to Development decision

Looking at development process, the concept of opportunity space describes possible development design decision. Developers decided if the investment is worth it base of the opportunity space (figure 2.2), the possible development size, design and area (Adam & Tiesdell ,2012). With more constraints on these aspects, developer will have less freedom in development.

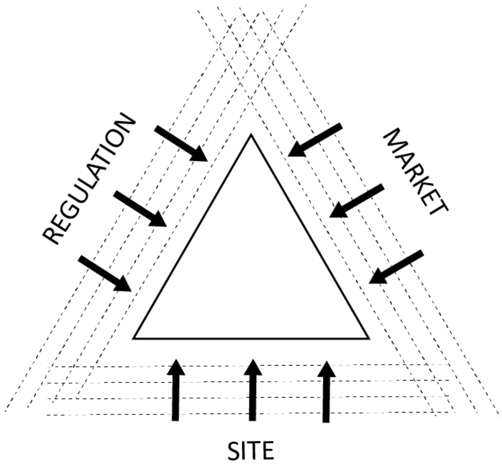

Figure 2.2: Opportunity space theory (Adam & Tiesdell ,2012)

In places with regulation and constraint, it shapes the possibility of constructing certain type of buildings. With support from municipality, there may be taller buildings in a certain area. Concept of opportunity space work as a frame that limited the development possibility, and it is different in each city.

Large amount of building develops in areas where the characteristics or the function suited the purpose of the location and the role of the city in the global economy (Chen, 2007), which related to market and regulations. Along with opportunity space theory, construct a city with these massive structures it will need a combination of investment, space, labor, construction materials along with the support of the local government and citizens. Some other theories will be discussed in the following part related to reasons why builders construct tall buildings also in situations where some exceeded the height to gain financial benefits.

Economical perspective

Looking at economical perspective, early research stated that height is a design approach that maximize value of a piece of land (Irish, 1989). Although development system and regulations could be different in each area, but construction cost and benefit is still one of the main factor that determine building height and design(Barr, 2012; Clark, 1930). Research have been done on to examine economical height of a building using construction cost and possible revenue (Barr, 2018), but due to the different context in each country and lack of data this research topic still requires more studies, therefore this will not be the main focus of the research.

From the perspective of the market, development is real estate follows theories related to supply and demand balance. Which links the concept from city scale into explaining the construction decision. As labor population and firms increase, demand of spaces increase along with it (Seeborg et al., 2000). As demand increase price of property increases, and rises possible profit in development, which triggers new construction, but due to the construction period there are a lag in relationship in supply after changes in demand (McDonald & McMillen, 2011), thus this will need to be taken into consideration during the research.

Competition and landmark effect

According to the explanation in the previous section on why skyscrapers are constructed, from a logical perspective these buildings should be built according to the function, within a boundary set with regulations, site and market. However, from observation on skyscrapers worldwide, researcher spot that there are also many buildings include a certain percentage of un-occupied able space, which is called the vanity height (CTBUH, 2019). Some theories provide explanation on this phenomenon.

From developer's perspective, due to competition between cities, developer tends to build higher to make sure other development does not take over within a period of time (Helsley & Strange, 2008). The reason for building taller than the surrounding is the landmark effect it could generate, a developer uses this as an advertisement for their company and increase their reputation and cities use it as an attraction not only for tourist but also investors and business to perform economic activities in the area (Moon et. al, 2009). An example of this would be the trump tower located in Manhattan, where it uses the name of the developer as its name. Another one is the Empire state tower, where it is still a famous landmark New York city (Barr, 2010). From researches, it shows that the height level of the new project influenced by the existing building in the surrounding (Moon et. al, 2009).

Looking at real estate properties as a product for the market, it should be able to provide functional performance value, but there are also other values that could increase the marketing of the project, including price value, social value and emotional value (Sweeney & Soutar, 2001) . These are costumer perceived value, which is taken into consideration during design process. Design aspects add on social value, by improving the ability for each inhabitant to connect to others; and emotional value, where it allows inhabitant to express themselves (Sweeney & Soutar, 2001).

Researchers agrees that skyscrapers sent out certain messages, provide certain meaning. Height premium of spaces that located more towards the top, shows that people are willing to pay more for properties that have higher power target (Dorfman et al., 2017). The wording that we used for describing success may be one of the reason why higher spaces could represent power (Dorfman et al., 2017). The reason why people are willing to pay more for taller spaces still require more research, but from this we can see that taller spaces and buildings do have certain added value. Some countries belief that building skyscrapers sent out signal to the world showing that they are ready for more business activities (Douglas, 2004). This also seems to be the case in China, where mayors support construction of skyscraper with an aim to attract more companies and workers into their city.

Design related factors

Looking into height determinant in more detail, specific function and design related factors affect both architectural height and vanity height of a skyscraper. Function allocation is one of the first steps in development process. Average floor height maybe different according to different functions. Due to the different needs, office space in average require more floor height for acoustics absorption, atmosphere for better work performance (Sundstrom et al., 1994). Compare to office, residential buildings require less floor height. Many of these function will be decided in the designing phase of the project. From this we can see that building with same height may have different floors and also residential with the same gross floor space may be shorter then office building. Function allocation then becomes one of the height determinant.

Other than functions there are also the aesthetical and cultural aspect of buildings. These aspects is taken into consideration by municipality, and many of them aim to develop city icon and development plan accordingly (Kong, 2007). Designer may also include their own background and culture into the design, nationality of construction coalition can also have influence on skyscraper shapes and height. Although there is freedom in design, but functions and height could be restricted according to negotiation possibility and types of regulations.

Regulation on Building level

Compare to regulations at a city level, including development direction and area planning, there are more detailed zoning plan for each building development projects. Urban development plans work as a guideline, but the documents that have legal power (Adams & Tiesdell, 2012). In order to start construction process, development plan would need to go through legal process for approval from the municipality. In area with low possibility in negotiation, development would be more restricted, while areas with possible negotiation would have more freedom in development (Winch, 2010).

System of regulation also have different impact on development possibilities (Adams & Tiesdell, 2012). Regulations on FAR (floor area ration) limited volume of buildings and focuses on population allocation, while height limitations control more of the skyline and city image. Shanghai is a city that uses FAR regulation to prevent urban sprawl (Shanghai Municipality, 2012), while Beijing uses height regulation to preserve city culture and heritage. The regulation aspects and development process will be discussed further in the next section, that focuses on development in China, and height determinant factors in China.

2.2 Research Background

From previous section we saw the studies of previous researches, many theories are established by modeling the situation. Later researchers proof some theory right and some wrong by using more statistical data, but due to data limitations these statistical quantitative researches is only done in some areas. Although many researches investigate factors that determines height, but due to the market structure in China, which is different from the rest of the world, some theories of skyscrapers would not apply. To understand the difference, this section provided background information of China.

2.2.1 History of City development of China

To interpret skyscraper development in China, first we need to have an understanding on urban development process. City development and urbanization in China have much to do with history and government development strategies. From 1949 until 1978 China publish a land reform law and focuses on heavy industry developments, where populations migrate less from cities to cities. In 1980 Chinese government focuses their strategies on economic development, where China allows foreign investment, permits citizens to start businesses. This process leads to development of industries and population aggregates towards eastern coastal regions and started the process of urbanization (Lu et al., 2014). Through cluster of population and company, cities start a “path dependent” development process. Cities around the coast, for example, Shanghai, Shenzhen, have the advantage of ports as the main trading route, further increases its competitive advantage due to agglomeration. After the economic reform in 1980, China started to unevenly develop, due to the geographical location and advantage of having less regulations (Guan et al., 2018).

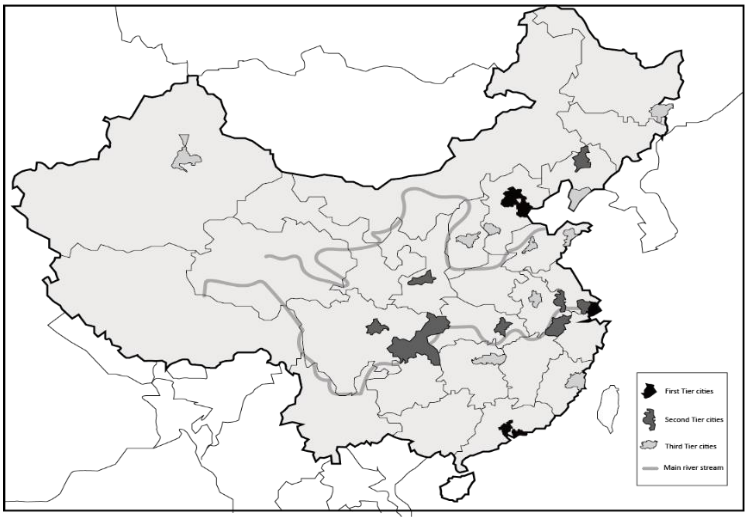

Figure 2.3: Location of first, second and third tier Cities in China

As we can see in figure 2.3, first tier cities located near the coast, which includes Shanghai, Shenzhen, Guangzhou and Beijing; second tier cities located along the Yangtze river. The reason why these cities developed is explain in the previous paragraph. According to council of building and urban habitat (CTBUH), excluding Hong Kong, three of the four first tier cities, shanghai, Shen Zhen, Guangzhou, are the cities that contains most skyscrapers in China (CTBUH, 2019). These cities also have population over 20 million and GDP over 300 billion US dollars (Hernández, 2016). In terms of politic structures first tier cities plus Chongqing are directly controlled by the central government, where more attention and resource will be used to develop these areas.

2.2.2 Government, Legal system

Government structure and power in China is an essential part in city and construction project development. China, as a communist country, have a unique government structure, the socialist legal system. Central government set up development direction and local municipality design detail urban development plans. In this case attitude of government will be an important issue in developer's opportunity space, or the possible building design developer could build.

Land policies have primary influence on urban development and development possibilities. Early studies on Height of skyscraper stated that extreme height is caused by high land values (Clark & Kingston, 1930). Later was also explain with the concept of agglomeration, where companies and workers prefer to cluster around a certain location, mostly city center to gain most benefit from the location. This may be the situation in some countries, but it is not the case in China, where lands are owned by the municipality. In 1986 government published land administration act, with the objective to promote social equality, all lands are owned state own, and there is no private ownership (Chen, 2007).

With different Legal system, urban development in China have strong connection with decisions of central government. Due to different government structure many theories that is proven in cities like New York and Chicago (previous studies done by Jason Barr) may not be the case in China. The first major difference may be related to the land use regulations, all lands in China are owned by the government. Developers need to lease land from the municipality, which give the municipality more power in the process to influence and manipulate the end result. This makes development process of skyscraper in China different from some other countries.

2.2.3 City Category explanation

China have large amount of land, where the central government cannot control everything, therefore there is a city hierarchy where main cities are directly administered by the central government; Prefectural level cities controlled by province municipality that is under supervision of the central government; Lastly county level cities that are controlled by regions under supervision of the provinces.

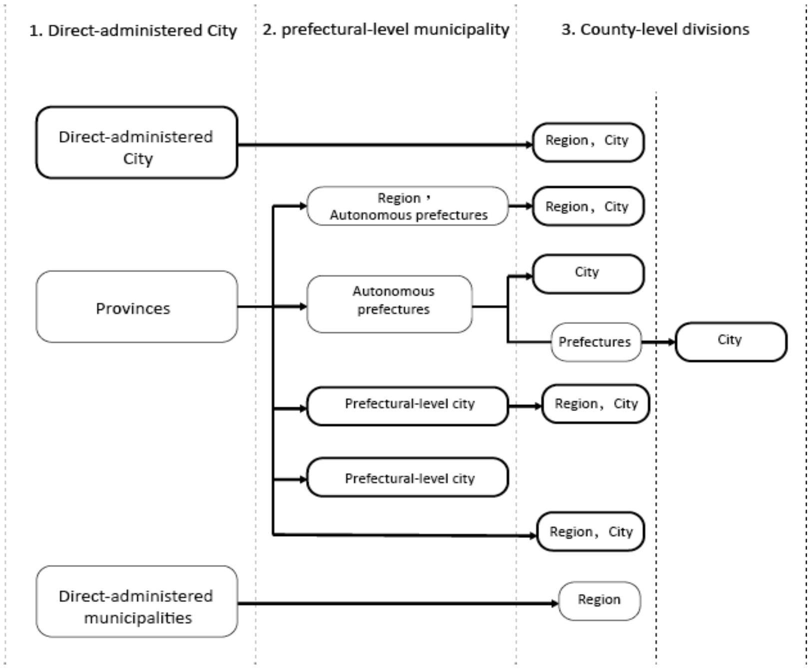

Figure 2.4: Chinese city levels (State council of China, 2009)

City level		Number of cities	Cities
1. Direct-administered City		4	Beijing, shanghai, Tianjin, chongqing
prefectural-level municipality	**2.** Consolidated district-governed prefectural level city	12	Suzhou, Foshan, Guangzhou, Haikou, Nanjing, Sanya, Shenzhen, Wuhai, Wuhan, Xiamen, Zhuhai
	3. Normal prefectural-level municipality	281	Sansha, Huaibei, Haikou, Zhongshan, Beihau, Sanzhou, Puyand, Xuchang, Wuxi, Huzhou, Wuhu…etc
4. County-level divisions		375	Chaohu, Jiehou, Mingguang, Ningguo, Tianchang…etc

Table 2.1: City under each level

Due to different city level, each city has different degrees of importance. When central government is setting up development plans, there are more focus on the higher level cities. With direct administered, there may be more controlled from the government, but there are also more development possibilities in these cities. Directly administered cities are all listed in the top 10 GDP ranking in 2018, half of the consolidated district-governed prefectural level city, are also having high ranking GDP contribution (Figure 2.5).

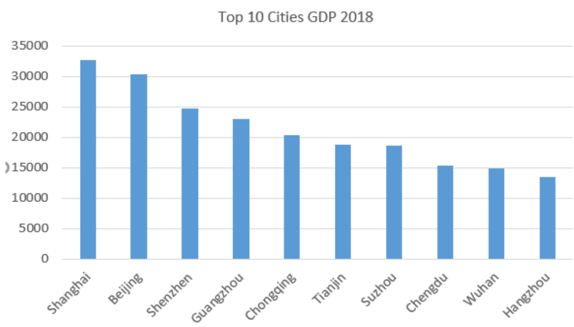

Figure 2.5: China GDP ranking 2018 (Sohu, 2019)

2.2.4 Urban development process

Major cities in China publish master plans for urban development every 5 to 10 year. This document included topics and arrangement on city position, urban development direction, control of population, economic, transportation and general FAR and zoning (Shanghai Municipal People's Government, 2018). Although regulations and zoning plans are set up, but there is still space for negotiation between the city municipality and developer. According to the result in negotiation, in some situations municipality is willing to give incentive to the developer (Cai, 2017).

Overall around China, land leasing has large effect on urban development (Yang et al., 2015), but in some cases there are also space for negotiation. In PPPs, Chinese municipality set up private companies with developers that could take up stocks in new developments, municipality take up 80% of the stock of Shanghai tower, in this case there will be more space for negotiation. To build tall in China will need the support from the local municipality, this aspect should be considering in the study.

Chinese local municipality generates 40% of their annual income from land lease, this make land leasing a strategic action if local government have the goal to generate maximum income (Cai, 2017). Land allocation plan and urban development strategies could be effected by complicated conflict of interest between stakeholders, which could also have affected the height of skyscrapers.

2.2.5 Skyscrapers in China

One of the early theory in skyscraper height and construction focuses on how skyscrapers could accommodate more people, have potential to decrease transportation cost and create agglomeration. Thus we first look at population distributions in China and relationship with skyscraper. According to CTBUH skyscraper distribution mostly align with population distribution (figure 2.6 & 2.7). Most of the skyscrapers cluster on the eastern part of China, where most of the first tier cities located. This to some extent explain that skyscraper in China located in areas that have a demand in space.

Figure 2.6: skyscraper locations (CTBUH, 2019)

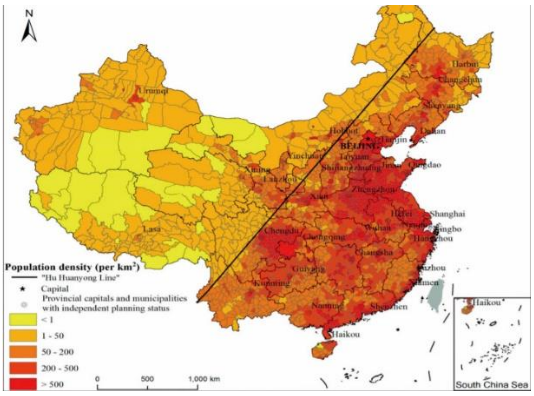

Figure 2.7: Population distribution in China 2015 (Li, 2018)

As stated above, in 1978 the Chinese government reduce the number of farmlands and allow these lands to be used for development (Zhu, 2005). Along with opening up the country for foreign investment, the government also encourage local development and business, started the economic growth (Chen & Feng, 2000). Along with the reform in 1978 government set up special development zones for the industrial and commercial sector to lead the top 500 companies into the city to increase the competitiveness of the area (Zhang, 2011). This growth has continued until now with an average of 6.5% increase each year, the Chinese government aims to continue the growth by supporting more innovative businesses and increase foreign investment. These could lead to an increase in demand for space and development of more skyscrapers. According to Barr, these skyscrapers could further attract labor and business to migrate into the city and accelerate economic growth (Barr, 2017).

Looking at skyscraper location from history, Shun Hing Square or the Di Wang tower location in Shenzhen is one of the first 200m+ skyscraper building in China. It was constructed in 1996, before that structure over 200 meters are mostly towers, including oriental pear tower, which is not consider as a skyscraper due to the minimal occupied able space. After the Di Wang tower have been constructed, CITIC Plaza in Guangzhou, Pingan Tower in Wuhan and Jinmao tower in shanghai is constructed in the next two years (CTBUH,2019). As we can see these building mostly located in first tier cities, but city Wuhan, not one of the first tier city, also continuously built skyscraper. From this phenomenon we could suspect that the city is using skyscrapers as an advertisement for their city.

From this information we can see some basic trend of skyscraper development in China, but these are the first observation, and more data collection will be done in the next sections to gain a better overview of skyscrapers in China

2.2.5 Theories on skyscraper height in China

Skyscrapers in China have been studied from different perspectives, including economic fundamentals, municipality's financial perspective, city advertisement, competition with rival cities, promotion of the mayor him/herself, and increase in investment for the city.

The result shows that the skyscrapers in China follow economic fundamentals, cities with larger population contains more skyscrapers and was not strategic complement, where buildings are constructed due to intercity competition (Barr, 2018). Also that smaller cities have more tendencies to overbuild, which he calls it the small city effect or the "me too effect" where these cities copy development of larger cities (Barr, 2018). There is also some correlation between the height of the building and the age of the mayor. Young mayors tend to build higher buildings to increase their reputation and seek promotion (Barr, 2017). Competition between cities are also proven in study of excessive construction in China (Li & Wang, 2018).

2.2.6 Summary of height determinants

Figure 2.8, Summarize the height determinant from literature review from city level and from the building level. These height determinants are classified into 4 categories, which some of them have connection to the demand side and some to the supply side. Different from countries like New York and Chicago, government in China have more control capabilities due to the land allocation and government system. This make it interesting to find out if regulations and different governmental structure effected the result and if there are some other reasons that leads to extensive development of skyscraper around China.

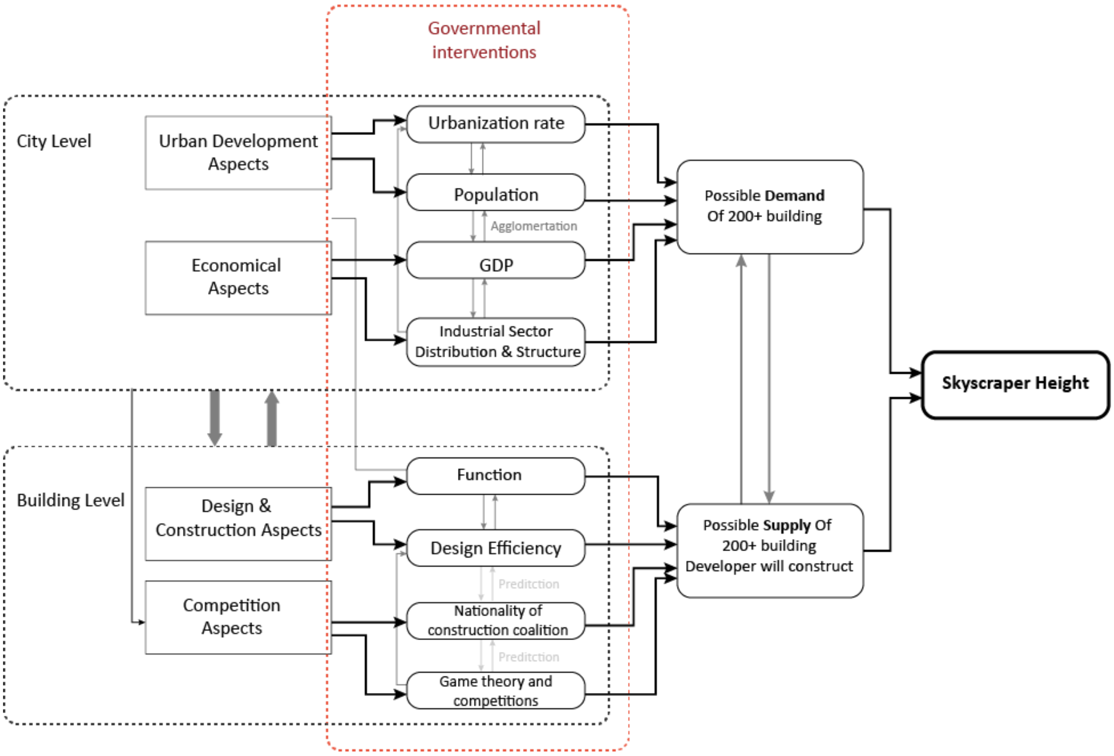

Figure 2.8: Height determinant relationship

2.3 Summary

The literature review section explain the general theories related to skyscraper construction and development decision along with height determinants that have strong link with skyscraper height. The first section explains the component of height and classifies height determinant variables into city level factors that is related to urban development and city situation; and building level factors that have more connection to the decision making of the developer and designer, these includes building function, height competition and other related aspects.

The second section provides background information of China, including city development history, city structure and current situation regarding to skyscraper in China. China have a diverse political system compare to other country around the world. Government have strong control over real estate development, which is something that need to be taken into consideration in this research.

3. Methodology

This chapter explains the research procedure and method that is used to answer the research question propose in the previous chapter. Section 3.1 explains the overall procedure of the research. Section 3.2 focuses on the method that is used to answer research questions, including an explanation on variable construction methods, and the reason behind choosing these variables. Section 3.3 explains the sample selection, data collection procedure and reliability of the source, and section 3.4 provides a summary of the chapter.

3.1 Research Design

This section explains the overall research procedure that is designed for answering the research question. The research is design to answer the main research question of what are the factors that effected skyscraper height. Results from related research are explained in the literature review section. There are theories related to urban development, economics, design efficiency, competition, and government intervention. Many of these theories are proven by using the database from New York and Chicago. Which is the place where skyscraper started to boom. Currently, the skyscraper development trend moves to Asia, especially in China. More than half of the 200m+ buildings develop in 2018 are located in China. Although the skyscraper boom in China and in the U.S seems to go through a similar process, but there is a major difference in these areas. China has a different political system and also size the size of cities in China are larger than many other countries around the world, thus some of these theories may not apply. These aspects will be taken into consideration when designing the variables and research method.

3.1.1 Research motivation and method selection

The motivation of this research is to provide empirical evidence that explains the mechanism of skyscraper development in China, where these results could be used as a base to make decisions on future development, and if possible provide a base for urban development policies. To achieve this goal, a quantitative approach is chosen for research over a qualitative approach. There have been many qualitative studies done on urban planning and development decision making aspects. These studies provided theories and observations on some phenomenon, but it does not give a robust result to their research topics. Moreover, decision making and social aspects that effected skyscraper development could contain personal bias in qualitative research. Therefore, this research uses a quantitative method to provide a more robust conclusion to the research question and eliminated personal bias throughout the process.

3.1.2 Research Objective and steps

The main objective of the research is to answer the research questions and sub-questions. This includes understanding the height patterns in China, finding out the factors that cause specific height pattern and to quantify the effect these factors have on the height patterns. To design a research process that could attain these objectives, they are broken down into steps, and listed as follows:

Step 1: Dig into previous studies on a related topic to define theories that stated possible aspects that effected skyscraper height.

Step 2: Identify variables that could be used to measure each aspect stated in previous studies.

Step 3: Collect data of 200m+ skyscraper in China and identify regression that is suitable for fitting the data collected.

Step 4: Understanding the database through graphs and statistical descriptive, and perform regression analysis on the database to identify the degree of effect each determinant has on skyscraper height.

Step 5: Explain the major findings of the analysis, and provide the suggestion on future development.

Step one is done through literature research, the results on this part are provided in the theoretical underpinning section. Step 2 and 3 would be explained in section 3.3 and 3.4 of this chapter, the result of step four will be provided in section 4, the empirical research section, and the suggestion for future development will be provided in the conclusion section.

3.1.2 Research Process

Based on the objectives and steps listed above, the research process could be divided into 5 phases. The phases are divided base on the sections of the report, including introduction, theoretical underpinning, methodology, empirical analysis, and conclusion. The table below provides an overview of the research topic, combing the research objective, steps, the question each phase answered and the method that is used in each phase.

Research **Phases**	**Ch.1 Introduction**	**Ch.2 Theoretical Underpinnning**	**Ch.3 Methodology and Data collection**	**Ch.4 Emprical Analysis**	**Ch.4 Conclusion**
Research **steps**		Step 1: Dig into previous studies on related topic to define theories that stated possible aspects that effected skyscraper height.	Step 2: Identify variables that could be used to measure each aspect stated in previous studies. Step 3: Collect data of 200m+ skyscraper in China and identify regression that is suitable for fitting the data collected.	Step 4: Understanding the database through graphs and statistical descriptive, and perform regression analysis on the database to identify the degree of effect each determinant has on skyscraper height	Step 5: Explain the major findings of the analysis, and provide suggestion on future development
Objective of the phase	Define the problem Feild	Dig into previous studies on related topic to define possible height determinant factors that have been proveto exsist and theories that stated possible height determinants	Identify variables that could be used to measure each theories and aspects, collect data of 200m+ skyscraper in China for each variables to form a data base, and identify regression that is suitable for fitting the data collected	Perform correlation analysis on the data base, to identify the the degree of effect each determinant have on skyscraper Height	Provide suggestion on future regulations and development according to the findings of the research
Research **Questions**		How does the height pattern of skyscrapers above 200 meters vary across China? What is the factor that causes the specific height pattern across the country?	What is the factor that causes the specific height pattern across the country?	How does the height pattern of skyscrapers above 200 meters vary across China? What is the factor that causes the specific height pattern across the country? To what extent does each height determinant factor affect the height pattern of skyscrapers in China?	
Research **Method**	Literature review	Literature review	Data collection Data analysis	Regression Analysis	Data analysis

Table 3.1: Research Phases and objective

(larger version of the table is provided in the appendix)

The introduction phase of the research defines the problem field, including the study motivations and the relevance of this research. Theoretical underpinning phase looks into previous studies related to skyscraper development and Chinese urban development to define the possible factors that could effects skyscraper height. Methodology and data collection phase explains the construction of variables, including the explanation on why these variables are chosen and what are they trying to model, along with the explanation on the data fitting method that is used. Empirical analysis phase looks into the database and aims to understand the relationship between each variable with skyscraper height, and conclusion phase provided the overall finding of the research, along with the suggestion to future skyscraper development and policies construction.

3.2 Research Method

The previous section explains the overall structure of the research, this section will explain in more detail about the method and approach used to answer each research questions and objectives for phase 3 and 4 (Table 3.1). This includes how variables are chosen and constructed, along with an explanation on data fitting model.

3.2.1 Analysis procedure

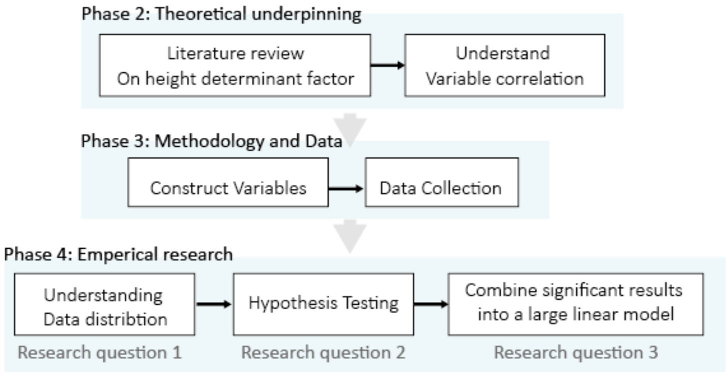

Figure 3.1: Analysis procedure

The analysis procedure of started in phase 3. In this phase, hypotheses are constructed according to theories from the literature review, specific variables are chosen to test each hypothesis and database for each variable will be collected. The detail explanation on hypotheses and data collection process will be provided in the following sections. After obtaining a database of selected variables, an overview of the data distribution will be provided to answer the first research question "How do height pattern of skyscraper varies across China". Hypothesis testing using the database would provide an understanding of the relationship between variables and height, which will answer the second research question on "what are the factor that causes the specific height pattern". Lastly, the variables that are proven to have a significant effect on skyscraper height will be included in a linear regression model that expresses the extent each height determinant factors affect the height of the skyscraper in China.

3.2.2 Hypothesis and Variables construction

This section explains the construction of hypothesis along with the variables that are chosen for testing each hypothesis.

City Level factors

Section 2.2.3 under theoretical underpinnings explain the process of skyscraper development in China, where population migrated into cities that provided them job opportunity and causes urban sprawl (Yaping & Min, 2009). The development of skyscraper decelerates the horizontal expansion of cities.

From this theory of skyscraper development, the main factors that drive skyscraper development process included population migration and urban size, but do these factors only affect either the amount of skyscraper developed and skyscraper height or it has an effect on both still remains a question. Thus these two variables are used test relationship between city growth and skyscraper development (figure 3.2).

Figure 3.2: City level hypothesis

Other than urban development aspect, there are also theories related to the relationship between city economic condition and skyscraper development that could add on to the aspect of city-level factors. According to literature, City GDP fluctuation is proven to have a correlation with skyscraper height. There is also research that focuses on the fluctuation of the tertiary industry of the city and the relationship with urbanization rate, and some theories stated that increase in tertiary increase leads to skyscraper development (Zeng, Xu & Chen, 2018). As the portion of the tertiary sector increases in Chinese cities, populations with agricultural jobs gradually moved into the city and work under secondary and tertiary sector, the willingness of foreign investments increases along with the increase process of urbanization (Zeng & Wu, 2016). Tertiary sector includes service, technological industries, which in theory increase demand for high rise space. These variables are also predicted to have a relationship with skyscraper height and development.

These variables are a portion of every variable the could have an effect on skyscraper height, therefore location fixed effect is also included into the study with the aim for it to pick up the location-specific effect, including possible regulations and land quality, on height.

City level factors have a strong relationship with the demand for space, increase in population increase demand for residential space, while an increase in GDP and tertiary sector increase the demand in office space. According to figure 3.2 Change in demand for space could have an effect on the amount of skyscraper and/or on the height of a skyscraper. Thus these variables are also being tested with the amount of skyscraper in the city as a control variable.

<u>The included variables use for this aspect</u>: City population, City urbanization rate, city GDP and city percentage of tertiary industry, city fixed effect, amount of skyscraper in the city

Building level factors

Different from city level factors, building level factors focuses more on separate construction and design decision. Design and development decision on building level is mostly done by the developer along with intervention from the municipality. According to different levels of government intervention, there may be distinctive freedom for the developer to decide on design and function allocation. Cities, in this case, are used as a control variable to take into consideration, the difference in the cities.

From the database collected, some general observations are done. Type of function and Average floor height is one of the first ones that appear by looking at the data set. Building over 200 meters in China is mostly offices, tallest residential buildings only have a maximum height of 261 meters and range from 97m until 261 meters (CTBUH, 2019). As explained in the literature review, design decision could have an effect on skyscraper height due to function allocation and cultural aspect.

The functions are predicted to affect all heights including architectural height, occupied height, and vanity height. While the type of finishing and shape of the building is predicted to have more effect on vanity height and effect architectural height due to its effect on vanity height. The predicted effect of the variable on skyscraper height is illustrated below:

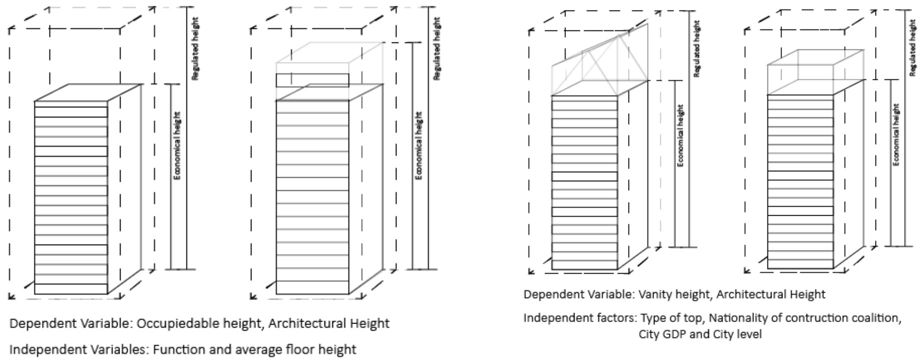

Figure 3.3: Possible effect design-related variables cause of skyscraper height

<u>The included variables use for this aspect</u>: Building function, design of the building top finishing, Nationality of construction coalition

Competition related aspects

Competition on skyscraper height is a widely researched topic around the world. This topic is one of the explanations for a developer to build buildings that are taller than economical building height, which is the height that generates a return (Helsley &Strange, 2007). This aspect is also included in the research because it has been proven to exist. Competition can be spotted by looking into the relationship between the average height of buildings in different cities, and the variables that are used for testing competition, is number of skyscrapers in a city, because, with more skyscraper in the city, there may be more competition due to the landmark effect to be the tallest.

<u>The included variables use for this aspect</u>: Year of completion of construction, the number of skyscrapers in the city, the city each building is located

These variables derived from literature review, but because this is an emerging field, so some of these variables does not have statistical prove that stated whether they have relationship with skyscraper height. The variables for GDP and vanity height are the one that have statistical prove for their relationships with skyscraper height using data base of other countries. Urbanization related variables and percentage city tertiary industry are the variables that are statistically proven to have relationship with skyscraper development, but not specifically height. The other variables derived from qualitative studies. Lastly, design of building finishing and nationality of construction coalition are added according to observation and predictions.

3.2.4 Introduction to Correlation and Regression

This research aims to find the factors that effected skyscraper height. Correlation research different from experimental research is a method used to understand the relationship between datasets of dependent and independent variables collected from natural events without manipulating and interfering the event. From the result, we can determine if these determinant place any effects on skyscraper height, also if these variables have an interesting relationship with each other. In the case of this research, skyscraper height is the dependent variable and the factors are the independent variables. Where the dependent variables cause an effect on the dependent variable (Field,2013). Regression analysis is a method that is used to understand the relationship between a dependent variable and multiple independent variables (Montgomery, Peck, & Vining, 2012). Regression uses databases from the previous event to predict future events. The equation that is used for linear regression is a combination of a model plus an error (Outcome = Model + error), where the model is a combination of a series of the effect each variable has one the outcome (Field, 2013). There are various methods to fit data points of variables to a model, the methods used in related previous researches (figure 3.2) are listed below:

Paper	Concept/ Theory	Variables used	Type of Model Used
Skyscrapers and skylines: New York and Chicago, 1885–2007 Barr, 2013	• strategic interaction across cities • Effect of zoning plan/ height regulation on city development	Maximum skyscraper height in each city, number of completions each year, average and maximum plot size, regulations and year of implementation	ordinary least squares, two-stage least squares, and seemingly unrelated regressions (SURE)
Skyscraper Height and the Business Cycle: International Time Series Evidence Barr et el., 2014	• Relationship between record-breaking height and the business cycle • Relationship between height competition and the business cycle	Announcement Dates & Completion Dates of Record-Breaking Buildings,	Granger causality tests, co-integration relationships
Is Chinese skyscraper boom excessive? Li& Wang, 2016	• Aim to spot excessive competition • Identify cities where skyscraper construction may be excessive	Cumulative height of the skyscraper in the city, population density, GCP per Capita, Annual FDI, the portion of the service sector, urban road area	Panel fixed effects model, Hausman test, Tobit random/ fix effects model
Growing skyline: The economic determinant of skyscrapers in China Barr, 2018	• Explore the amount of skyscraper construction with political factors • Aim to analyze the effect height competition bring into a city	Number of skyscraper completions each year, highest construction each year, other economic and political data	OLS, Spatial autoregression

Table 3.2: Previous research methods

As we can see, previous researches use various data, fitting model. Including OLS, SURE, panel fixed the effect, spatial autoregression, depend on the research design and variable collection method. The model used in this research is the OLS (least-squares regression), this model provided a general prediction on the correlation between each variable, by calculating the best fitting line of the database between the dependent variable and the dependent variables.

3.2.4 Dependent, Independent and control variables

The concept of dependent and independent variables are used in regression analysis, and as stated in the previous section, it is used to answer research question 2 and 3. The dependent variables in all parts of the research are the height of skyscrapers which includes architectural height, occupied height, and vanity height. The independent variables will change according to the hypothesis that is being tested, and control variables would also be slightly different depending on the theory that is tested. These variables will be explained in section 3.4.

Variable Name	Form	Unit	Description	Source	Sample
Architectural Height	Linear, Log	Meter	Distance between the lowest point of a building above ground, up on till the highest point of a building	CTBUH	807
Occupiable height	Linear, Log	Meter	The height that provided usable space, and could perform the functional value the construction	CTBUH	807
Vanity Height	Linear	Meter	height of unoccupied able space in the building	Calculated	807

Table 3.3: Dependent variable

3.2.5 Research output

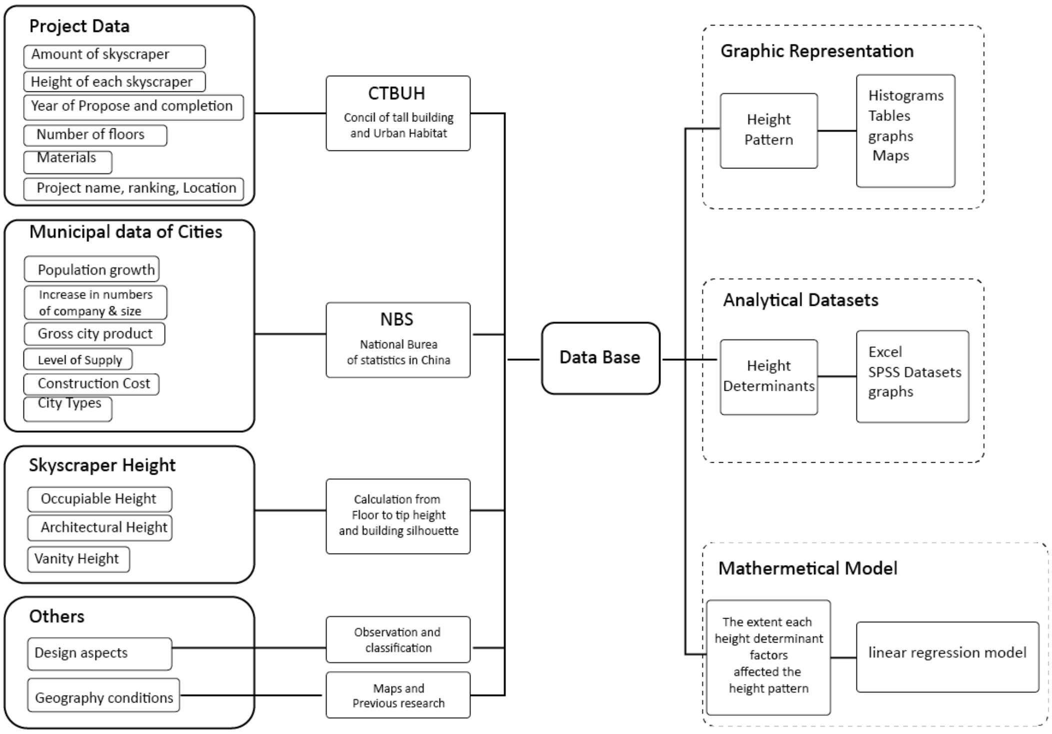

Figure 3.4: Research Flow and Output

This research aims to study height determinant of skyscrapers in China, the main research goals is to develop the understand how these factors affect skyscraper height and develop a mathematical model that models height determinants through equations. Graphic representation including histograms, maps, and graphs are used to demonstrate height pattern and distribution of skyscraper in China. Analytical datasets are used to define the height determinants that actually have a significant effect of skyscraper height. As stated above mathematical model will be the output for the last research question, that describes the extent each height determinant factor affected height pattern in China.

3.3 Data collection

In this section, the process of data sample selection and data collection is explained. Sample selection explains the data that is collected and the variables and cases that are left out. Variable and data source section explains the sources each data set is collected.

3.3.1 Sample selection

The Data set used in this research contains a finished building that are over 200 meters in China from 1980 until 2018. Due to the different government structure, demand and economical system Hong Kong, Macau, and Taiwan are not included in this study. Buildings that are just proposed, never complete, on hold, and demolished are also not used for the data sets since these development plans could change throughout the process and many proposed projects are not constructed. List of buildings and basic data including height, function, materials, floors, and date of each development process are collected from CTBUH, Council of tall building and urban habitat. Case with a large amount of essential data missing, including height, amount of floors, construction time is excluded.

3.3.2 Data source and reliability

This section explains the source where the data are collected. There are three main sources, including CTBUH for skyscraper development data, NBS for city economic and population related data, and municipality websites for urban planning related information. CTBUH stands for Council on tall buildings and urban habitat. It is an organization that provides the latest information, data, and researches related to tall buildings. Skyscraper development related data are obtained from the documents provided by CTBUH. NBS stands for National Bureau of statistic China. It is a government department in charge of collecting statistic data on economic performance, population fluctuation and other related information. Each city collected statistical data yearly under the control of NBS, and publish the statistical yearbook. Economic and population related data are obtained from these documents. Lastly, Information on city classification and urban development plans are obtained from the articles published on these websites. These are municipality official websites including state council website and city municipal government website.

3.3.3 List of variables

This section focuses on the variables needed for the research. These Data are divided into 5 categories. The first one included skyscraper development data, which is the basic information of project names, ranking, location, height, function, and dates. The second category focuses on skyscraper height, which divides skyscraper height into 3 different portions for detail analysis. The third category is the municipal data of the city each year, includes the population data, gross city product, companies output data. The next category is also municipal data but these ones have more relationship with city development and urban planning. The last category is the other variables including geographical condition, design aspects of skyscrapers and others. From this basic data set collected from CTBUH additional data is added on from other sources including information related to the city, construction efficiency; some are calculated using existing data for example average height per floor and vanity height. The table below (Table 4) listed the variables for testing each hypothesis and the data source each variable is taken from:

Determinant	Label	Variables	Unit	Description	Signs	Form	Source
Skyscraper development data	Building Name	Building Name	-	Name of the tall building	.	.	**CTBUH** Council of tall building and urban habitat
	City	City fixed effect	-	City the building located in	+/-	Dummy	
	Arch Height	Architectural Height	Meter	Architectural Height of the building	.	Linear, Log	
	Floors	Floors	-	Amount of Floors the building have	+	Linear	
	Proposal	Proposal year	Year	Proposal Year of the building	+	Linear	
	Started	Started Year	Year	Year the construction started	+	Linear	
	Complete	Completion year	Year	Year the construction is complete, also used as time fixed effect	+	Linear	
	Completion	Building Complete	-	Building construction complete	.	Dummy	
	Occ Height	Occupied height	Meter	The height where the building is occupied-able	.	Linear, Log	Calculation from Floor to tip height and building silhouette
	Van Height	Vanity Height	Meter	The Height that is not Occupied	.	Linear	
Design and construction aspects	Material	Construction material	-	The Material of the main structure	+/-	Dummy	**CTBUH** Council of tall building and urban habitat
	Function	Building Function	-	The function/usage of the building	+/-	Dummy	
	Height/floor	Avg. floor height	Meter	The average height of each floor	+	Linear	
	Tot	Type of Finishing	-	The type of finishing on the roof	+/-	Dummy	Building silhouette and pictures
	Construct team	Construction Coalition	-	The nationality of construction Coalition	+/-	Dummy	**CTBUH**
Urban Development Aspects	City Size	City Size	Km2	Size of the city in Kilometer square	-	Linear, Ln	**NBS** National Bureau of statistic in China
	City Pop	City Population	10Thousand rmb	Population of the city in thousands	+	Linear, Log	
	Pop density	Population density	Pp/ Km2	Population density	+	Linear	
	City Government	City administered level	-	Amount of Control by the government	+/-	Dummy	**Municipal websites** Government Articles
Economical Aspects	GCP	Gross City product	100 million Rmb	GDP of each city in 100 million RMB	+	Linear, Log	**NBS** National Bureau of statistic in China
	Indus size	Industrial size	100 million Rmb	Size of primary, secondary and tertiary industry	+	Linear	
Competition Aspects	# skyscraper	Number of skyscraper	-	Number of skyscraper in the city	+	Linear	**CTBUH**

Table 3.4: Variables used in this study

3.4 Summary

The methodology section explains the structure of the research and how the research is done. This research uses a quantitative method to provide empirical evidence for future development decision and plans. The variables used in the research derived from the literature review and aims to test the relationship between city development, city economic situation, design aspect and possible competitions to skyscraper height. The relationship between these variables and height is done by doing a regression analysis against skyscraper height including architectural height, occupied height and vanity height as a dependent variable.

The sample that is chosen for the study are skyscrapers that are constructed with 200m+ in height in China, excluding Hong Kong and Macau. Skyscraper development data is obtained from CTBUH, which provides latest data and research related to tall building, City economic and population related data come from the statistical yearbook of each city from NBS, the National Bureau of statistic China. Other information is found on articles published by municipality office websites.

The final product of the research leads to an understanding of the mechanism of skyscraper development in China that leads to developing a certain height pattern. The result provides a better understanding of skyscraper development in China. From understanding the data, we aim to spot problems that occur in previous development and could develop suitable advice connect to skyscraper development in the future and create a more efficient city.

4. Empirical Results

This chapter answers the research questions, by discussing results that have been derived from the statistical analyses. Section 4.1 answers the first question related to the distribution of skyscrapers and height patterns in China. Section 4.2 looks into the variables collected from the CTBUH and NBS database to spot the potential relationships between predicted height determinant variables and skyscrapers height. Section 4.3 analyzes the results from the regression analyses and examine the factors that have a significant relationship with height and section 4.4 shows some interesting findings not discussed in section 4.3 yet. Lastly, section 4.5 provides a discussion that combines the results of each research question and presents possible suggestions.

4.1 Skyscraper Distribution and height pattern

Understanding the relationship between the urban context and the architecture typology of a city is necessary to develop a sustainable and efficient city (Schläpfer, Lee, & Bettencourt, 2015). Thus, this section looks into the height patterns and location of skyscrapers, to recognize skyscrapers height patterns and the mechanism of high rise development in China.

4.1.1 Overall distribution

China is a large country in terms of land area and population. It contains the largest population and fourth largest land area around the world. China has a population of 1.4 billion people, and a land area of 9.6 million square kilometers (World Atlas, 2019). The land area is similar to the united states with 9.8 million square kilometers, but the population size in China is four times larger (World Atlas, 2019). Although there is a difference between the populations, the similarity is that skyscrapers in both countries are distributed unevenly.

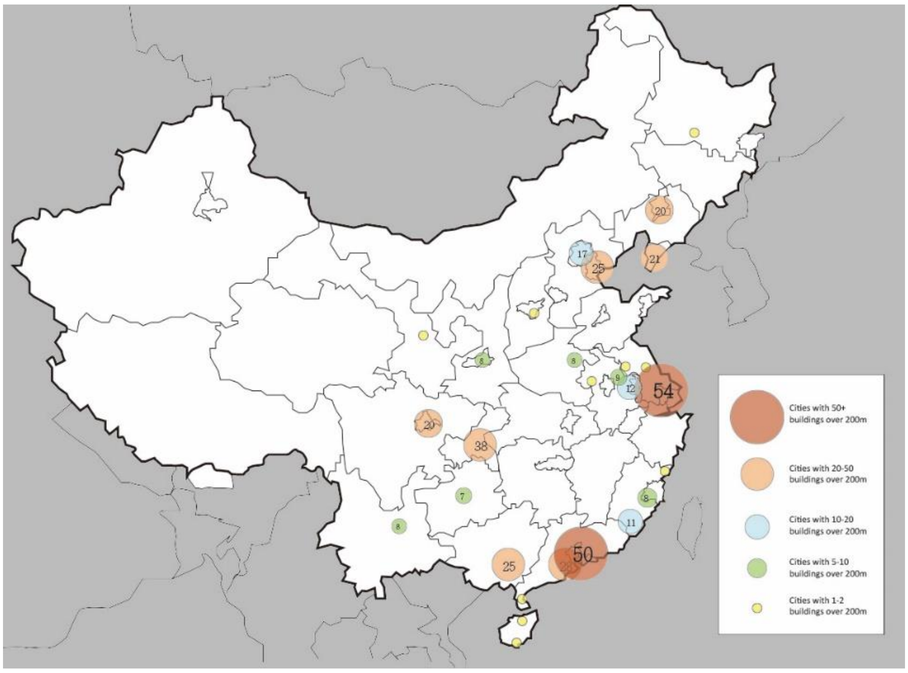

Figure 4.1: skyscraper distribution in China (Larger version in the appendix)

Most of the skyscrapers in China are located around the coastal areas in cities including shanghai, Shenzhen, Guangzhou and Beijing (Figure 4.1). These areas contain large amounts of buildings over two hundred meters, and they are also the center of the main urban agglomeration in China (Figure 4.2). As explained in chapter two, cities in China developed through a path dependent process, where cities that historically contain major ports, or is on the way of ancient trading routes grow into major cities. Guangzhou and Shanghai are ancient ports. Until present days, these two cities are still the largest shipping ports in China. Shenzhen is the first special economic zone in China and currently contains the largest amount of small to medium enterprises, accompanied by a lot of large technology companies. With this as a base, the population migrated to these cities for better job opportunities, which further increased the urbanization and development in these cities. As the population and companies move into these cities, it has strengthened the agglomeration effect and has formed city urban clusters.

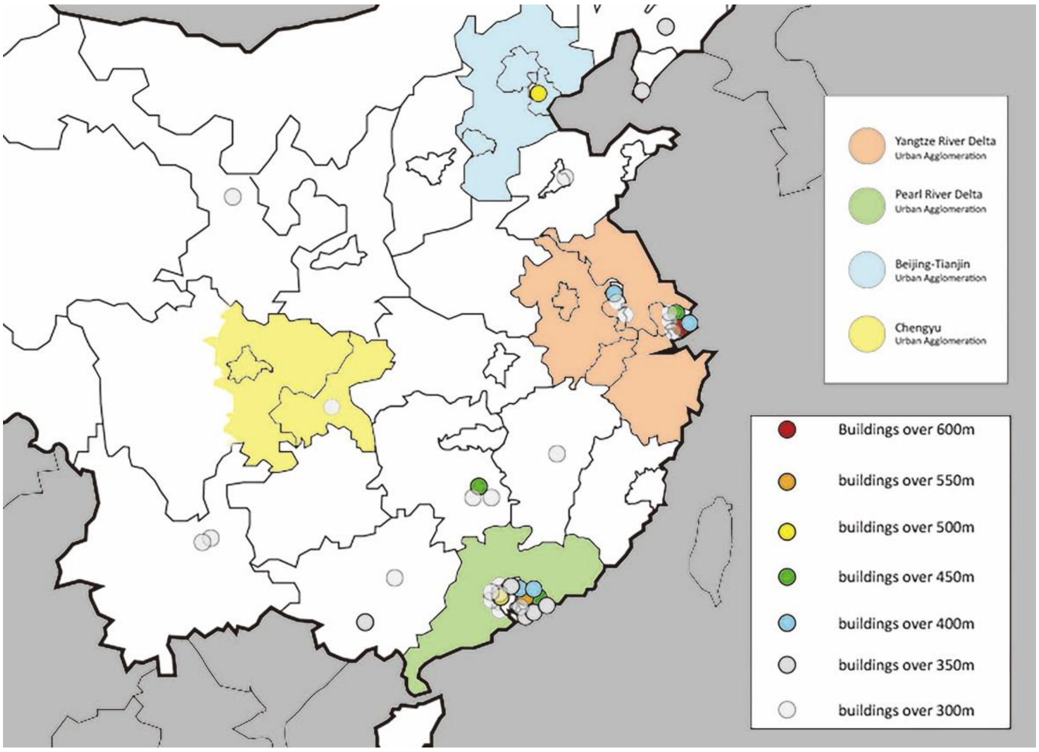

Figure 4.2: skyscraper height distribution in China (Larger version in the appendix)

The major city cluster in China includes the Yangtze river delta, Pearl River Delta, Beijing Tianjin cluster and Chengyu cluster (figure 4.2). Although these areas are stated as urban agglomeration clusters, many of them still have not developed efficient systems between cities (Miaoxi, Zhifeng, Ye & Ben, 2016). Also, due to a difference in physical location, development direction and level of economic development, there are major differences between these areas. The Yangtze river cluster is monocentric with Shanghai as the center. While the Pearl river delta is polycentric with Guangdong and Shenzhen as the two centers. The location of a city within the cluster could lead to the development of different building typologies and height. Comparing to other area Shanghai is one that has plans on limiting urban sprawl, because it is located close to the surrounding cities that is also to a certain level developed, while Shenzhen has more development possibilities and space to expand. This shows that geographical location and different city structure could lead to different development plans.

4.1.2 Distribution by year and city cluster

The amount of skyscrapers development each year in China increases exponentially. As shown in figure 4.3, the amount of skyscraper constructions remained stable until 2004 and started to grow in 2005. In 2004 there are six skyscrapers constructed over 200 meters, by 2014 this number rose to 70, and by 2017 there were 116. The amount of completions has grown ten times over ten years of time. The variable also follows this slope is city GDP. Average GDP of the cities duplicates within ten years. City and urban population also have an upward slope. Although these variables all increase through time, due to the difference in units of measurement, the relationship between these variables and skyscraper construction will be explained in the next section.

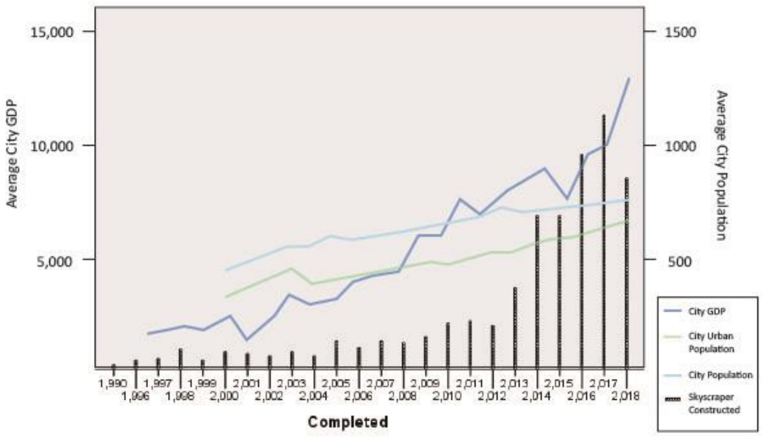

Figure 4.3 skyscraper completed each year

Constructing new skyscrapers provides more supply in space, but the amount of supply also depends on the height of skyscrapers. Building higher provided more space on a single location. The next table shows the amount of buildings within each height range and also whether they are located within an urban agglomeration cluster. Figure 4.4 shows that most of the skyscrapers constructed over 200 meters, lie within the range of 200 to 300 meters, followed by buildings around 300 to 400 meters. There are only twelve projects that are above 400 meters in China and only four of them are over 500 meters. This shows that “building higher” is not the main focus regarding most of the construction in China. The tallest building located are in larger cities and these areas contain a wider range of skyscraper height.

Figure 4.4 Height distribution within the city

Looking into the amount of skyscrapers around China, buildings located in the city clusters make up sixty percent of all the skyscrapers, while buildings located in other cities make up the other forty percent. Overall buildings located under the category of “other”, eighty percent of them are within the range of 200 to 300 meters. Furthermore, all record breaking buildings nationwide are located in major cities.

4.1.3 Record Breaking skyscraper distribution

In the introduction (chapter one) of this report is mentioned that one of the reasons for starting this research is to investigate the large amount of new projects proposed by cities in China. Among these projects, Shenzhen has proposed a new construction with the height of 700 meters, which is 68 meters taller than the Shanghai Tower, which is currently the tallest in China. Shanghai has the vision of constructing a building over one kilometer in height (1228 meters). This leads to the question of why do these buildings exist. The literature explains it as height competition and these buildings are considered to be record breaking buildings, which is the tallest building within its category. Thus, this section looks into completion year, construction time, height, and the located city of record breaking skyscrapers within the country.

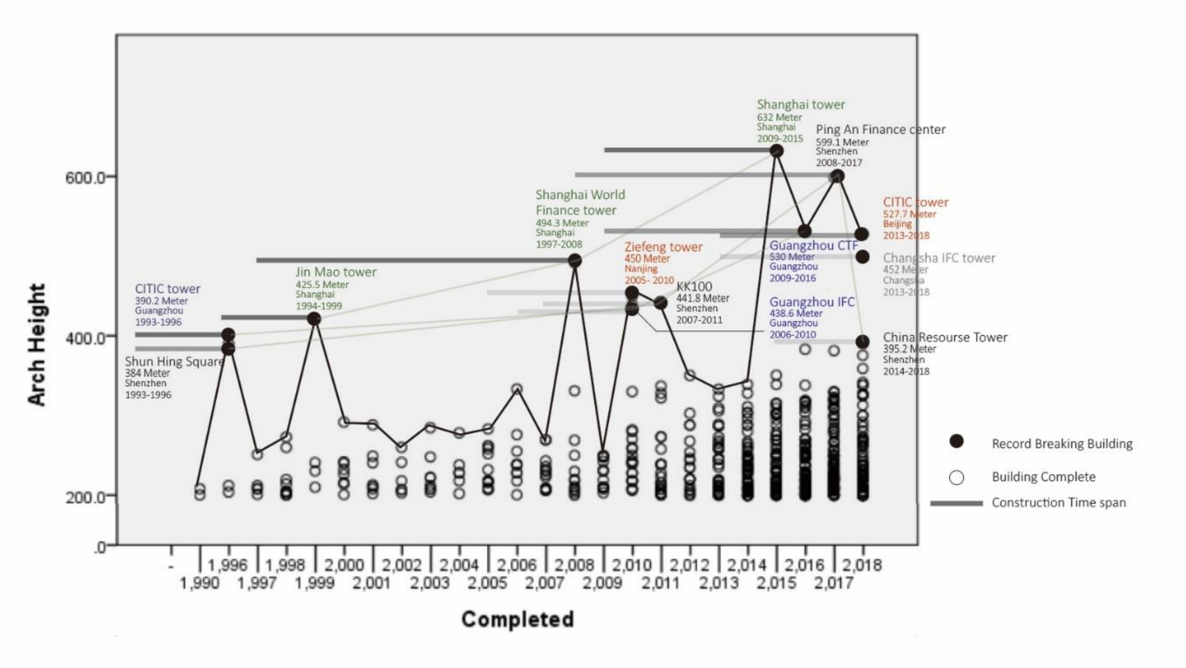

Figure 4.5: Record breaking skyscraper in Height (Larger version in the appendix)

Figure 4.5 shows the nationwide record breaking skyscrapers. These buildings are mostly located in the major cities in China, including Guangzhou and Shanghai. While observing the graph, one can derive that these buildings were constructed one after another between 1990 and 2008. When one project finished construction another started. Buildings in the major cities like shanghai and Shenzhen continuously increase in height. The construction period took longer in between buildings from year 1990 till 2008, but after that the time between each of them shortened. This was accompanied by more projects starting construction during the same period of time.

From 1990 until 2018 there are four record breaking skyscrapers within the country. Shanghai Tower, one of the buildings that is famous for its height was completed in 2015 with a height of 632 meters, while Burj Khalifa was already constructed in 2010 and is 828 meters in height. This means that it did not become the tallest building worldwide, only the tallest one among surrounding countries, where height is used as an advertisement. This suggests that there are different levels of height competition worldwide, within continents and within a country.

After 1990, Shanghai started to construct record breaking buildings and up until today remains to be the city with the tallest building. Other cities like Shenzhen and Guangdong both constructed tall buildings, but the height does not exceed the tallest building in the country. This suggests that there is limited competition between major cities, which is also what is stated in previous research about skyscraper competition in China.

4.2 Variable distribution

This section looks into the variables in the dataset to spot potential relationships and further explain the connection of each variable towards skyscraper construction and height. The variables will be observed in more detail in the form of distribution tables, cross tab analysis and correlation analysis using SPSS.

4.2.1 Descriptives

According to the explanation in chapter two there are city level factors and building level factors that could affect a skyscraper's height. The table below explains the distribution of the data collected from various sources and also shows the number of cases each database provided. These numbers give a general understanding of the dataset, including information on the maximum, minimum, average and standard deviation (SD), which shows the range of distribution of each variable.

Variables	**N**	**Min**	**Max**	**Mean**	**SD**
Arch Height	664	200	632	243.243	53.2594
Occ Height	657	154.88	583.400	226.502	48.25809
Van Height	664	0	133.400	17.21721	18.6798
City Level variables					
Number of skyscraper	664	1	87	18.071	18.4365
City Size	664	927.0	82300.0	13,544.736	18,556.8161
City population	620	37.871	3048	1016.053	699.79801
City population growth	620	37.871	809.730	318.4045	251.36405
City GDP	652	110.2390	48,043.67	8145.00965	6724.7287
City GDP growth	664	-38	26944.79	12505.60993	8363.5797
Population density	620	.04167107	1.18985	.901314	.26472229
Urbanization rate	620	.22780851	1.056756	.7063604	.20024511
% of city tertiary industry growth	620	-6.923501	33.20	13.0516636	9.3551446

Building level Determinants					
Concrete	664	0	1	.343	.4752
Steel	664	0	1	.021	.1438
Composite	664	0	1	.589	.4924
Office	664	0	1	.557	.4971
Residential	664	0	1	.083	.2758
Hotel	664	0	1	0.053	.2236
Mixed	664	0	1	.307	.4617
Type of top 1: flat top	663	0	1	.53	.499
Type of top 2: Decrease in size	663	0	1	.30	.409
Type of top 3: Bullet shape	663	0	1	.05	.218
Type of top 4: slanted top	663	0	1	.08	.271
Type of top 5: Unoccupied top	663	0	1	.10	.293
Type of top 6: Other Design	663	0	1	.03	.167
City Year fixed effect					
1990-1995	664	0	1	.003	.0548
1995-2000	664	0	1	.033	.1791
2000-2005	664	0	1	.053	.2236
2005-2010	664	0	1	.095	.2933
2010-2015	664	0	1	.256	.4368
2015-2018	664	0	1	.560	.4967
City Clusters					
Pearl Delta	664	0	1	.214	.4103
Yangtze	664	0	1	.220	.4145
Beijing	664	0	1	.081	.2735
Chengyu	664	0	1	.093	.2912
Other	664	0	1	.392	.4885

Table 4.1: descriptive table of the dataset

Architectural height of buildings has a minimum of 200 meters, due to the boundary that is set up by this research; and has a maximum of 632 meters, which is the tallest building in China, the Shanghai Tower. The average height of all buildings within the country is 243 meters, with a standard deviation of +/- 53.2594 meters. This shows that there are on average more buildings around two hundred meters, within the range of 190 to 296.25 meters. For the variable 'occupied height', there is a minimum of 154.88 meters, a maximum of 583.4 meters and an average of 226 meters. This shows that there are buildings with at least 50 meters of space that is not occupiable, and similar to architectural height, the mean (average) also shows that there are more buildings with a range of 178 to 274.25 meters in usable space. Vanity height of the buildings fall within a range of 0 to 133.4 meters. The skyscrapers with the largest vanity height is the Zifeng tower in Nanjing completed in 2010. With an architectural height of 450 meters, currently the 16th tallest building in the world, 13th in Asia and 8th in China. It is not one of the record breaking buildings nationwide, but it was the tallest building located in Nanjing.

The descriptive table above also provided information for city level and building level determinants. City determinant variables show that both city population and city urban population is growing in all cities, but the GDP of the city may increase or decreases depending on the city. This is also the same for the tertiary industry, some of the city has decreased in the percentage of tertiary industry throughout the period from 1998 until 2017. This makes it interesting to see if fluctuation in these variables will affect the height of skyscraper constructed. Compare to linear variables, building level determinants are mostly dummy variables, which is categorical variables, same as variables for year fixed effect and location fixed effect. The mean under category of city fixed effect shows that the amount of building increases as year increases, but the table does not show much about the distribution of the data regarding to height; therefore, some cross tab analysis is done in the next section for more information.

4.2.2 Data cross tab analysis

This section looks into the categorical variables and attempts to explain their relationship with height. The variables that are focused on here include: building function, material, type of building top design, political level and other.

Some cases in the literature show that an office, in general, requires a taller floor height compared to residential buildings. Thus, the first table (Table 4.2) shows the height per floor for each function, including office, residential, hotel and mixed-use functions. 41.3% of the office buildings has an average height of 4.5-5 meters, while 76% of the residential building has an average height of 3-4 meters. From this, one can verify that office buildings, in general, have a taller floor height, and the range of the floor height varies from 3-6.5 meters. While most of the residential buildings remain within a range of 3-4.5 meters. The average height per floor is calculated by dividing the architectural height by the number of floors. The outcome might show that residential buildings may require less height to reach the same gross floor area compared to an office building, this could also indicate that an office building contains more vanity height compared to residential buildings. This can be observed in the next section, where one can see that offices, in general, have more vanity height compared to residential buildings.

Height/ floor	Office	%	Residential	%	Hotel	%	Mixed	%	Total N
3-4m	29	6.5%	38	76%	8	21.1%	36	12.8%	108
4-4.5m	135	30.6%	11	22%	19	50%	95	33.8%	260
4.5-5m	182	41.3%	0	0.0%	5	13.2%	103	36.7%	280
5-5.5m	81	18.4%	1	2%	6	15.8%	35	12.5%	113
5.5-6m	7	1.59%	0	0.0%	0	0.0%	12	4.3%	19
6-6.5m	4	0.91%	0	0.0%	0	0.0%	3	1.1%	7
6.5-7	0	0.00%	0	0.0%	0	0.0%	0	0.0%	0
7-7.5m	2	0.45%	0	0.0%	0	0.0%	0	0.0%	2
Avg. Height	4.71m		3.72m		4.38m		4.56m		4.59m
Total N	440		50		38		281		812

Figure 4.2: Cross tab analysis on building function and floor height

The second table (table 4.3) shows the height distribution of skyscrapers constructed with different materials. This variable focuses on the materials the structure is constructed upon. From the previous section, by looking at the mean, maximum and minimum of architectural height, the prediction can be made that there will be more buildings that have a architectural height close to 200 meters, which is shown in this table. 62% of all skyscrapers fall under the height of 200-250 meters, while only 3% of the buildings are over 400 meters and 5% of them are over 350 meters. Other than the total building height distribution, table 4.1.2.1 also shows the number of buildings constructed with each material. 65.55% of skyscrapers over 200 meters in China are constructed using composite materials, which is a combination of RC structures (Concrete in the variable) and a steel structure. The table also shows that buildings over 400 meters are all constructed using composite materials.

Arch. Height	Concrete	%	Steel	%	composite	%	Total N	% of total N
200-250	194	83.98%	20	64.52%	264	53.01%	478	62.9%
250-300	32	13.85%	9	29.03%	116	41.28%	157	20.66%
300-350	3	1.29%	2	6.45%	80	28.47%	85	11.18%
350-400	2	0.865%	0	0.00%	15	3.01%	17	2.233%
400-450	0	0.00%	0	0.00%	11	2.208%	11	1.447%
450-500	0	0.00%	0	0.00%	5	1.004%	5	0.658%
500-550	0	0.00%	0	0.00%	5	1.004%	5	0.658%
550-600	0	0.00%	0	0.00%	1	0.020%	1	0.132%
600-650	0	0.00%	0	0.00%	1	0.020%	1	0.132%
% of total	30.395%		4.07%		65.55%		-	-
Total N	231		31		498		760	-

Figure 4.3: Cross tab analysis on building material and architectural height

Compared to the composite structure, concrete and steel are used in buildings ranging in height between 200-350 meters and only 4.07% of the buildings use steel as the only structural material. From this table, one can predict that a steel structure is not the best choice to construct buildings taller than 400 meters, while composite materials could be suitable for many different height ranges. A further investigation of the effect of these variables on height will be performed by carrying out a number of regression analyses in the next section.

4.2.3 Data correlation

Data correlation analysis is able to give an idea regarding specific data relationships. Variables with a high correlation between them shows that these variables have some connection with each other. Along with understanding the relationship between each variable, this can also uncover cases of multi-collinearity. In models that involve many predictors, if there is a strong correlation between them, the two predictors could be predicting the similar things. This makes it more difficult to understand the contribution of each variable to the model. Moreover, collinearity increases the standard error of the b-value and limits the explanatory power of the R^2 of the model (Field, 2013).

		Arch Height	Occ Height	Van Height	# of skyscraper of the year	City Size	CityPop of the year	City pop growth	City Urban population growth	GCP of the year	GCP Growth rate	Population density of the year	Urbanization rate of the year	Third industry of the year	Industry in GDP of the year	Concrete	Steel	Composite	office	residential	hotel	Mixed
Pearson Correlation	Arch Height	1.000	.939	.388	.148	-.031	.022	.115	.068	.195	.151	-.036	.146	.110	.132	-.235	-.030	.282	-.100	-.161	-.100	.258
	Occ Height	.939	1.000	.064	.204	-.008	.020	.106	.091	.246	.141	-.031	.147	.137	.108	-.230	-.059	.289	-.089	-.146	-.096	.234
	Van Height	.388	.064	1.000	-.118	-.071	.025	.077	-.031	-.088	.084	-.008	.050	-.041	.122	-.083	.109	.039	-.035	-.086	-.041	.112
	# of skyscraper of the year	.148	.204	-.118	1.000	-.056	.168	.379	.314	.649	.447	-.089	.499	.299	.295	-.025	-.057	.102	.029	-.028	-.104	.036
	City Size	-.031	-.008	-.071	-.056	1.000	.619	-.196	.501	-.002	.046	.044	-.346	-.110	.044	.237	-.034	-.185	-.240	.097	.068	.169
	CityPop of the year	.022	.020	.025	.168	.619	1.000	.450	.764	.300	.587	.291	.133	.085	.605	.125	.043	-.124	-.108	-.019	.033	.114
	City pop growth	.115	.106	.077	.379	-.196	.450	1.000	.669	.491	.810	-.052	.601	.304	.808	-.063	.109	-.001	.080	-.149	-.040	.025
	City Urban population growth	.068	.091	-.031	.314	.501	.764	.669	1.000	.441	.681	-.011	.382	.106	.609	.110	.083	-.128	-.071	-.072	.013	.116
	GCP of the year	.195	.246	-.088	.649	-.002	.300	.491	.441	1.000	.603	.027	.466	.520	.520	-.146	-.050	.234	.079	-.104	-.112	.032
	GCP Growth rate	.151	.141	.084	.447	.046	.587	.810	.681	.603	1.000	-.025	.649	.377	.887	.012	.080	-.079	.051	-.158	-.042	.063
	Population density of the year	-.036	-.031	-.008	-.089	.044	.291	-.052	-.011	.027	-.025	1.000	-.018	.004	-.064	-.053	-.043	.134	-.027	.046	.047	-.022
	Urbanization rate of the year	.146	.147	.050	.499	-.346	.133	.601	.382	.466	.649	-.018	1.000	.300	.521	-.019	.055	-.032	.084	-.112	-.043	-.002
	Third industry of the year	.110	.137	-.041	.299	-.110	.085	.304	.106	.520	.377	.004	.300	1.000	.448	-.108	-.019	.139	.030	-.069	-.030	.024
	Industry in GDP of the year	.132	.108	.122	.295	.044	.605	.808	.609	.520	.887	-.064	.521	.448	1.000	.020	.091	-.079	.007	-.096	-.034	.068
	Concrete	-.235	-.230	-.083	-.025	.237	.125	-.063	.110	-.146	.012	-.053	-.019	-.108	.020	1.000	-.107	-.866	-.103	.249	.025	-.055
	Steel	-.030	-.059	.109	-.057	-.034	.043	.109	.083	-.050	.080	-.043	.055	-.019	.091	-.107	1.000	-.174	.058	-.006	-.033	-.044
	Composite	.282	.289	.039	.102	-.185	-.124	-.001	-.128	.234	-.079	.134	-.032	.139	-.079	-.866	-.174	1.000	.094	-.210	-.070	.062
	office	-.100	-.089	-.035	.029	-.240	-.108	.080	-.071	.079	.051	-.027	.084	.030	.007	-.103	.058	.094	1.000	-.361	-.261	-.740
	residential	-.161	-.146	-.086	-.028	.097	-.019	-.149	-.072	-.104	-.158	.046	-.112	-.069	-.096	.249	-.006	-.210	-.361	1.000	-.070	-.200
	hotel	-.100	-.096	-.041	-.104	.068	.033	-.040	.013	-.112	-.042	.047	-.043	-.030	-.034	.025	-.033	-.070	-.261	-.070	1.000	-.144
	Mixed	.258	.234	.112	.036	.169	.114	.025	.116	.032	.063	-.022	-.002	.024	.068	-.055	-.044	.062	-.740	-.200	-.144	1.000
	Year Fixed Effect 1990-1995	-.042	-.027	-.049	-.055	-.005	.001	.039	.027	-.057	.066	-.175	.026	.022	.070	.018	-.008	-.068	-.066	-.018	-.013	.089
	Year Fixed Effect 1995-2000	-.001	-.065	.159	-.166	-.069	.007	.114	.044	-.183	.131	-.521	.052	-.181	.141	.025	.094	-.175	.095	-.060	-.043	-.046
	Year Fixed Effect 2000-2005	-.063	-.109	.148	-.139	-.058	.031	.154	.084	-.209	.166	-.070	.104	-.111	.157	.107	.113	-.229	-.007	-.075	.111	.002
	Year Fixed Effect 2005-2010	-.046	-.080	.090	-.120	.049	.174	.147	.104	-.173	.186	.161	.038	-.004	.207	.181	.063	-.259	-.076	.026	.049	.044
	Year Fixed Effect 2010-2015	-.016	-.030	.017	-.192	.082	.145	-.029	.043	-.012	-.009	.246	-.136	-.110	-.020	-.032	-.030	.078	-.030	.009	.031	.012
	Year fixed effect 2015-2018	.076	.152	-.191	.371	-.048	-.248	-.182	-.159	.287	-.238	-.064	.024	.213	-.241	-.144	-.098	.268	.047	.035	-.089	-.031
	City cluster pearl delta	.140	.158	-.026	.406	-.284	-.150	.152	.017	.230	.322	.000	.532	.079	-.004	-.004	-.025	-.023	.077	-.101	-.050	.003
	City cluster yangze	-.001	-.049	.153	-.027	-.152	.160	.315	.036	.041	.272	.051	.101	.022	.404	-.015	.003	-.022	-.016	-.085	.042	.051
	City cluster beijing	.055	.082	-.038	-.085	.002	.160	.407	.404	.320	.278	-.049	.158	.249	.302	-.107	.120	.097	-.014	-.031	-.013	.041
	City cluster chengyu	-.075	-.053	-.079	.019	.773	.587	-.053	.494	.061	.099	.097	-.209	-.004	.094	.198	-.049	-.145	-.158	.066	.050	.107
	other	-.105	-.109	-.039	-.292	-.105	-.464	-.602	-.583	-.455	-.734	-.077	-.508	-.226	-.575	-.045	-.019	.074	.053	.137	-.017	-.136

Table 4.4: Variable correlation

Variable correlations are demonstrated in table 4.4. The ones that have high correlations are adjusted and some are taken out during the regression analyses. Variables with correlations larger than 0.7 are considered to have too high a correlation. These variables are highlighted in dark gray and blue and will be taken into consideration when running a regression analysis. Correlations larger than 0.5 but lower than 0.7 are highlighted in light gray and will be checked during the process.

The cells that show a positive correlation between variables remains white, and the ones that show negative correlations are marked with a light orange color. Positive correlations indicate that when one of the variable decrease the other also decreases. On the other hand, a negative correlation indicates that as one of the variables increases another variable decreases. This could predict some of the relationship between variables.

The first 3 Rows contain the correlations between the types of heights and other variables. As expected, architectural height and occupied height have a high correlation with each other, but their relationship with vanity height is different. Architectural height has a strong and significant relationship with vanity height, while occupied height has a weaker and insignificant relationship with vanity height. This is because architectural height is a combination of occupied height and vanity height. Looking into height related variables, there is a positive correlation between city level determinants with architectural height and occupied height, except city size and population density in the city. According to the explanation on city development processes in chapter 2, cities expand horizontally until they reach their limit and start to develop vertically. This entails that in areas with more land, there is more freedom in developing horizontally. Different from architectural height and occupied height, vanity height has a negative correlation with the number of skyscrapers in a city, city urban population growth and city GDP. This relationship will be taken into consideration in the next section.

The number of skyscrapers in a city has a high correlation with GDP of the city, and has a negative correlation with vanity height and city size. This shows that as GDP increases, the number of skyscrapers in a city should also increase. On the other hand, regarding city size with a larger land area, the number of skyscrapers in the city will be less compared to cities with a smaller land area.
Other interesting relationships include the high correlation between city GDP and population. This may have a connection with an increase in the agglomeration effect within a city. Another interesting correlation shows that city population of that specific year has a high correlation with urban population growth. This suggests that the population that moved into the city before, went on to live in the urban area. This also matches with the situation discussed in chapter 2, where laborers move into the city for better job opportunities.

In general, the political level of the city does not have a significant correlation with height, so it is not included in this table. However, it does have a high correlation with the city level variables, including urban population and tertiary industry growth. Directly administrated cities (city level 1) have a positive correlation with these variables, which shows that these cities coincide with the cities with increasing urban population and tertiary industry growth. Then again, the political level may not have a large contribution on explaining a skyscrapers' height.

Correlations between city GDP growth and other variables show that GDP growth of a city correlates with population, urban population, urban population density and percentage of the tertiary industry. This shows that these variables have an effect on each other. After understanding the basic relationship between the variables, this can be used this as a base to construct the linear regression models that are discussed in the next section.

4.3 Regressions on height

To answer the second research question of "what factors affect a skyscrapers' height", information has been gathered from multiple databases to construct variables, with which regression analyses relevant to this research can be performed. This section explains the data fitting method and provides the results of the regression analyses.

4.3.1 Data fitting method

The research uses linear regression as the fitting model. As stated in the previous section, some variables are similar. Therefore, in the process of running the regressions, the variables that explain the data best will be selected. Thus, the end result is more than one model for each dependent variable and the model that explains the situation best will be selected as the final model. The regressions have been performed with and without location fixed effects. As predicted in the method section, each city has their own regulation and direction for skyscraper development, thus the location fixed effects is added to control for these location specific factors that have not been included in the other variables.

The variables are inserted into the model using the enter method in SPSS, where all the variables are treated as equal. As stated in the previous section, some variables are similar, therefore in the process of running the regression analyses, some variables will be excluded and adjusted to find the model that explain the data best. The analysis uses height related variables (architectural height, occupied height, vanity height) as the dependent variable. As stated in the previous section, architectural height and occupied height are highly correlated. Therefore, the regression analysis performed for these variables are compared with each other. The difference between the regressions will explain the different characteristics of these variables. As shown in the previous section, the height of the skyscrapers in China clustered around 200 meters. Although a lower bound has been set for the data, it still contains a positive skew. Thus, for some of the models a log transformation of the dependent variable has been applied (e.g. log. Arch height and log. Occ. Height in the table). By doing so, it also corrects for positive kurtosis, unequal variances and the lack of linearity between data points.

4.3.2 Architectural height

The first table uses architectural height as the dependent variable and thus aims to explain the effect each variable has on architectural height. The result of the regression analysis is listed in table 4.5, with five models, two with location fixed effects and another three without. Model 5 uses the natural logarithm of architectural height as the dependent variable. Year fixed effects are only included in model 4. Due to the lack of statistical significance with the dependent variable it was excluded in the final model selected.

	Model 1			Model 2			Model 3			Model 4			Model 5		
	Dependent Variable: Arch Height			Dependent Variable: Arch Height			Dependent Variable: Arch Height			Dependent Variable: Arch Height			Dependent Variable: Log Arch Height		
Variables	**Coefficient**	**T-Value**	**VIF**	**Coefficient**	**T-Value**	**VIF**	**Coefficient**	**T-Value**	**VIF**	**Coefficient**	**T-Value**	**VIF**	**Coefficient**	**T-Value**	**VIF**
Constant	201.091**	15.02	-	231.321**	18.695	-	233.9345**	18.8173	-	264.0135**	13.5259	-	2.36282 **	130.0103	
Vanity Height	1.308**	12.104	1.083	1.197**	11.64	1.086	0.9447**	8.3492	1.42770	0.98175**	8.4351	1.50988	0.00147**	9.0573	1.44446
Number of skyscraper	0.243	1.666	1.996	0.232	1.672	2.001	0.1573	1.126509	2.031383	-0.062930	-0.341378	3.538997	0.000330	1.440408	2.688148
City population	-0.006	0.997	4.541	-	-	-	-	-	-	-	-	-	-	-	-
City population growth	-0.016	-1.145	3.537	-0.015	-1.581	1.788	-0.0093	-0.9346	1.8650	0.0048	0.3473	3.6250	0.0000	-0.7413	2.8065
City Urban Pop growth	0.015	0.881	4.518	-	-	-	-	-	-	-	-	-	-	-	-
City GDP	.002*	3.47	2.756	.001*	2.93	2.485	0.001*	2.5684	2.4866	0.0009	1.6957	3.7035	.00000139*	2.0678	3.0579
City GDP growth	-0.000004	-0.007	5.731	-	-	-	-	-	-	-	-	-	-	-	-
Population Density	-1.836	-0.21	1.45	-7.36	-1.049	1.037	-9.9593	-1.4083	1.0551	-5.0582	-0.1710	18.4407	-	-	-
Urbanization rate	3.253	0.213	2.536	13.892	1.122	1.85	15.3713	1.2397	1.8566	4.4540	0.2904	2.8397	-0.0032	-0.1533	2.5704
Percentage of Tertiary ind.	0.124	0.662	1.514	0.052	0.302	1.396	0.0067	0.0392	1.4108	-0.0749	-0.4134	1.5604	0.0000	-0.1512	1.4246
Office	-	-	-	.052**	-5.373	1.286	-21.321**	-5.08796	1.29593	-22.4673**	-5.09970	1.43173	-0.0342**	-5.56773	1.36518
Residential	-	-	-	-22.436**	-3.704	1.303	-29.354**	-4.0141	1.3051	-31.083**	-4.1087	1.3960	-0.0512**	-4.8631	1.3273
Hotel	-	-	-	-27.091*	-3.308	1.141	-27.741*	-3.0396	1.1579	-28.8321*	-3.0521	1.2399	-0.04648**	-3.5741	1.1557
Mixed	-	-	-	-	-	-	-	-	-	-	-	-			
Composite	-	-	-	-	-	-	-	-	-	-	-	-			
Concrete	-	-	-	-20.316**	-5.018	1.119	-29.354**	-4.01406	1.30505	-16.15788**	-3.66102	1.33040	-0.0257**	-4.27441	1.21156
Steel	-	-	-	-26.607*	-2.035	1.057	-27.74135	-3.03961	1.15789	-20.59679	-1.49439	1.17676	-0.02881	-1.52875	1.08188
Type of top 2	-	-	-	-	-	-	-1.5555	-0.2810	1.4970	1.5605	0.2554	1.8236	0.0019	0.2387	1.5237
Type of top 3	-	-	-	-	-	-	28.71756*	3.2837	1.0968	28.9399*	3.1985	1.1734	0.043018*	3.4395	1.1027
Type of top 4	-	-	-	-	-	-	16.5974*	2.3271	1.1799	17.067*	2.3255	1.2488	0.02918*	2.8595	1.1874
Type of top 5	-	-	-	-	-	-	20.8147*	3.0703	1.2127	19.504*	2.8272	1.2552	0.03176*	3.2815	1.2148
Type of top 6	-	-	-	-	-	-	12.3975	1.0857	1.0498	12.1107	1.0407	1.0897	0.0204	1.2478	1.0590
Observation	620			620			619			619			619		
Fixed Effect	No			No			No			Location and Year fixed effect			Location Fixed Effect		
R2 / Adjusted R2	.231 / .219			.309/ .295			.313 / .295			.333 / .290			.359 / .337		
F-value	18.339			22.578			16.284			29.172			16.718		
Standard Error in %		0.1869		0.18315			0.18629			0.18634			0.06463		

Significant at 5% * significant at 1% **

Table 4.5: output of regression model for architectural height

The process of variable selection for constructing the model started by looking into the correlation between the variables. The first model included all the city level variables. From the variance inflation factor (VIF) column, multi-collinearity can be spotted. The second model eliminates the variables with a high correlation with other variables, also the ones that are statistically very insignificant compared to the other ones. The final model selected is model 5. It has the largest R^2 (explanatory power) compared to the other models. This number means that the independent variables are able to explain 33.7% of the variation in the data regarding the dependent variable, architectural height. This model included most of the variables and simultaneously has the lowest standard error. The final model that explains architectural height is listed as follow.

$$\mathbf{ArchH}_i = \beta_0 + \beta_1\,\mathbf{VH}_i + \beta_2\,\mathbf{GDP}_i + \beta_3\,\mathbf{F}_i + \beta_4\,\mathbf{M}_i + \beta_4\,\mathbf{Tot}_i + \boldsymbol{\lambda}_L + \varepsilon_i$$

Model one included all the city level determinant factors to filter out the ones with multi-collinearity. Three out of ten variables have a VIF over 4, thus these variables are excluded in model two. Model two included two categorical variables from the list of building level height determinants. These variables show high correlations with the dependent variables and do not show multi-collinearity, thus they are kept in the next model. Model 3 included type of top design. This variable does not increase the R^2 much, but it does have a statistically significant relationship with architectural height. Model 4 included both location and year fixed effects. These two sets of variable do not provide a significant F-change to the model. But, by comparison, the location fix effect has a higher level of statistical significance, thus it was kept in the final model.

Under city level height determinants, vanity height and city GDP are the two variables that have a significant relationship with architectural height. While most of the building level height determinants are significant. Building function and material show a high level of significance throughout all models. This shows that building function and material have a strong relationship with the skyscrapers' height decision making. The "design of building finishing", type of top design is also significant in all models. City GDP in model 5 has a higher VIF due to the inclusion of location fixed effects, but it is still within an acceptable range. An interesting observation with regard to the T-value for vanity height is that it started to decrease when the variable "type of building finishing design" was added to the model. The T-value drops from 11.64 to around 8, and the VIF also increases by 0.4. This suggests some relationship between these two variables, which will be discussed in detail in the next section.

The dependent variables used in model four is the logarithm of the variable architectural height, thus the coefficient is the expected change in percentage of the dependent variable, when there is a unit increase in the independent variable. From the result, every meter increase in vanity height will result in a 0.981% increase in architectural height.

The same interpretation applies for city GDP. The coefficient shows that an increase of 100 million in city GDP, increases the height in general by 0.009%. We can also see the coefficient in model 3, the coefficient shows that every 100 billion RMB increase in city GDP would result in a 1 meter increase in architectural height. City GDP is one of the variables that is significant throughout all the models. GDP from 1999 until 2017 of selected cities is shown in figure 4.4. Larger cities including shanghai, Chongqing, Shenzhen, Beijing could have a large GDP increase each year, but cities like Changsha, Kunming, and

Fuzhou may take up to ten years to increase GDP by 100 Billion RMB. Thus from an economic point of view, this change in height is not as significant.

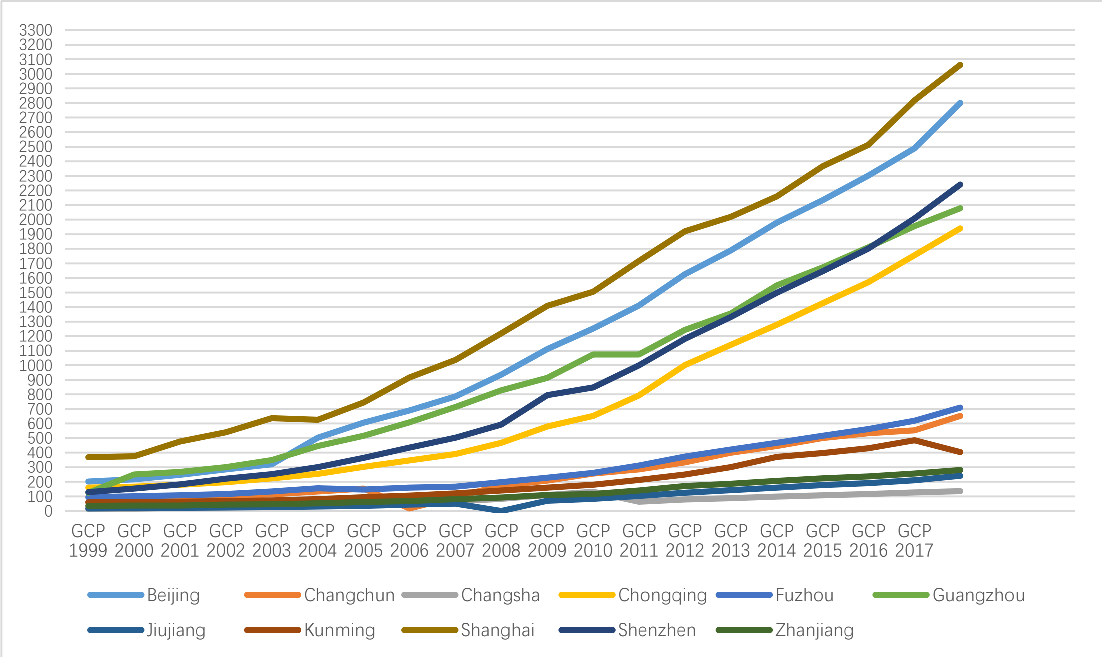

Figure 4.6: GDP of selected cities from 1999-2017 in billion RMB

Building level factors, as stated above, are mostly significant. The results show that all of the coefficients for building material and function have a negative sign. This shows that they contain less height compared to the baseline, which are the variables that are left out. For building function, mixed use buildings are left out in the model as a baseline. The result shows that buildings with all functions other than mixed use have a lower height in general, and all these variables have a high significance level. By comparison, Hotel in general has the lowest architectural height, followed by residential buildings and office building, and mixed use buildings are the tallest buildings across the country. Similar to the result in figure 4.2, the result of the model (table 4.7) also shows that office buildings in general require more height per floor, which may result in more total architectural height compared to the other functions. This also applies to mixed used buildings.

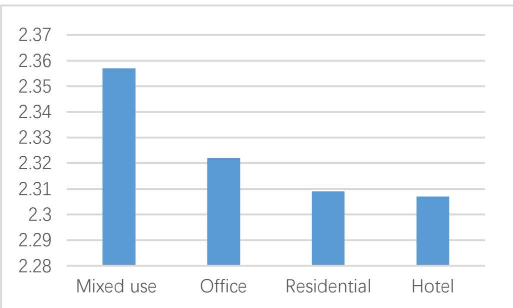

Figure 4.7: General building height to Function

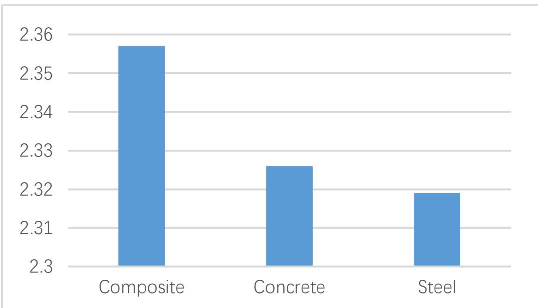

Figure 4.8: General building height to building material

Regarding the construction materials, buildings with a structure constructed with composite materials are in general taller than the ones that are constructed by reinforced concrete and steel. Although steel is one of the materials that allows construction of buildings in becoming taller, the current state of technology forces builders more towards building with composite materials. Taking the advantage of both material, one can reach further in height. Burj Khalifa, currently the tallest building worldwide is also constructed with a structure with the combination of steel and concrete, as is the Shanghai Tower, the tallest skyscraper in China (CTBUH, 2019).

The model also shows a significant relationship with "Type of tops", which is a variable that considers the design of the skyscrapers. These variables are significant at the 5%-level throughout the model, which is a bit lower than to building function and material, but still consider to have significant relationships with architectural height. The coefficient of these variables are all positive in the final model. This shows that all other designs have more height compared to buildings with a flat top. More findings regarding building design will be discussed in section 4.3.6.

4.3.3 Occupied height and Vanity height

The second coefficient table (table 4.6) uses occupied height and vanity height as the dependent variable, including one model with the linear form of occupied height as the dependent variable and one with the logarithmic format. The model construction process is similar to the one applied for architectural height. The aim is to understand how these variables affect occupied height and vanity height differently from architectural height.

	Model 1			Model 2			Model 1			Model 2		
	Dependent Variable: Occ Height			Dependent Variable: Log Occ Height			Dependent Variable: Vanity Height			Dependent Variable: Vanity Height		
Variables	**Coefficient**	**T-Value**	**VIF**	**Coefficient**	**T-Value**	**VIF**	**Coefficient**	**T-Value**	**VIF**	**Coefficient**	**T-Value**	**VIF**
Constant	223.548**	20.8948	-	2.35079**	140.7721	-	17.2198**	4.0064	-	6.32769344	1.6379	-
Vanity Height	0.02908626	0.2585	1.42742	-6.9395E-05	-0.3951	1.42742	-	-	-	-	-	-
Number of skyscraper	0.18364439	1.337882	1.984690	0.00037229	1.737627	1.984690	-0.1578*	-2.800876	1.920674	-0.08194322	-1.653251	1.975735
City population	-	-	-	-	-	-	-	-	-	-	-	-
City population growth	-0.0071	-0.7220	1.8588	0.0000	-1.0168	2.8065	0.0087*	2.1827	1.7469	0.0014	0.3873	1.8583
City Urban Pop growth	-	-	-	-	-	-	-	-	-	-	-	-
City GDP	0.001*	2.3799	2.4527	0.0000	1.8570	3.0579	-0.0003	-1.5818	2.3791	-0.0001	-0.9725	2.4489
City GDP growth	-	-	-	-	-	-	-	-	-	-	-	-
Population Density	-	-	-	-	-	-	-	-	-	-	-	-
Urbanization rate	14.9223	1.2117	1.8516	0.0247	1.2845	1.8516	9.5738	1.8757	1.8275	8.6957	1.9572	1.8399
Percentage of Tertiary ind.	0.0165	0.0965	1.4101	-0.000014	-0.0527	1.4101	-0.024962	-0.3523	1.3886	0.029989	0.4843	1.4096
Office	-20.613**	-4.94614	1.29580	-0.035573**	-5.46866	1.29580	-4.193988*	-2.43321	1.27361	-2.98312*	-1.98433	1.28739
Residential	-29.2815**	-4.0345	1.2995	-0.053419**	-4.7155	1.2995	-8.08367*	-2.7595	1.2165	-7.09796*	-2.7188	1.2838
Hotel	-28.1274*	-3.1032	1.1545	-0.05064**	-3.5792	1.1545	-8.584687*	-2.2971	1.1278	-7.9264*	-2.4282	1.1434
Mixed	-	-	-	-	-	-	-	-	-	-	-	-
Composite	-	-	-	-	-	-	-	-	-	-	-	-
Concrete	-17.3011**	-4.22788	1.15681	-0.0294**	-4.60294	1.15681	-	-	-	-3.2555*	-2.20710	1.14754
Steel	-15.30757	-1.17101	1.07065	-0.02529	-1.23968	1.07065	-	-	-	10.773*	2.28700	1.06145
Type of top 2	-1.8230	-0.3314	1.4951	-0.0023	-0.2670	1.4951	-	-	-	20.6996**	11.4764	1.2271
Type of top 3	27.37851*	3.1482	1.0964	0.04054*	2.9864	1.0964	-	-	-	16.413**	5.3367	1.0470
Type of top 4	14.183151*	2.0041	1.1745	0.025652*	2.3222	1.1745	-	-	-	17.6576**	7.1830	1.0819
Type of top 5	18.6777*	2.7768	1.2068	0.02876*	2.7394	1.2068	-	-	-	18.96277**	8.2142	1.0854
Type of top 6	10.7239	0.9455	1.0470	0.0150	0.8483	1.0470	-	-	-	7.7253	1.8876	1.0408
Observation	619			619			619			619		
Fixed Effect	Location Fixed Effect			Location Fixed Effect			No			No		
R2 / Adjusted R2	.198 / .171			.217 /.191			.058 / .046			.299/.282		
F-value	7.371			8.288			4.742			17.182		
Standard Error in %		0.19823		0.07016			1.09204			0.947366		

Table 4.6: Models for Occupied height and vanity height

Model 2 is selected for occupied height and no model are selected for vanity height, but compared to the other two height variables, the model with vanity height as the dependent variable has a lower R^2 by comparison. Also the percentage of standard error for the model is a lot higher than the other two. This shows that these variables may not explain vanity height as much as architectural height and occupied height do.

The model for occupied height is similar to the one for architectural height, both models also contain city GDP, building function building materials and type of top design as variables. The difference is that the model for occupied height does not shows statistical significance with vanity height. The final model for Occupied height is expressed as follows.

$$\mathbf{OccH_i} = \beta_0 + \beta_1\, \mathbf{GDP_i} + \beta_2\, \mathbf{F_i} + \beta_3\, \mathbf{M_i} + \beta_4\, \mathbf{Tot_i} + \boldsymbol{\lambda}_L + \varepsilon_i$$

The results for vanity height seems to be a bit different from the other two models and has a less significant relationship with both city level determinants and building level determinants. The R^2 and F-value are relatively lower and the standard error is higher. Thus the model is relatively a worse representation of the dataset compared to the other models, so no models are chosen, but model two seems to be a better representation between the two, so the final model for vanity height is still expressed as follows:

$$\mathbf{VanH_i} = \beta_0 + \beta_1\, \mathbf{F_i} + \beta_1\, \mathbf{M_i} + \beta_5\, \mathbf{Tot_i} + \varepsilon_i$$

Although the model of vanity height all could not model the situation well, there are still some interesting relationships between vanity height and other variables. First, the other models both have a positive relationship with the number of skyscrapers in the city, while vanity height has a negative coefficient. Additionally, the variable “number of skyscrapers” in the city is significant in one of the models. This suggests that in cities with less skyscrapers, the buildings will contain more vanity height. This is a sign of height competition between buildings in cities with less skyscrapers. Another interesting relationship is the connection between city GDP and vanity height. Similar to the number of skyscrapers in the city, the coefficient for city GDP in the model for vanity height also contains a negative sign. This suggests that in cities with a lower GDP, may in general have a larger vanity height in buildings. However, this result is not significant, thus more research could be done on vanity height concerning this matter.

4.3.5 Comparing Models

The results with each type of height as the depedent variable shows high correlations with City GDP. This potentially shows that skyscraper development is highly correlated with city’s economic situation, but there are also differences between them. The coefficient for GDP in the model with occupied height as the dependent variable has a smaller number (Table 4.7). This shows that although both variables have a significant relationship with city GDP, it has more influence on architectural height compare to occupied height. On the other hand, building function and materials have a strong relationship with both occupied height and architectural height, and in this case, they have a larger effect on occupied height than architectural height according to the coefficient.

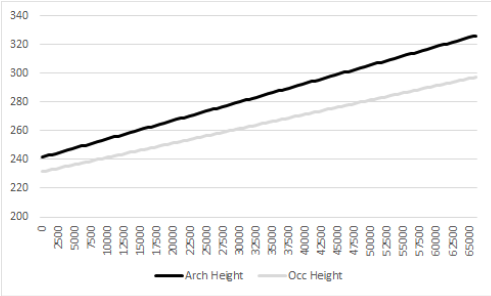

Figure 4.9: City GDP to Heights

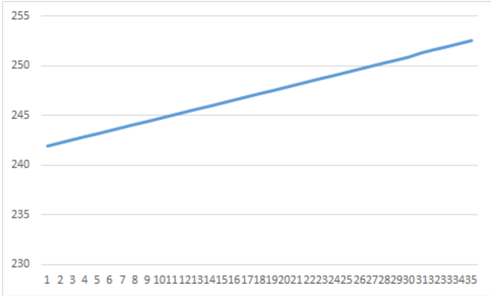

Figure 4.10: Architectural height to Vanity Height

As stated above, the model of vanity height does not perform well considering explaining the data, according to the results shown in table 4.6. Architectural height has a strong relationship with vanity height and it has a coefficient of 0.98 in model 4. This shows that an increase of one meter in vanity height would result in a 0.98 meter increase in architectural height. This number does not show exactly how vanity height affects each building, because it takes all buildings in the city into consideration. It basically shows that there are buildings that have a certain vanity height and on average an increase of 1 meters of vanity height in the city, increases architectural height by around one meter on average.

Regarding location fixed effects, city administered level and political level of the city a strong influence on the height of the building cannot be found. Cities that are directly administered by the central government do not necessarily have higher skyscrapers, but in general these cities have more skyscrapers compared to the other cities. Similar to location fixed effects that look into city clusters, these only show insignificant effects on skyscraper height.

Different from location fixed effects, time fixed effects do show some differences between the different heights. For time fixed effects there are no significant findings in both models with architectural and occupied height as the dependent variable, but have a higher significance level in the model for vanity height. The result does not show a noticeable direction for the relationship between vanity height and the year of completion, but it does show that buildings constructed after 2013 all have lower vanity heights compared to buildings constructed before the year 2000. This is also shown in figure 4.11.

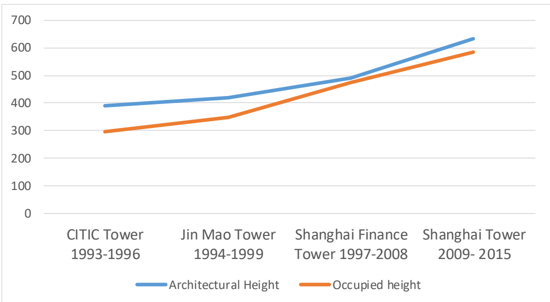

Figure 4.11.1 Height of national record breaking building

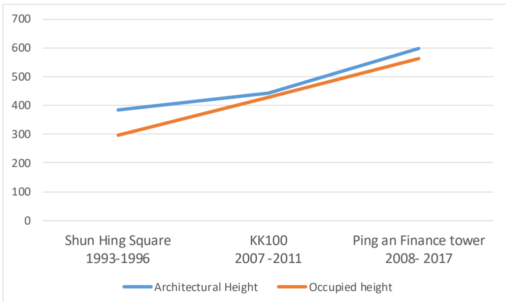

Figure 4.11.2: Height of record breaking building in Shenzhen

Figure 4.11 Vanity height of record breaking building

According to the graph above, vanity height of record breaking buildings nationwide and buildings within the city Shenzhen both show decrease over time. What is different from research that study skyscrapers worldwide, is where vanity height increases as the construction and completion year is approaching the present day. This shows that the logic and system behind the skyscraper construction in China may be different from the rest of the world. This also suggests that these buildings do not focus as much on height competition compared to other buildings around the world. One can compare this for example to the Burj Khalifa that contains 245.3 meters of vanity height, and the Jeddah Tower that predicted to have around 360 meters of vanity height, both buildings outside of China. The tallest building in China, The Shanghai Tower, only contains 48.6 meters of vanity height (Moon, 2018).

4.4 Other Findings

There are a number of interesting, additional findings when observing the results of the regression analyses, including for example the relationship between type of building top design and vanity height, which will be discussed in this section. There are also variables applied for testing some predictions, including time fixed effects, location fixed effects and nationality of the construction coalitions that do not have a significant relationship with the dependent variable. To understand these variables better, individual models have been performed with only these variables and height. Although models without control variables does not that in consideration of other variable, but it could show if the variables have relationship with the dependent variable in situation when other influence are included. According to the results, many of the variables still do not show any statistical significance or have multi-collinearity with other variables, but it shows some interesting findings. This will also be explained in this section.

4.4.1 Building design

Dependent Variable: Architectural height				
Model		Coefficient B	t	Sig.
1	(Constant)	231.286	86.264	0.000
	type 2	11.054	2.151	.032
	type 3	46.383	5.007	.000
	type 4	35.861	4.786	.000
	type 5	39.109	5.623	.000
	type 6	29.045	2.422	.016

Model 4.7.1

Dependent Variable: Occupied height				
Model		Coefficient B	t	Sig.
1	(Constant)	223.800	89.859	0.000
	type 2	-10.015	-2.098	.036
	type 3	29.214	3.395	.001
	type 4	17.324	2.489	.013
	type 5	19.798	3.064	.002
	type 6	20.341	1.826	.068

Model 4.7.2

Dependent Variable: Vanity height				
Model		Coefficient B	t	Sig.
1	(Constant)	7.726	8.808	.000
	type 2	22.368	13.305	.000
	type 3	16.930	5.586	.000
	type 4	18.296	7.464	.000
	type 5	19.235	8.453	.000
	type 6	8.465	2.158	.031

Model 4.7.3

Table 4.4: Regression model for Type of tops

Firstly, the result of building top design is discussed. The model with Type of top as the independent variable shows a strong relationship with all height related varaibles. The model with Architectural and vanity height as the dependent variable have significant results for buildings under all categories. The categories are listed in figure 4.12. Similarly, models with occupied height as the dependent variable show significant relationships with all types of top, except type six, which is the category of others. Vanity height shows 0.01% level significant with type one to five, and 0.05% significant level with type six design. This shows that Building design have most relationship with vanity height, followed bu architectural height and occupied height.

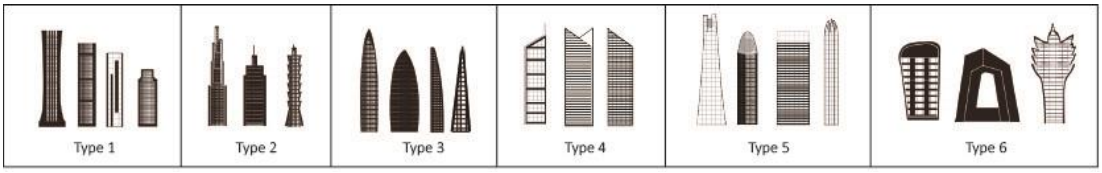

Figure 4.12: Type of top design

All models leave out type one, flat top, as it is used as a baseline. The result of model 4.4.1 shows that buildings with designs other than type 1 have taller architectural height compared to buildings with a flat top and buildings falling under the category of type three are in general taller than the other designs. The other two models (4.4.2, 4.4.3) show that skyscrapers under type two in general have less occupied height compared to buildings with a flat top. This is also shown in the regression model for vanity height. It shows that buildings under the category of type two in general have more vanity height compared to the other types. According to the explanation under section 4.2.1, the building that contain the most vanity height in China is Zifeng tower in Nanjing, which has a type two top design. This suggests that building with a design that decreases in size as height increases, contains more vanity height compared to the other designs, while buildings that have a slanted top (type 3) are in general taller then buildings with other designs.

This is also shown in figure 4.13, buildings that have a vanity height over 75 meters are all buildings with a type two building shape, and most of them are located in cities that are not directly administered by the central government (Directly administered city are marked by a red dot). Much of the height comes from the spires on top of the building. These kind of structures do not add on as much construction cost to the buildings compared to occupiable space, thus these structures are mainly used to increase height. For example the Shimao International Tower has a vanity height of 87 meters, which comes from the spires that are placed on top of the building roof, similar to the CITIC plaza with 120.3 meters of vanity height. These structures are considered design features and it does affect a skyscrapers' height. The building that is slightly different from the other ones is the Ziefeng Tower, which has 133.39 meters of vanity height, which means that not only the spires are not usable, but also some of the building spaces are not occupiable. This suggests that the building is not designed for function. Rather it focuses on height, which makes the building not as efficient compared to the others.

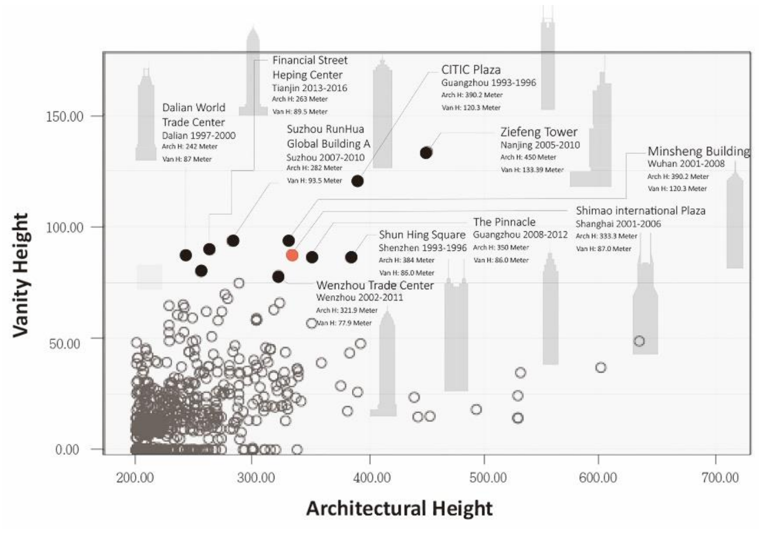

Figure 4.13 : Building vanity height (Larger version in the appendix)

Buildings with a vanity height of 75 meters and above are buildings with an architectural height from 200 meters to 500 meters. Regarding buildings over 500 meters, the vanity height is below 50 meters. At the same time, buildings around 200 to 400 meters have a wider range of vanity height. The buidling with more than 75 meters of vanity height are not record breaking buildings national wide, but most of them were once the tallest building in the city, except The Pinnacle in Guangzhou Financial Street Heping Center and Shimao International Plaza in Shanghai. This suggests some form of height competition between the buildings, but it may also have to do with the design trend during the period.

Excluding these buildings, the other buildings are all completed before 2011. During the periodfrom 1931 until 1993, buildings over 300 meterss around the world (mainly in the U.S.) uses the design where buildings decrease in size as height increases and end with a tip or spires on top of the building. Out of fifteen buildings eleven of them use this design.

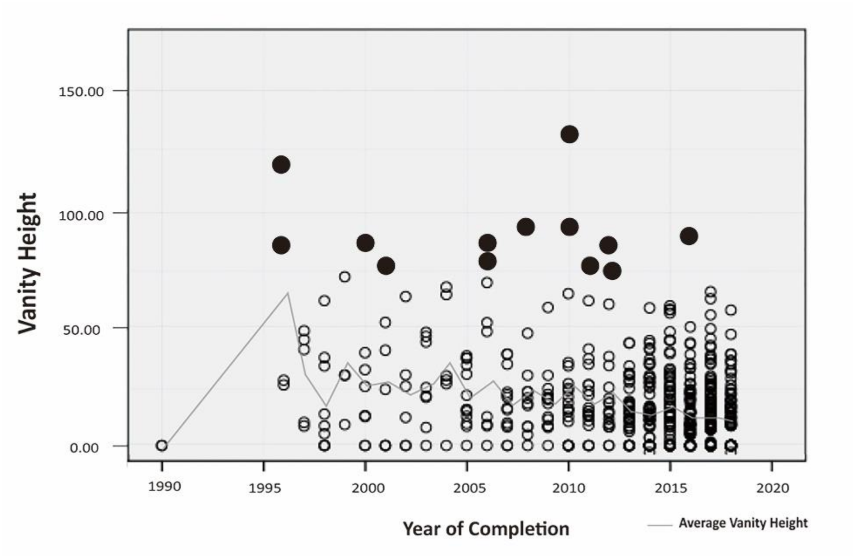

Figure 4.14 : Building vanity height

There are seven building with more than fifty meter vanity height that is constructed after 2015. Most of the building range from 200-350 meter. Also these buildings located in cities that is not directly administered by the central government. Three of them located in the city of Nanchang, under a building project including Jiangxi Nanchang Greenland central plaza 1, A and B, with average height of 303 meters, they are the tallest in Nanchang. Another one in Yantai with architectural height of 323 meters also the tallest in the city. There are also buildings that are not the tallest in the city, one in Wuhan with 223 meter and another in Shenyang with 249 meters. This shows that vanity could be used in competition to be the tallest building in a location, but could also be used as a design feature.

4.4.2 Nationality of construction Coalition

Another independent variable that is excluded in the previous model is the nationality of the construction coalition. It is not significant in the previous models, but in the model below with Nationality of construction coalition as the independent variable it shows a significant relationship with the category of international and mix. Models with architectural height and occupied height as the dependent variable yield similar results, thus the model shown are model for architectural height and vanity height. These models have an R^2 of 0.011 till 0.02, which does not explain the variation in the data points very well, but it does give an idea about the relationship between these variables and height.

Dependent Variable: Architecutral height					
Model		Unstandardized Coefficients B	Std. Error	t	Sig.
1	(Constant)	244.255	3.980	61.368	.000
	Mixed	34.687	5.731	6.053	.000
	International	-12.442	5.522	-2.253	.025

Dependent Variable: Vanity height					
Model		Coefficients B	Std. Error	t	Sig.
1	(Constant)	13.685	1.889	7.246	.000
	International	6.056	2.411	2.512	.012
	local	11.988	4.762	2.518	.012
	Mixed	6.162	2.502	2.463	.014

Table 4.8: Regression model for Nationality of construction coalition

The result shows that buildings design by international construction coalition in general have less height compared to buildings constructed by local and mixed coalitions. In general, buildings design by local design coalition also contain the most vanity height, while buildings design by international and mixed coalitions contain similar amounts of vanity height. In the model with architectural height as the dependent variable, buildings design by international and mixed both show significant results, while the category 'local' does not. This shows that local buildings have a wider range of heights compared to the other two categories. This result suggests that international construction coalitions do not have a strong focus on height competition and the tallest buildings in China are mostly built by a construction coalition with a mix of international and local parties.

4.4.3 Relationship between year of completion, location and height

From the observations one can derive architectural and occupied height of buildings in general are not affected by time fixed effects. This means that the events specific to each year does not have a unify direction of effects towards skyscrapers height. However, because there are a lot of skyscrapers around 200 meters, that may cause the mean of skyscrapers' height to cluster around 200 meters. Thus, two more models were run using height above 250 meters as the dependent variable and another one with a height of 300 meters and above as the dependent variable. The results of these two models show the time fixed effects are still insignificant in models with 250 meters above and 300 meters above. This result is similar to the result obtained for the dependent variables with a height above 200 meters.

	Arch Height above 250m		Arch Height above 300m		Arch Height above 400m	
	B	Sig.	B	Sig.	B	Sig.
Completed 2010	-8.658	.799	7.967	.894	-	-
Completed 2011	-10.798	.758	-41.083	.462	23.800	.728
Completed 2012	-37.983	.298	-71.733	.283	21.300	.787
Completed 2013	-45.612	.140	-80.108	.153	-	-
Completed 2014	-40.940	.185	-81.273	.130	-	-
Completed 2015	-24.391	.395	-60.503	.198	211.500	.045
Completed 2016	-33.026	.249	-53.543	.267	109.500	.211
Completed 2017	-18.860	.500	-49.721	.281	105.050	.175
Completed 2018	-1.457	.959	-15.920	.730	107.200	.149

Table 4.9 : Regression analysis for Architectural Height with different benchmark and year of completion

The result shows that there is still only an insignificant relationship between year of completion and architectural height. Thus the individual models with different heights are also performed to understand the relationship between completion year and height.

	Architectural height		Occupied height		Vanity Height	
	B	Sig.	B	Sig.	B	Sig.
(Constant)	240.017	.000	210.226	.000	29.791	.000
Completed 2011	8.742	.578	20.365	.150	-11.618	.037
Completed 2012	.893	.956	7.118	.623	-6.225	.277
Completed 2013	2.545	.855	16.487	.189	-13.941	.005
Completed 2014	-7.131	.572	8.469	.455	-15.847	.000
Completed 2015	8.865	.482	21.144	.062	-12.279	.006
Completed 2016	-2.318	.849	15.615	.153	-16.851	.000
Completed 2017	5.825	.626	22.321	.038	-16.497	.000
Completed 2018	15.691	.202	33.980	.002	-18.414	.000

Table 4.10 : Regression analysis for Height and year of completion

The result (table 4.10) suggests that the height of skyscrapers does not increase or decrease in certain years between the years 1990-2016. There are some significant effects in the year 2017 and 2018, but in general there is no significant difference between the years. With regard to vanity height, although it is significant from 2013 until 2018, it has a negative coefficient, which shows that vanity height is decreasing. From these observations, one could predict that most of skyscrapers in China are developed according to function and economical purposes rather than competition in height with other buildings. There is an increase in the amount of skyscrapers constructed, but this does not really have an impact on the height of the skyscrapers.

Regarding to location fixed effect, most of the most shows only significant for Pearl Delta City agglomeration, which is the cluster that contains Shenzhen and Guangzhou. The model that included all cities as the independent variable also shows that Shenzhen, Guangzhou are the cities with relationship with architectural height. In these cities height of building is in general taller than the other cities, while the other does not shows significant patterns.

Dependent Variable: LogArch Height

Model		Coefficients B	Std. Error	t	Sig.
1	(Constant)	2.375	.003	762.101	0.000
	City 13	.049	.013	3.711	.000
2	(Constant)	2.373	.003	754.922	0.000
	City 13	.051	.013	3.892	.000
	City 2	.060	.017	3.498	.000
3	(Constant)	2.370	.003	704.979	0.000
	City 13	.054	.013	4.145	.000
	City 2	.063	.017	3.698	.000
	City 43	.025	.009	2.688	.007

Dependent Variable: LogArch Height

Model		Unstandardized Coefficients B	Std. Error	t	Sig.
1	(Constant)	2.361	.010	238.500	0.000
	City cluster pearl delta	.038	.012	3.224	.001
	City cluster yangze	.020	.012	1.653	.099
	City cluster beijing	.027	.015	1.854	.064
	other	.007	.011	.647	.518

Table 4.11: Analysis results for location fixed effect

There are literatures that spotted height competition between smaller cities (Barr, 2018), but this research does not spot strong sign of competition after year 2010. To understand the situation more a map is drawn (Figure 4.15) with the cities that contains tallest building, under the category of “other” (cities that is not located in any of the clusters). All of these buildings have height within the range of 250 meter to 400 meter. From the year of construction and the height of the tallest building in each city, there are not clear sign of competition between three cities that located on the north eastern part of China including Shenyang, Dalian and Yantai.

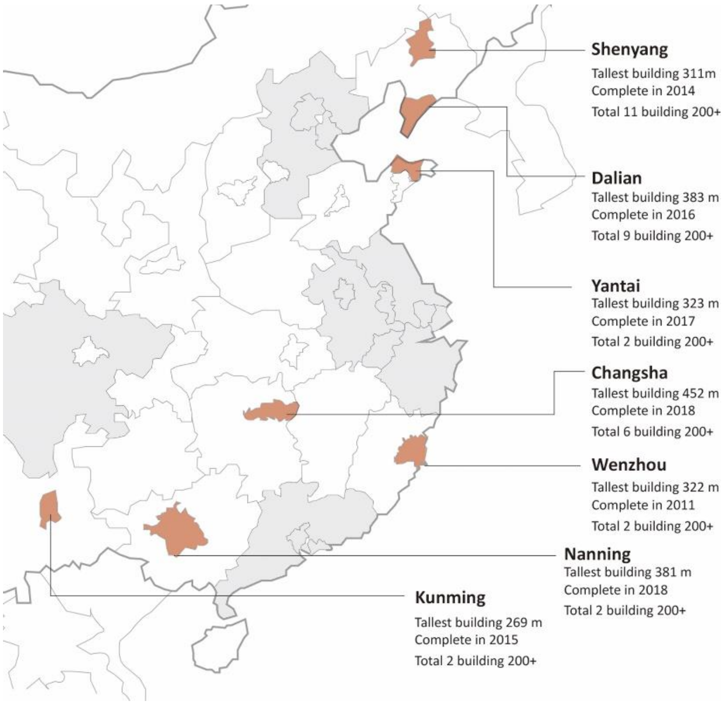

Figure 4.15: Location of cities with tallest building that is not located in any urban cluster

Regarding to cities on the south eastern side of china, Changsha is the city that contains the tallest building (452 meter). Currently Changsha propose new projects that have a height of 400 meter, which is not taller than the tallest building now, and the new building propose in Nanning have a height of 445 meter (CTBUH, 2019). These are also cities with lower GDP growth rate (figure 4.16 in appendix). From these observation, I conclude that there is no clear sign of height competition between cities in China.

4.5 Discussion

In general, from the results one infer that building height does not have a significant relationship with city level height determinants. Looking into the height distribution around the country, it also shows that there are more buildings around 200 to 300 meters compared to the ones above 300 meters. This on one hand shows that most of the skyscrapers constructed in China related more to the economical perspectives, including construction cost and demand of a location, rather than competition. On the other hand, it also shows that lands in the urban area are not used efficiently. This is also proven by the expansion of cities in China.

From the correlation table one can derive that the amount of skyscrapers in a city has a high correlation with these city level determinants. This suggests that the demand of space is absorbed by the amount of skyscrapers constructed rather than height. According to the theory stated in the literature review, skyscrapers are first designed to provide more space in a location due to high land prices and a limited amount of land, but China has large amounts of empty land around. This may be the reason why there are more skyscraper development projects that stay around 200 meters. Currently there are also many new projects constructed below 200 meters, many of which are in the range of 50 to 100 meters.

This causes many cities to expand and could lead to more transportation time between places in the city, which makes the city less efficient. Due to this reason, it is suggested to set up lower limits for height, or higher FAR around the CBD. This could lead to more constructions with increased height, which could contain a larger portion of the population in an area, to enhance city agglomeration and efficiency.

4.5.1 Other Findings

In terms of location and time, there is no significant pattern that could be spotted from the data. This shows that the average skyscraper height is around the same across different cities and time period. There is mainly an increase in the amount of skyscraper constructed each year, rather than average height. The only significant variable is cities in Pearl Delta urban cluster under city fixed effect. This shows that there is a higher average height in these cities. The coefficient shows that it has 3.8% more height which is around two more floors more than the other cities. Which is a lot more space in cities like Shenzhen and Guangzhou, because they also contain a large number of skyscrapers. More study could be done on the amount of skyscraper and the actual space these buildings provided in these cities.

Regarding competition and record-breaking buildings, the result does not show competition in major cities. Usage of vanity height to compete between smaller cities seems to happen before the year 2010. After 2010 the amount of average vanity height of buildings constructed in the year decreases, this may be due to the design trend of buildings. When vanity height decreases, a larger percentage of a building could be used to accommodate function. This makes the building in China more efficient in terms of occupiable space. There is also no sign of competition in cities that are not located in urban clusters. This result is similar to the study of Barr, that does not spot competition between cities. Which is different from the studies that spotted competition in other country. This shows that there may be difference between skyscraper construction in each area.

Looking into skyscraper construction in China does follow the curve of the GDP, but there are also cities with a decrease in GDP in general that contains skyscraper over 200 meters. This result aligns with other studies, stated that skyscraper construction highly correlated with the economic situation of a location. There are some situations where cities with low economic growth constructed buildings over 400 meters, for example, Changsha IFC (figure 4.16 in appendix). This shows that a small number of cities in China did use skyscraper as an advertisement to attract companies and population, with the goal to improve the economic situation of the city, but this is not the majority.

4.5.2 Summary

Some of the results in this research show similarity to previous research, including the connection between skyscraper development and economic situation; there are also results that contradict the previous research results, including height competition and location-specific factors. This shows that skyscraper development in each country could be different due to many reasons. Some Specific characteristic could largely influence the construction pattern. Also, skyscraper development connects with height and also the number of buildings. This research focuses on height, the results derived also from the perspective of height, so more studies could be done on the connection between the amount of skyscraper and height.

5. **Conclusion**

This research focused on skyscraper height in China. The aim was to find out height determinants that effect height and produce a linear regression model that expresses the relationship between all the variables to height. Quantitative research was chosen as the method from the beginning of the research. The motivation of this research was to provide empirical evidence that explains the mechanism of skyscraper development in China, where these results could be used as a base to make decisions on future development.

Variables from city level and building level were used to see if they have a significant effect on skyscraper height pattern. Each variable went through regression analysis to find out the relationship with height. The variables that always have a significant relationship with height include the function of the building, material used to construct the structure, building finishing design and the GDP of each city. Location, in this case, does not show significant influence on height. By looking into skyscraper distribution across China, there are clusters of skyscrapers in cities, for example, Shenzhen and Shanghai, but these cities contain buildings with a wide range of heights, therefore city level factors may not portray much relationship towards skyscraper height while building specific variables are mostly significant.

Although China seems to have many skyscraper constructions, it is not as dense across the country, due to the large amount of land. The cities that contain a high density of skyscrapers are the ones that are stated to be the cities with leading economic status. Skyscraper distribution in China is uneven which means that the demand for space is different in each area across the country. This is explained by the path-dependent development process of urbanization and population migration in China. Population and resources flow into these cities which starts to make the other cities shrink in population. A skyscraper could be a good typology for areas that need many people and aims to create an agglomeration effect, but it also creates uneven city development. Previous research stated that current city clusters do not have efficient connection with each other, this could also be the reason why a large amount of population and companies cluster around one city.

To solve the problem of uneven city development, the suggestion to the government is to develop a city cluster that has more efficient connections between each other in terms of transportation, information and resource sharing, and leads to clusters that contain more than one center. This prevents tall buildings clustering in nearby blocks, and also separates the crowd of workers during rush hours. Along with decreasing transportation cost within a city.

Next to vertical growth, there is horizontal growth in cities in China. If we look at another aspect, we can see that the development in China has a wide range of heights, which makes the cities grow more horizontally than vertically. As these cities grow in size and in population, it will reach situations where cities start to become less efficient in terms of transportation and also the quality of life. Many large cities in China require one to one and a half hour in transportation to travel from the out-skirt of the city to the city center.

As stated in the discussion section, more buildings are constructed around 200 meters and there are also many newly constructed buildings around 50 to 150 meters. This is due to the large amount of empty land in China, which gives these cities a large possibility for expansion. Cities like Shenzhen are still planning new development projects on the out skirt of the city.

To create an efficient city, the suggestion is that the government could set up lower height limitations. The lower limit could be used to provide efficient space within a building, and to prevent developers from constructing buildings that are too low. This leads to developing a more compact city, where citizens are closer to the city center. Furthermore, this solves the problems for city growth in size. There little signs of competition spotted, thus there is no need for upper height limitations.

Regression analysis

Comparing regression analysis results of each type of height. Building level height determinants show a strong relationship with height in all of the models. While GDP is the only variable that has a strong connection to height within city level height determinants. From the cross tab analysis, 54% of buildings constructed over 200meter are office buildings and another 28% is mixed use which mostly also contains office space. This shows that the office is currently the function that is constructed taller compared to the other spaces. The cross tab analysis also shows that there are 50 residential buildings over 200m while there are 440 office buildings over 200m. This explains why skyscraper height is connected to city GDP because these buildings are mostly office building that highly correlate with the economic condition of a city.

Although the variable "GDP of the city" is not economically significant, it is statistically significant and shows that GDP does have a correlation with skyscraper height. Cities with a high GDP tend to have taller buildings, and these results have higher relationship with architectural and occupied height compare to vanity height. This also suggests that most of the skyscrapers in China follow economical reasoning rather than height competition. Although there are record breaking buildings in the list of newly proposed buildings, these are the minority compared to all other buildings constructed in cities. They only take up 1.5% of all buildings over 200 meters. Furthermore, the results suggest that height competition is a trend, related to popular building shapes and design. There may be competition between smaller cities in China, which mostly occurs before 2010. This also proves that buildings are primarily designed efficiently in China.

In terms of urban development, there are minimum relationships between skyscraper height and city level height determinant. This could be caused by several different reasons. The first one is related to the planning process. According to the research motivation, there is a lack of statistical base for governmental planning decisions. This could lead to development that does not correspond to the demand. This shows that skyscraper height is an important topic to study because it affects many aspects of a city, including the capacity for a city to accommodate population, activities, and efficiency. Another reason could be rooted in the variables used in this research. this variable does not pick up the actual supply of space that each building provides. Without complete data base it is hard to understand whether the current development aligns with the real demand, thus this is a possible future study to achieve better development plans.

From the perspective of building construction decision, the results show relationship between height, design trend in China, building function and material. This result suggested that skyscraper height has more connection with building level decision rather than city level demand and planning directions. This may be cause by a lack of regulations regarding skyscraper height. Moreover, it could show that the aspect of skyscraper height is not taken into consideration during the planning period. As height is a tool for the municipality to developed efficient cities. Doing city planning without taking into consideration the city level variables, including population growth, urbanization rate, and population density, could lead to negative effects. Thus, this research provides a first understanding for the situation, but more research could be done.

5.2 Limitation

The limitation of this research mainly derives from data availability. There are other aspects that are stated in literature to have a connection to skyscraper height, but due to the lack of data, it was not included in the model. The model is constructed using the available variables. The R2 of all the models related to height lies around .15 to .35 which means that there are many other aspects that could be used to explain the data. Also, from looking into the skyscraper distribution, more buildings could be involved in the database. In the next research, we could lower the boundary to 150m + building or even 100m+ buildings.

There are also limitations in the ability for each variable to take in consideration the aspects that we want to research on. We used amount of population and urbanization rate to understand city demand for space, but amount of skyscraper in a city does not fully address the supply of space in a location. Although this is not the main focus of this research, having more variables provides a better understanding of the situation. The best model of this research explains around 30% of the fluctuation of the data points, which is considered as not high. Thus, more research could be done on this topic.

5.3 Possible future research

The topic of my research is an emerging field, and skyscrapers are a building typology that just started to bloom in the past 10 to 20 years. There are still many aspects that remain unstudied. As stated in the limitation section, if more data is available, more precise models could be built to improve the understanding of height distribution.

Furthermore, each country has specific characteristics. This research found out that some phenomena applicable in China do not necessarily apply to other countries. Thus, the study on skyscraper height could also be done in other countries to see if they yield similar results.

Another further research could look into even smaller levels, into skyscraper distribution in each city, and analyze specific factors that affect development in each area. This research used a fixed effect to consider these factors, but to understand this topic in more detail, there is still a possibility for doing analysis on a smaller scale.

Although the questions are answered, there are more interesting aspects that require more studies. Including determinants of vanity height. This research does not provide a model that could best explain vanity height, as the error of the model is high and the R2 is relatively low. This shows that the variables included are not able to explain the large amount of the data points. Although the amount of vanity height decreases as years increase in China, there is still an amount of vanity height included in the newly constructed buildings. This is another interesting direction for further research.

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7. Appendix

7.1 Tables and Figures

Table 3.1: Research Phases and objective

Research **Phases**	**Ch.1 Introduction**	**Ch.2 Theoretical Underpinnning**	**Ch.3 Methodology and Data collection**	**Ch.4 Emprical Analysis**	**Ch.4 Conclusion**
Research **steps**		Step 1: Dig into previous studies on related topic to define theories that stated possible aspects that effected skyscraper height.	Step 2: Identify variables that could be used to measure each aspect stated in previous studies. Step 3: Collect data of 200m+ skyscraper in China and identify regression that is suitable for fitting the data collected.	Step 4: Understanding the database through graphs and statistical descriptive, and perform regression analysis on the database to identify the degree of effect each determinant has on skyscraper height	Step 5: Explain the major findings of the analysis, and provide suggestion on future development
Objective of the phase	Define the problem Feild	Dig into previous studies on related topic to define possible height determinant factors that have been proveto exsist and theories that stated possible height determinants	Identify variables that could be used to measure each theories and aspects, collect data of 200m+ skyscraper in China for each variables to form a data base, and identify regression that is suitable for fitting the data collected	Perform correlation analysis on the data base, to identify the the degree of effect each determinant have on skyscraper Height	Provide suggestion on future regulations and development according to the findings of the research
Research **Questions**		How does the height pattern of skyscrapers above 200 meters vary across China? What is the factor that causes the specific height pattern across the country?	What is the factor that causes the specific height pattern across the country?	How does the height pattern of skyscrapers above 200 meters vary across China? What is the factor that causes the specific height pattern across the country? To what extent does each height determinant factor affect the height pattern of skyscrapers in China?	
Research **Method**	Literature review	Literature review	Data collection Data analysis	Regression Analysis	Data analysis

Figure 4.1: Skyscraper distribution in China

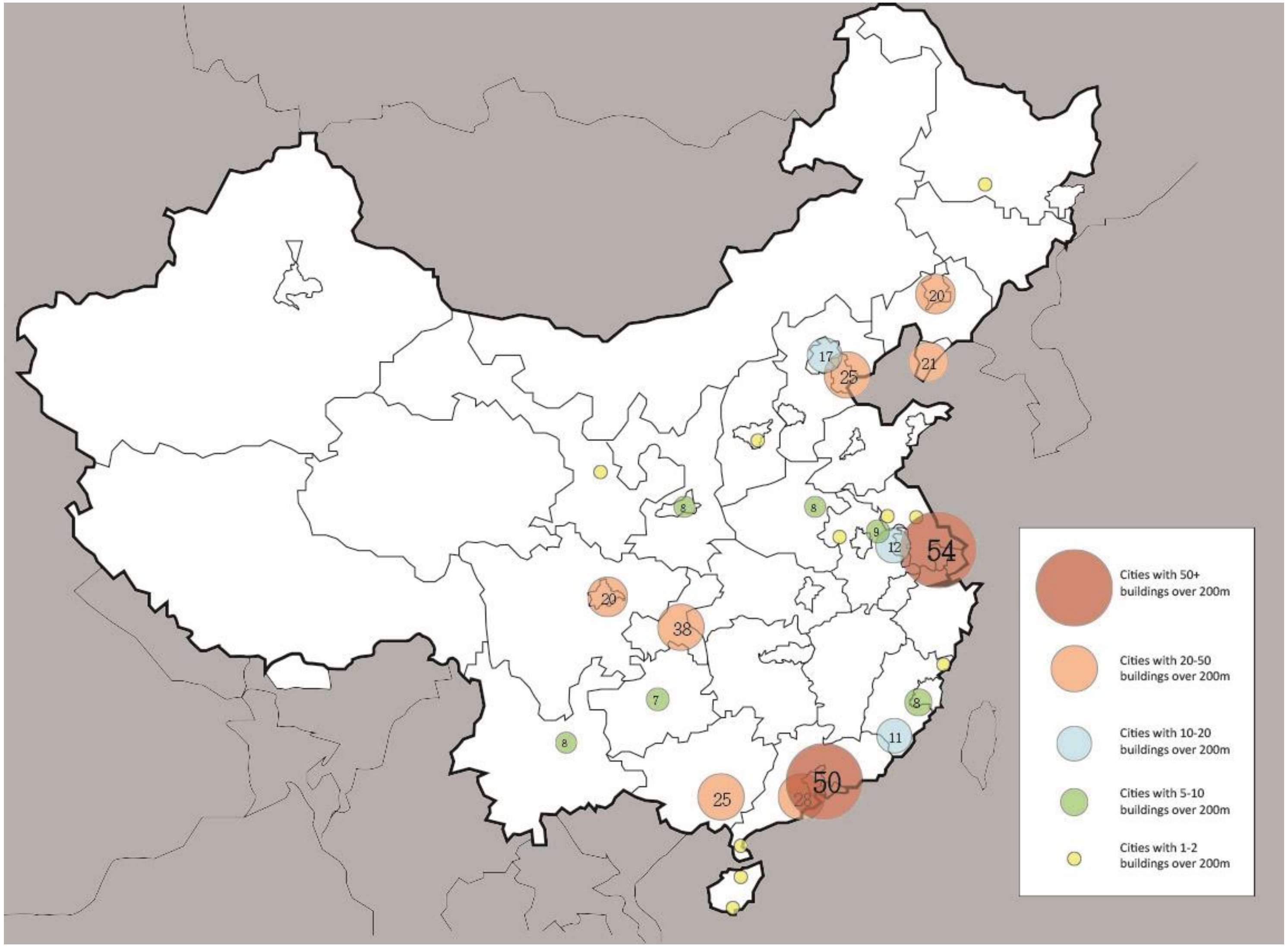


Figure 4.2: Skyscraper height distribution

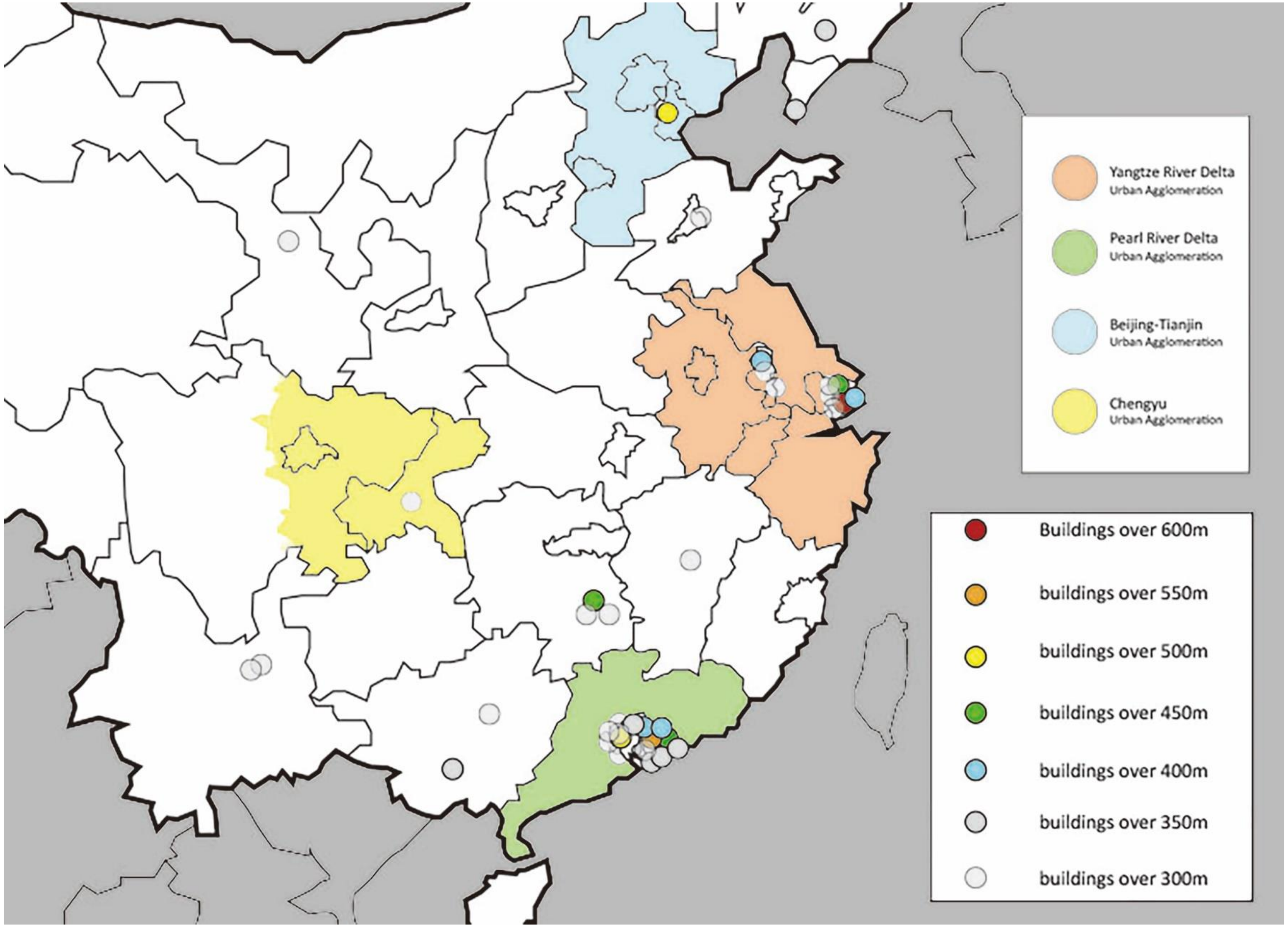


Figure 4.5 Record Breaking skyscraper in Height

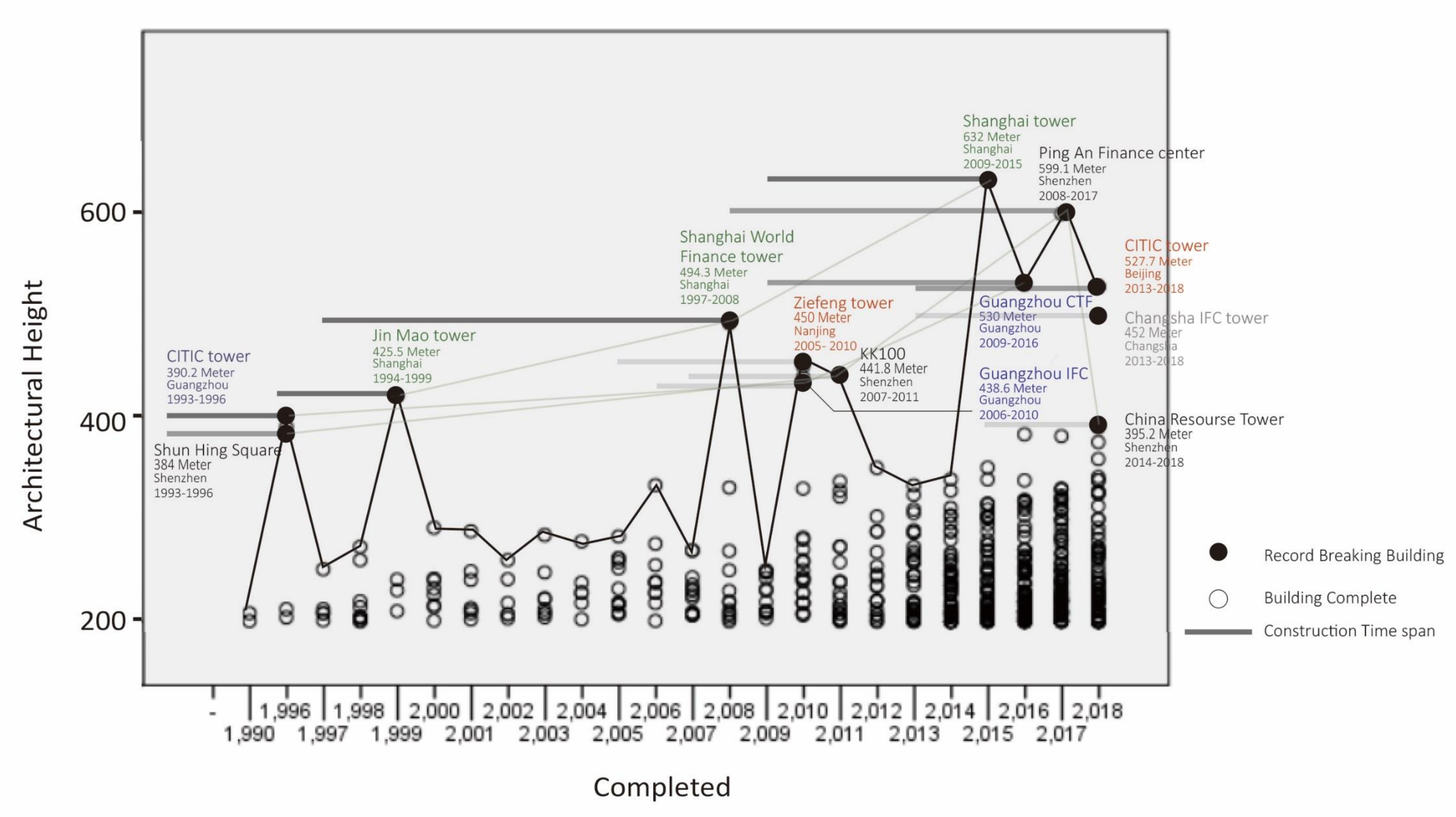


Figure 4.13: Building Vanity height

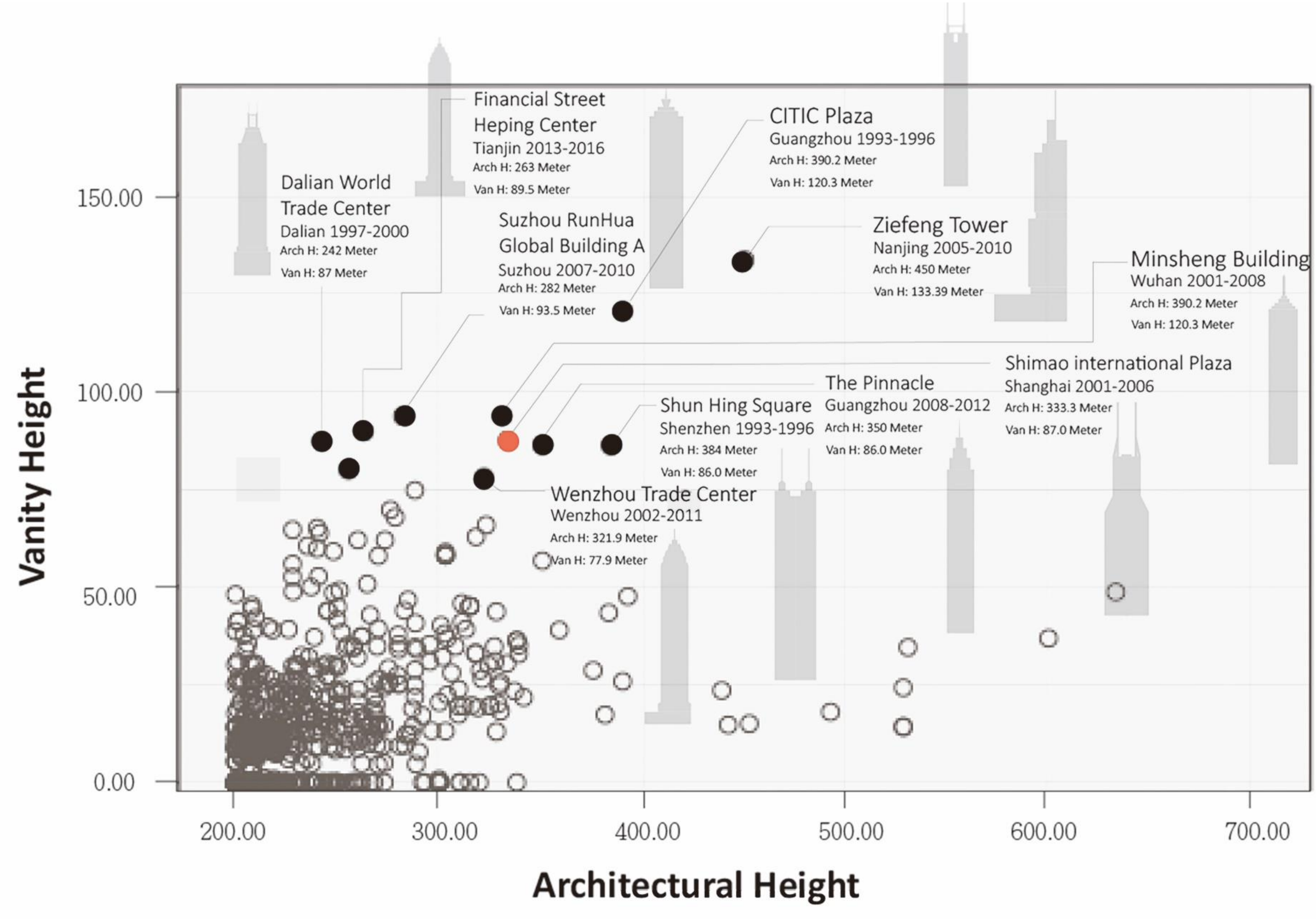
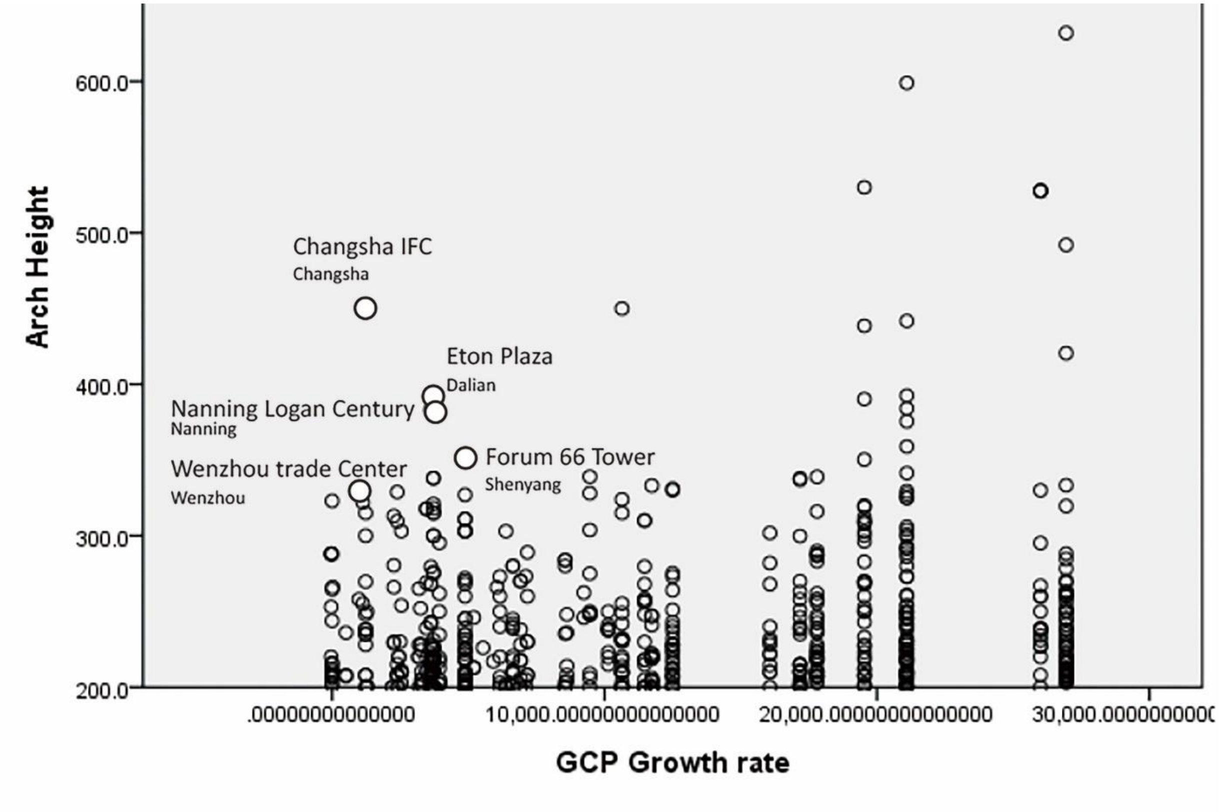


Figure 4.16: Cities with low GDP growth rate that contains taller buildings



7.2 Statistical Models

Table 4.5: Output of regression model for Architectural Height

Model 1

Model Summary[f]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.481[a]	.231	0.2188	47.738	.231	18.339	10.0000	609.000	.000	.468

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	417,935.567	10	41,793.557	18.339	.000[b]
	Residual	1,387,870.805	609	2,278.934		
	Total	1,805,806.372	619			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	201.091	13.388		15.020	.000	174.799	227.384					
	Van Height	1.308	.108	.448	12.104	.000	1.096	1.521	.402	.440	.430	.923	1.083
	# of skyscraper of the year	.243	.146	.084	1.666	.096	-.043	.529	.148	.067	.059	.501	1.996
	CityPop of the year	-.006	.006	-.076	-.997	.319	-.017	.006	.022	-.040	-.035	.220	4.541
	City pop growth	-.016	.014	-.076	-1.145	.253	-.045	.012	.115	-.046	-.041	.283	3.537
	City Urban population growth	.015	.017	.067	.881	.379	-.018	.048	.068	.036	.031	.221	4.518
	GCP of the year	.002	.000	.205	3.470	.001	.001	.003	.195	.139	.123	.363	2.756
	GCP Growth rate	.000	.001	-.001	-.007	.995	-.001	.001	.151	.000	.000	.174	5.731
	Population density of the year	-1.836	8.729	-.009	-.210	.833	-18.978	15.306	-.036	-.009	-.007	.690	1.450
	Urbanization rate of the year	3.253	15.258	.012	.213	.831	-26.712	33.218	.146	.009	.008	.394	2.536
	Third industry of the year	.124	.188	.029	.662	.508	-.244	.493	.110	.027	.024	.660	1.514

Model 2

Model Summary[f]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
3	.556[c]	.309	.295	45.3530	.031	13.636	2	607	.000	.466

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
3	Regression	557,273.894	12	46,439.491	22.578	.000[d]
	Residual	1,248,532.478	607	2,056.890		
	Total	1,805,806.372	619			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
3	(Constant)	231.321	12.373		18.695	.000	207.021	255.620					
	Van Height	1.197	.103	.409	11.640	.000	.995	1.399	.402	.427	.393	.921	1.086
	# of skyscraper of the year	.232	.139	.080	1.672	.095	-.040	.504	.148	.068	.056	.500	2.001
	City pop growth	-.015	.010	-.071	-1.581	.114	-.034	.004	.115	-.064	-.053	.559	1.788
	GCP of the year	.001	.000	.156	2.930	.004	.000	.002	.195	.118	.099	.402	2.485
	Population density of the year	-7.360	7.014	-.036	-1.049	.294	-21.134	6.414	-.036	-.043	-.035	.964	1.037
	Urbanization rate of the year	13.892	12.381	.052	1.122	.262	-10.423	38.208	.146	.045	.038	.541	1.850
	Third industry of the year	.052	.171	.012	.302	.763	-.284	.388	.110	.012	.010	.716	1.396
	office	-22.436	4.176	-.206	-5.373	.000	-30.637	-14.235	-.100	-.213	-.181	.777	1.286
	residential	-27.091	7.314	-.143	-3.704	.000	-41.454	-12.728	-.161	-.149	-.125	.767	1.303
	hotel	-29.991	9.065	-.119	-3.308	.001	-47.794	-12.188	-.100	-.133	-.112	.877	1.141
	Concrete	-20.316	4.049	-.179	-5.018	.000	-28.268	-12.364	-.235	-.200	-.169	.893	1.119
	Steel	-26.607	13.073	-.071	-2.035	.042	-52.281	-.933	-.030	-.082	-.069	.946	1.057

Model 3

Model Summary[g]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
4	.562[d]	.315	.296	45.3157	.027	4.717	5	601	.000	1.503

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
4	Regression	568,452.538	17	33,438.385	16.284	.000[e]
	Residual	1,234,159.146	601	2,053.509		
	Total	1,802,611.684	618			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
4	(Constant)	233.935	12.432		18.817	.000	209.519	258.350					
	Van Height	.945	.113	.337	8.349	.000	.722	1.167	.390	.322	.282	.700	1.428
	# of skyscraper of the year	.157	.140	.054	1.127	.260	-.117	.432	.146	.046	.038	.492	2.031
	City pop growth	-.009	.010	-.043	-.935	.350	-.029	.010	.116	-.038	-.032	.536	1.865
	GCP of the year	.001	.000	.137	2.568	.010	.000	.002	.193	.104	.087	.402	2.487
	Population density of the year	-9.959	7.072	-.049	-1.408	.160	-23.848	3.930	-.034	-.057	-.048	.948	1.055
	Urbanization rate of the year	15.371	12.399	.057	1.240	.216	-8.980	39.723	.145	.051	.042	.539	1.857
	Third industry of the year	.007	.172	.002	.039	.969	-.331	.345	.108	.002	.001	.709	1.411
	office	-21.321	4.190	-.195	-5.088	.000	-29.551	-13.091	-.102	-.203	-.172	.772	1.296
	residential	-29.354	7.313	-.155	-4.014	.000	-43.716	-14.992	-.161	-.162	-.135	.766	1.305
	hotel	-27.741	9.127	-.110	-3.040	.002	-45.665	-9.817	-.100	-.123	-.103	.864	1.158
	Concrete	-17.292	4.118	-.153	-4.199	.000	-25.380	-9.204	-.234	-.169	-.142	.863	1.159
	Steel	-19.400	13.150	-.052	-1.475	.141	-45.226	6.426	-.030	-.060	-.050	.933	1.072
	tot 2	-1.555	5.535	-.012	-.281	.779	-12.425	9.314	-.020	-.011	-.009	.668	1.497
	tot 3	28.718	8.745	.116	3.284	.001	11.542	45.893	.155	.133	.111	.912	1.097
	tot 4	16.597	7.132	.085	2.327	.020	2.591	30.604	.139	.095	.079	.848	1.180
	tot 5	20.815	6.779	.114	3.070	.002	7.501	34.129	.172	.124	.104	.825	1.213
	tot 6	12.398	11.419	.038	1.086	.278	-10.028	34.823	.041	.044	.037	.953	1.050

Model 4

Model Summary[g]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
6	.584[f]	.341	.296	45.3269	.019	.861	19	578	.632	1.518

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
6	Regression	615,094.147	40	15,377.354	7.485	.000[g]
	Residual	1,187,517.538	578	2,054.529		
	Total	1,802,611.684	618			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
6	(Constant)	264.014	19.519		13.526	.000	225.677	302.350					
	Van Height	.982	.116	.350	8.435	.000	.753	1.210	.390	.331	.285	.662	1.510
	# of skyscraper of the year	-.063	.184	-.022	-.341	.733	-.425	.299	.146	-.014	-.012	.283	3.539
	City pop growth	.005	.014	.022	.347	.729	-.022	.032	.116	.014	.012	.276	3.625
	GCP of the year	.001	.001	.110	1.696	.090	.000	.002	.193	.070	.057	.270	3.703
	Population density of the year	-5.058	29.573	-.025	-.171	.864	-63.143	53.026	-.034	-.007	-.006	.054	18.441
	Urbanization rate of the year	4.454	15.338	.017	.290	.772	-25.672	34.580	.145	.012	.010	.352	2.840
	Third industry of the year	-.075	.181	-.017	-.413	.679	-.430	.281	.108	-.017	-.014	.641	1.560
	office	-22.467	4.406	-.206	-5.100	.000	-31.120	-13.814	-.102	-.208	-.172	.698	1.432
	residential	-31.083	7.565	-.164	-4.109	.000	-45.942	-16.225	-.161	-.168	-.139	.716	1.396
	hotel	-28.832	9.447	-.115	-3.052	.002	-47.386	-10.278	-.100	-.126	-.103	.807	1.240
	Concrete	-16.158	4.413	-.143	-3.661	.000	-24.826	-7.489	-.234	-.151	-.124	.752	1.330
	Steel	-20.597	13.783	-.055	-1.494	.136	-47.667	6.474	-.030	-.062	-.050	.850	1.177
	tot 2	1.560	6.110	.012	.255	.799	-10.441	13.562	-.020	.011	.009	.548	1.824
	tot 3	28.940	9.048	.117	3.199	.001	11.169	46.711	.155	.132	.108	.852	1.173
	tot 4	17.068	7.339	.088	2.326	.020	2.653	31.483	.139	.096	.079	.801	1.249
	tot 5	19.504	6.899	.107	2.827	.005	5.954	33.054	.172	.117	.095	.797	1.255
	tot 6	12.111	11.637	.037	1.041	.298	-10.745	34.966	.041	.043	.035	.918	1.090
	City cluster yangze	-16.796	6.606	-.130	-2.543	.011	-29.770	-3.822	.000	-.105	-.086	.439	2.277
	City cluster beijing	-8.057	10.472	-.041	-.769	.442	-28.625	12.510	.055	-.032	-.026	.400	2.498
	City cluster chengyu	-14.939	8.464	-.083	-1.765	.078	-31.562	1.685	-.074	-.073	-.060	.514	1.945
	other	-13.242	6.958	-.118	-1.903	.058	-26.909	.424	-.104	-.079	-.064	.294	3.400
	Completed 1990-2000	-22.047	16.137	-.079	-1.366	.172	-53.741	9.647	-.013	-.057	-.046	.342	2.924
	Completed 2000	-25.020	20.178	-.052	-1.240	.215	-64.651	14.610	-.022	-.052	-.042	.639	1.565
	Completed 2001	-25.773	27.487	-.047	-.938	.349	-79.759	28.214	-.019	-.039	-.032	.458	2.185
	Completed 2002	-17.705	27.287	-.032	-.649	.517	-71.298	35.888	-.038	-.027	-.022	.464	2.153
	Completed 2003	-25.926	25.187	-.054	-1.029	.304	-75.395	23.544	-.037	-.043	-.035	.410	2.438
	Completed 2004	-53.311	26.947	-.097	-1.978	.048	-106.236	-.386	-.021	-.082	-.067	.476	2.100
	Completed 2005	-10.521	23.719	-.028	-.444	.658	-57.107	36.065	-.026	-.018	-.015	.287	3.485
	Completed 2006	-18.214	24.338	-.043	-.748	.455	-66.015	29.588	.005	-.031	-.025	.353	2.837
	Completed 2007	-22.546	22.887	-.060	-.985	.325	-67.497	22.405	-.042	-.041	-.033	.308	3.245
	Completed 2008	-4.549	23.374	-.012	-.195	.846	-50.457	41.359	.025	-.008	-.007	.320	3.129
	Completed 2009	-21.663	22.299	-.062	-.971	.332	-65.460	22.135	-.053	-.040	-.033	.282	3.542
	Completed 2010	-1.090	21.192	-.004	-.051	.959	-42.714	40.533	.071	-.002	-.002	.236	4.231
	Completed 2011	-4.176	21.617	-.013	-.193	.847	-46.634	38.281	-.006	-.008	-.007	.252	3.975
	Completed 2012	-21.689	22.197	-.058	-.977	.329	-65.287	21.908	.006	-.041	-.033	.328	3.052
	Completed 2013	-11.939	19.728	-.050	-.605	.545	-50.685	26.808	.003	-.025	-.020	.164	6.087
	Completed 2014	-21.267	19.550	-.121	-1.088	.277	-59.666	17.131	-.064	-.045	-.037	.092	10.822
	Completed 2015	-7.118	18.964	-.042	-.375	.708	-44.364	30.128	.035	-.016	-.013	.093	10.731
	Completed 2016	-11.767	18.751	-.078	-.628	.531	-48.596	25.062	-.048	-.026	-.021	.073	13.644
	Completed 2017	-4.533	18.509	-.031	-.245	.807	-40.886	31.820	.037	-.010	-.008	.069	14.428

Model 5

Model Summary[g]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
5	.599[e]	.359	.337	.06463	.009	1.986	4	598	.095	

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
5	Regression	1.397	20	.070	16.718	.000[f]
	Residual	2.498	598	.004		
	Total	3.895	618			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
5	(Constant)	2.363	.018		130.010	0.000	2.327	2.399					
	Van Height	.001	.000	.357	9.057	.000	.001	.002	.414	.347	.297	.692	1.444
	# of skyscraper of the year	.000	.000	.077	1.440	.150	.000	.001	.147	.059	.047	.372	2.688
	City pop growth	.000	.000	-.041	-.741	.459	.000	.000	.105	-.030	-.024	.356	2.806
	GCP of the year	.000	.000	.118	2.068	.039	.000	.000	.188	.084	.068	.327	3.058
	Urbanization rate of the year	-.003	.021	-.008	-.153	.878	-.044	.038	.139	-.006	-.005	.389	2.570
	Third industry of the year	.000	.000	-.006	-.151	.880	-.001	.000	.096	-.006	-.005	.702	1.425
	office	-.034	.006	-.213	-5.568	.000	-.046	-.022	-.105	-.222	-.182	.733	1.365
	residential	-.051	.011	-.183	-4.863	.000	-.072	-.030	-.182	-.195	-.159	.753	1.327
	hotel	-.046	.013	-.126	-3.574	.000	-.072	-.021	-.110	-.145	-.117	.865	1.156
	Concrete	-.026	.006	-.154	-4.274	.000	-.037	-.014	-.249	-.172	-.140	.825	1.212
	Steel	-.029	.019	-.052	-1.529	.127	-.066	.008	-.029	-.062	-.050	.924	1.082
	tot 2	.002	.008	.010	.239	.811	-.014	.018	-.011	.010	.008	.656	1.524
	tot 3	.043	.013	.118	3.439	.001	.018	.068	.154	.139	.113	.907	1.103
	tot 4	.029	.010	.102	2.860	.004	.009	.049	.156	.116	.094	.842	1.187
	tot 5	.032	.010	.118	3.281	.001	.013	.051	.186	.133	.107	.823	1.215
	tot 6	.020	.016	.042	1.248	.213	-.012	.053	.040	.051	.041	.944	1.059
	City cluster pearl delta	.022	.009	.115	2.398	.017	.004	.040	.146	.098	.079	.469	2.134
	City cluster beijing	.019	.012	.065	1.506	.133	-.006	.043	.043	.061	.049	.580	1.725
	City cluster chengyu	.000	.011	.000	-.002	.999	-.021	.021	-.074	.000	.000	.638	1.568
	other	.005	.009	.033	.602	.547	-.012	.023	-.105	.025	.020	.347	2.880

Table 4.6: Models for Occupied Height

Model 1

Model Summary[g]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: Change	F Change	df1	df2	Change	Durbin-Watson
5	.445[e]	.198	.171	44.977533947486100	.009	1.618	4	598	.168	

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
5	Regression	298,232.767	20	14,911.638	7.371	.000[f]
	Residual	1,209,741.179	598	2,022.979		
	Total	1,507,973.946	618			

Coefficients[a]													
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
5	(Constant)	227.505	12.647		17.989	.000	202.666	252.343					
	Van Height	.052	.113	.020	.462	.644	-.170	.274	.066	.019	.017	.692	1.444
	# of skyscraper of the year	.210	.159	.079	1.317	.188	-.103	.523	.202	.054	.048	.372	2.688
	City pop growth	-.005	.012	-.028	-.455	.649	-.029	.018	.107	-.019	-.017	.356	2.806
	GCP of the year	.001	.000	.119	1.855	.064	.000	.002	.243	.076	.068	.327	3.058
	Urbanization rate of the year	1.030	14.481	.004	.071	.943	-27.409	29.469	.145	.003	.003	.389	2.570
	Third industry of the year	.020	.172	.005	.116	.908	-.317	.357	.134	.005	.004	.702	1.425
	office	-20.689	4.269	-.207	-4.847	.000	-29.073	-12.305	-.091	-.194	-.178	.733	1.365
	residential	-28.976	7.320	-.167	-3.959	.000	-43.352	-14.600	-.145	-.160	-.145	.753	1.327
	hotel	-27.415	9.050	-.119	-3.029	.003	-45.188	-9.641	-.096	-.123	-.111	.865	1.156
	Concrete	-16.574	4.179	-.160	-3.966	.000	-24.782	-8.366	-.229	-.160	-.145	.825	1.212
	Steel	-16.884	13.114	-.049	-1.287	.198	-42.638	8.871	-.059	-.053	-.047	.924	1.082
	tot 2	-1.422	5.542	-.012	-.257	.798	-12.307	9.462	-.138	-.010	-.009	.656	1.524
	tot 3	27.396	8.704	.121	3.148	.002	10.303	44.490	.130	.128	.115	.907	1.103
	tot 4	14.744	7.101	.083	2.076	.038	.798	28.691	.088	.085	.076	.842	1.187
	tot 5	17.882	6.734	.107	2.655	.008	4.656	31.108	.118	.108	.097	.823	1.215
	tot 6	12.160	11.383	.040	1.068	.286	-10.196	34.517	.048	.044	.039	.944	1.059
	City cluster pearl delta	12.674	6.328	.107	2.003	.046	.247	25.102	.155	.082	.073	.469	2.134
	City cluster beijing	13.815	8.635	.077	1.600	.110	-3.143	30.773	.083	.065	.059	.580	1.725
	City cluster chengyu	-.365	7.541	-.002	-.048	.961	-15.175	14.445	-.052	-.002	-.002	.638	1.568
	other	3.000	6.354	.029	.472	.637	-9.479	15.479	-.107	.019	.017	.347	2.880

Model 2

Model Summary[g]										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
5	.466[e]	.217	.191	.07016	.009	1.808	4	598	.126	

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
5	Regression	.816	20	.041	8.288	.000[f]
	Residual	2.944	598	.005		
	Total	3.760	618			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
5	(Constant)	2.359	.020		119.589	0.000	2.321	2.398					
	Van Height	.000	.000	-.008	-.175	.861	.000	.000	.039	-.007	-.006	.692	1.444
	# of skyscraper of the year	.000	.000	.098	1.646	.100	.000	.001	.214	.067	.060	.372	2.688
	City pop growth	.000	.000	-.062	-1.017	.310	.000	.000	.085	-.042	-.037	.356	2.806
	GCP of the year	.000	.000	.118	1.857	.064	.000	.000	.246	.076	.067	.327	3.058
	Urbanization rate of the year	.000	.023	.001	.013	.990	-.044	.045	.138	.001	.000	.389	2.570
	Third industry of the year	.000	.000	.000	-.004	.997	-.001	.001	.129	.000	.000	.702	1.425
	office	-.035	.007	-.225	-5.322	.000	-.049	-.022	-.097	-.213	-.193	.733	1.365
	residential	-.052	.011	-.191	-4.590	.000	-.075	-.030	-.160	-.184	-.166	.753	1.327
	hotel	-.049	.014	-.136	-3.503	.000	-.077	-.022	-.105	-.142	-.127	.865	1.156
	Concrete	-.028	.007	-.174	-4.367	.000	-.041	-.016	-.242	-.176	-.158	.825	1.212
	Steel	-.028	.020	-.051	-1.347	.178	-.068	.013	-.067	-.055	-.049	.924	1.082
	tot 2	-.002	.009	-.010	-.229	.819	-.019	.015	-.154	-.009	-.008	.656	1.524
	tot 3	.041	.014	.114	2.994	.003	.014	.067	.121	.122	.108	.907	1.103
	tot 4	.027	.011	.094	2.395	.017	.005	.048	.097	.097	.087	.842	1.187
	tot 5	.027	.011	.104	2.610	.009	.007	.048	.114	.106	.094	.823	1.215
	tot 6	.017	.018	.036	.954	.340	-.018	.052	.043	.039	.035	.944	1.059
	City cluster pearl delta	.021	.010	.114	2.151	.032	.002	.041	.168	.088	.078	.469	2.134
	City cluster beijing	.021	.013	.075	1.588	.113	-.005	.048	.069	.065	.057	.580	1.725
	City cluster chengyu	.000	.012	-.001	-.031	.975	-.023	.023	-.047	-.001	-.001	.638	1.568
	other	.003	.010	.018	.290	.772	-.017	.022	-.105	.012	.010	.347	2.880

Table 4.6: Models for Vanity height

Model 1

Model Summary[g]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
2	.241[b]	.058	.046	18.802173731022000	.019	4.003	3	610	.008	

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
2	Regression	13,350.050	8	1,668.756	4.720	.000[c]
	Residual	215,648.260	610	353.522		
	Total	228,998.310	618			

Coefficients[a]													
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
2	(Constant)	17.220	4.298		4.006	.000	8.779	25.661					
	# of skyscraper of the year	-.158	.056	-.153	-2.801	.005	-.268	-.047	-.116	-.113	-.110	.521	1.921
	City pop growth	.009	.004	.113	2.183	.029	.001	.016	.076	.088	.086	.572	1.747
	GCP of the year	.000	.000	-.096	-1.582	.114	-.001	.000	-.086	-.064	-.062	.420	2.379
	Urbanization rate of the year	9.574	5.104	.100	1.876	.061	-.450	19.598	.051	.076	.074	.547	1.828
	Third industry of the year	-.025	.071	-.016	-.352	.725	-.164	.114	-.039	-.014	-.014	.720	1.389
	office	-4.194	1.724	-.108	-2.433	.015	-7.579	-.809	-.034	-.098	-.096	.785	1.274
	residential	-8.084	2.929	-.120	-2.759	.006	-13.837	-2.331	-.087	-.111	-.108	.822	1.216
	hotel	-8.585	3.737	-.096	-2.297	.022	-15.924	-1.245	-.041	-.093	-.090	.887	1.128

Model 2

Model Summary[g]										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
4	.547[d]	.299	.282	16.311036758509300	.230	39.606	5	603	.000	

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
4	Regression	68,570.208	15	4,571.347	17.182	.000[e]
	Residual	160,428.102	603	266.050		
	Total	228,998.310	618			

Coefficients[a]													
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
4	(Constant)	6.328	3.863		1.638	.102	-1.260	13.915					
	# of skyscraper of the year	-.082	.050	-.079	-1.653	.099	-.179	.015	-.116	-.067	-.056	.506	1.976
	City pop growth	.001	.004	.018	.387	.699	-.006	.008	.076	.016	.013	.538	1.858
	GCP of the year	.000	.000	-.052	-.973	.331	.000	.000	-.086	-.040	-.033	.408	2.449
	Urbanization rate of the year	8.696	4.443	.090	1.957	.051	-.030	17.421	.051	.079	.067	.544	1.840
	Third industry of the year	.030	.062	.020	.484	.628	-.092	.152	-.039	.020	.017	.709	1.410
	office	-2.983	1.503	-.077	-1.984	.048	-5.936	-.031	-.034	-.081	-.068	.777	1.287
	residential	-7.098	2.611	-.105	-2.719	.007	-12.225	-1.971	-.087	-.110	-.093	.779	1.284
	hotel	-7.926	3.264	-.088	-2.428	.015	-14.337	-1.516	-.041	-.098	-.083	.875	1.143
	Concrete	-3.256	1.475	-.081	-2.207	.028	-6.152	-.359	-.084	-.090	-.075	.871	1.148
	Steel	10.773	4.711	.080	2.287	.023	1.522	20.024	.109	.093	.078	.942	1.061
	tot 2	20.700	1.804	.433	11.476	.000	17.157	24.242	.328	.423	.391	.815	1.227
	tot 3	16.413	3.076	.186	5.337	.000	10.373	22.453	.094	.212	.182	.955	1.047
	tot 4	17.658	2.458	.255	7.183	.000	12.830	22.485	.156	.281	.245	.924	1.082
	tot 5	18.963	2.309	.292	8.214	.000	14.429	23.497	.176	.317	.280	.921	1.085
	tot 6	7.725	4.093	.066	1.888	.060	-.312	15.763	-.012	.077	.064	.961	1.041

Table 4.7 Regression model for type of top

Model 1: Arch. Height

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.294[a]	.086	.082	57.5781

a. Predictors: (Constant), International, Mixed

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	142,081.521	2	71,040.760	21.429	.000[b]
	Residual	1,505,117.994	454	3,315.238		
	Total	1,647,199.515	456			

a. Dependent Variable: Arch Height

b. Predictors: (Constant), International, Mixed

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	244.255	3.980		61.368	.000
	Mixed	34.687	5.731	.272	6.053	.000
	International	-12.442	5.522	-.101	-2.253	.025

a. Dependent Variable: Arch Height

Model 2: Occ. Height

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.231[a]	.053	.046	47.321033850289400

a. Predictors: (Constant), type 6, type 3, type 4, type 5, type 2

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	83,114.365	5	16,622.873	7.423	.000[b]
	Residual	1,473,446.401	658	2,239.280		
	Total	1,556,560.766	663			

a. Dependent Variable: Occ Height

b. Predictors: (Constant), type 6, type 3, type 4, type 5, type 2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	223.800	2.491		89.859	0.000
	type 2	-10.015	4.774	-.083	-2.098	.036
	type 3	29.214	8.606	.131	3.395	.001
	type 4	17.324	6.961	.097	2.489	.013
	type 5	19.798	6.461	.120	3.064	.002
	type 6	20.341	11.138	.070	1.826	.068

a. Dependent Variable: Occ Height

Model 3: Van. Height

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.517[a]	.267	.262	16.664598505532500

a. Predictors: (Constant), type 6, type 3, type 4, type 5, type 2

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	66,621.858	5	13,324.372	47.980	.000[b]
	Residual	182,732.419	658	277.709		
	Total	249,354.277	663			

a. Dependent Variable: Van Height

b. Predictors: (Constant), type 6, type 3, type 4, type 5, type 2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.726	.877		8.808	.000
	type 2	22.368	1.681	.465	13.305	.000
	type 3	16.930	3.031	.190	5.586	.000
	type 4	18.296	2.451	.256	7.464	.000
	type 5	19.235	2.275	.291	8.453	.000
	type 6	8.465	3.922	.073	2.158	.031

a. Dependent Variable: Van Height

4.8: Regression model for Nationality of construction Coalition

Model 1: Architectural height

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.294[a]	.086	.082	57.5781

a. Predictors: (Constant), International, Mixed

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	142,081.521	2	71,040.760	21.429	.000[b]
	Residual	1,505,117.994	454	3,315.238		
	Total	1,647,199.515	456			

a. Dependent Variable: Arch Height

b. Predictors: (Constant), International, Mixed

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	244.255	3.980		61.368	.000
	Mixed	34.687	5.731	.272	6.053	.000
	International	-12.442	5.522	-.101	-2.253	.025

a. Dependent Variable: Arch Height

Model 2: Vanity Height

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.154[a]	.024	.017	20.664016154351000
a. Predictors: (Constant), Mixed, local, International				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4,663.424	3	1,554.475	3.640	.013[b]
	Residual	193,004.707	452	427.002		
	Total	197,668.131	455			

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	13.685	1.889		7.246	.000
	International	6.056	2.411	.142	2.512	.012
	local	11.988	4.762	.123	2.518	.012
	Mixed	6.162	2.502	.138	2.463	.014

Table 4.11: Analysis result for Location Fixed Effect

Model 1

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.143[a]	.020	.019	.07804
2	.195[b]	.038	.035	.07739
3	.220[c]	.049	.044	.07703

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.084	1	.084	13.769	.000[b]
	Residual	4.032	662	.006		
	Total	4.116	663			
2	Regression	.157	2	.079	13.120	.000[c]
	Residual	3.959	661	.006		
	Total	4.116	663			
3	Regression	.200	3	.067	11.237	.000[d]
	Residual	3.916	660	.006		
	Total	4.116	663			
a. Dependent Variable: logarchheight						
b. Predictors: (Constant), City 13						
c. Predictors: (Constant), City 13, City 2						
d. Predictors: (Constant), City 13, City 2, City 43						

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2.375	.003		762.101	0.000
	City 13	.049	.013	.143	3.711	.000
2	(Constant)	2.373	.003		754.922	0.000
	City 13	.051	.013	.149	3.892	.000
	City 2	.060	.017	.134	3.498	.000
3	(Constant)	2.370	.003		704.979	0.000
	City 13	.054	.013	.158	4.145	.000
	City 2	.063	.017	.141	3.698	.000
	City 43	.025	.009	.103	2.688	.007
a. Dependent Variable: logarchheight						

Model 2

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.166[a]	.028	.022	.07793

a. Predictors: (Constant), other, City cluster beijing, City

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.113	4	.028	4.670	.001[b]
	Residual	4.003	659	.006		
	Total	4.116	663			

a. Dependent Variable: logarchheight

b. Predictors: (Constant), other, City cluster beijing, City cluster pearl delta, City

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.361	.010		238.500	0.000
	City cluster pearl delta	.038	.012	.199	3.224	.001
	City cluster yangze	.020	.012	.103	1.653	.099
	City cluster beijing	.027	.015	.093	1.854	.064
	other	.007	.011	.044	.647	.518

a. Dependent Variable: logarchheight