Tall buildings and their expansion in time and space

A study on global determining factors

Marinos Panousis

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TU Delft Delft University of Technology

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Tall buildings and their expansion in time and space

A study on global determining factors

by

M. Panousis

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Acknowledgements

This thesis marks the end of my studies at TU Delft. In this report, an effort of approximately 8 months is depicted, bringing the Master programme in Construction Management and Engineering to completion. The topic treated regards tall buildings and the driving forces behind their construction and height determination. A tall building itself attracts people's attention due to its imposing appearance, but there is much more to it. I am really glad I worked on this subject and discovered to a certain extent the side of urban economics connected with tall buildings.

There are certain people I would like to thank for their contribution to this research. First and foremost, a special thanks goes to my first supervisor, Ilir Nase. Without him, this thesis would never have started. Ilir was willing enough to arrange a meeting with me, after a quite vague e-mail from my side, where I was just stating a general interest on the field of Real Estate. During this meeting, he introduced me to the topic of tall buildings and it immediately caught my interest. Ilir's guidance and ability to provide clear answers to my questions were of remarkable help for me, with every online meeting being quite productive, especially during times of social distancing due to Covid19. Another share of gratitude goes to Peter de Jong, second supervisor for this thesis. His critical remarks on the qualitative nature of the elements of this study widened my perspective and pushed me to think outside the barriers of statistical analysis. His feedback was always contributing added value to the research. And of course, I would like to thank the Chairman of my graduation committee, Peter Boelhouwer. From the beginning, he was eager to supervise a thesis on a topic not directly within his immediate interest. His key comments are greatly appreciated, together with his willingness to facilitate graduation procedures when needed. Overall, I feel in debt to all three members of the committee for their patience throughout the entire process.

Last but not least, I would like to thank my parents and sister for always being there for me and providing me with the opportunity to study abroad. The support of my friends, scattered in different countries, was also critical to the execution of this research. Without them, this thesis might not be feasible.

Enjoy reading!

Marinos Panousis

Delft, July 2020

*The picture on the cover page portrays the buildings of the Dutch Ministries of Justice and Internal affairs, located in the Hague, as captured on December 21st, 2017 from ground level during a misty night. The picture is taken and edited by the author.

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Executive Summary

Introduction and problem field

A significant growth in the development of tall buildings has taken place within the past two decades, during which approximately 75% of the total existing tall buildings has been constructed. This construction boom has happened in alignment with the phenomenon of the increasing urbanization of cities worldwide. More than 50% of the world's population in 2018 was concentrated in urban cities and the building typology of tall buildings has begun to be dominant.

A tall building offers the capability to accommodate large volumes of people and satisfy both their residential and business needs in cities with limited margins of horizontal expansion. Consequently, tall buildings can act as a solution to the phenomenon of increasing urbanization. In addition to this, the determination of height is a manner towards a more efficient allocation of the population of a location, and as a result improving the urban efficiency of the location. However, the field is still understudied and the reasons why certain buildings of such impact are developed are not clearly unraveled. The existence and especially the height of tall buildings cannot be solely attributed to the demand for hosting increasing populations. For instance, the city of Chicago has taller buildings compared to the city of New York, although the latter has four times the population of the former. Dubai also is a city displaying extreme heights, not justified by the population size. This research aspires to provide a solid comprehension of the situation from a global point of view, through the contribution of quantitative evidence, able to establish fruitful ground for future urban planning policies. Based on the above, the main and supporting research questions to guide this research are formulated as follows.

Research questions

The main research question of this study is expresses as follows:

"To what extent determinants influence the height and amount of tall buildings from a global point of view? "

In order for the answering of the main research question to be facilitated, the following supporting sub-questions have occurred:

1) Which factors are regarded as height determinants?
2) How does the distribution of tall buildings vary per region?

Research objective and scope

The research aims to expand the pool of existing knowledge around the subject of the development of tall buildings, providing a global perspective. Particular focus is placed on the factors that determine the height of tall buildings and to lesser extent their amount. Every tall building with architectural height larger than 150 meters is included in the research and all geographic regions are covered. This regards tall buildings still in use and completed between 1960 and 2019, with all building functions being included.

Relevance

The research contributes scientifically by examining a relatively recent and dominating building typology and by enriching the pool of knowledge with empirical evidence. From a societal perspective, better understanding of the field can bring more efficient urban planning policies and aesthetically pleasant skyline, suitable to each location's cultural traits. It is also in alignment with the recent call by United Nations to approach the issue of exceeding urbanization growth in a sustainable manner. In terms of practicality, the findings can add value and benefit the relevant actors and stakeholders involved in the development of tall buildings.

Methodology

The research employs a quantitative research methodology. Based on literature study, four main categories are created in order for the determinants in investigation to be classified. These four classifications are: economic, building-related, location-related and others. The category of other determinants includes more abstract factors, such as height competition and cultural preferences. According to this classification and the formulated research questions and scope, relevant data are collected. The main variables acquired through the data collection phase regard the characteristics of the buildings, national economic and demographic indicators. More specifically, the aforementioned variables include height, floor count, material, use, proposal and completion date, population size and urbanization rate per country, GDP, FDI and real interest rate at country level as well. Main sources for the data collection phase is the Council of Tall Buildings and Urban Habitat (CTBUH), the World Bank Database, Emporis.com and the United Nations annual reports. The main too used for the analysis phase is Multiple Linear Regression, complemented by correlation analysis and descriptive statistics. Since the research focus is on height determinants, regression models are mostly constructed having architectural height as the dependent variable. Apart from the investigation of determinants, the effects of space and time are also taken into account with appropriately constructed variables.

Findings

The amount of tall buildings has increased significantly during the last 20 years. Regarding regions, a shift from North America towards Middle East and China took place in terms of quantity of completions. The global average height has increased by 20 meters during the last decade, and a tendency for buildings taller than 300 meters is marked. At this moment, the main tall buildings' type is of mixed functions and residential. The average construction duration of tall buildings is around 3.5 years and a timeframe of 2 years is required between proposal and starting construction works. Regarding driving factors, the global amount of completions is linked with the world's economic health and increasing demand for accommodating population. Most influential, in a positive manner, proved to be world's level GDP and urbanization rate, followed in terms of impact by population size and FDI.

Turning the attention to height determination, strongest impact is proven to derive from location-related factors. Certain regions and countries intend to build higher than others, regardless of the demand. For instance, the region of Middle East develops buildings taller by 15% compared to Europe. The population size at country level turned out to have no impact on height, and urbanization rate showed limited linkage.

Economic factors proved to have smaller impact in magnitude. Of moderate significance is detected to be the impact of national real interest rate, connecting low interest rates with increase in height. This reflects the opportunity to borrow money at low cost of capital in order to be used for construction purposes. National GDP and FDI showed limited influence. Stronger impact compared to economic factors is indicated for the use a building is designed to accommodate. Residential type of tall buildings drives height negatively, whereas mixed type and office space affect it positively. In addition to building related factors, the use of composite materials can increase height by 15%. The impact of technological advancements on architectural height is reflected in this research through the effect of time progression. It was concluded that buildings developed the last two decades are taller by 10%, compared to previous decades. Evidence also regards the existence or not of the phenomenon of height competition. Findings do indicate the existence of the phenomenon, especially when it concerns buildings taller than 300 meters. Again, the individual location plays important role on height, with Middle East showcasing stronger tendency to go higher. Evidence also suggests height competition within the region of Europe the last 15 years, as well as for Asia.

Basic outcome of this research is that the decision to develop a tall building is location-based and to further extent dependent on the current economic conditions. The selection of building use and material are also influential on height, as well as motives behind height competition.

Limitations & further research

Main research limitations concern the availability of data collected. More robust results could have been delivered with the use of additional relevant data. A complete database would have included every building that is characterised as tall building by CTBUH. However, available data for tall buildings shorter than 150 meters were characterised by lower quality and missing information. Variables that could have improved the performance of the models employed include construction costs per location, land values, presence of land-use regulations. An optimal scenario would have also been to have city related variables, rather than having them at country level. More precise conclusions could have been generated. Suggestions for future research include studies with additional variables. More targeted research scope in terms of locations or height range are encouraged, as well as investigating buildings, for which construction was aborted or put on hold.

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1 Introduction

This first chapter introduces the topic of the development of tall buildings across the globe. Section 1.1 provides an introduction both to the history and to the modern development of tall buildings. Section 1.2 elaborates on the problem field and Section 1.3 establishes the research scope and objective. In Section 1.4, the main and supporting research questions are presented. In Section 1.5, the conceptual model of the research is described, and Section 1.6 elaborates on the relevance of the research.

1.1 Topic Analysis

1.1.1 Introduction to Tall Buildings

The Great Pyramid of Giza, found in Egypt, has been for long regarded as the first structure of significant height on earth, having a height of almost 147 meters (481 feet). This unofficial title of the world's highest structure was valid until the appearance of taller cathedrals during the middle-ages, especially in the region of Europe. These cathedrals belonged to the era of masonry construction, a construction style with limited further technological advancements in order to reach larger heights (Peet, 2011). The introduction of structural steel as a construction material for structural elements, around 1870, was a game changer. One of the most striking examples of the use of steel frame in structures is the Eiffel Tower in Paris, France, constructed in 1889 with a total height to tip of 324 meters (1063 feet) (Helsley & Strange, 2008).

The aforementioned structures, though, were not designed for human habitation purposes and belonged to the era of masonry construction (Helsley & Strange, 2008). Therefore, they do not qualify to be characterised with the term "tall building". The first structure that was qualified as the first tall building in the course of human history is the Home Insurance Building (50 meters tall), located in Chicago and completed in 1885 by the architect William Le Baron Jenney (CTBUH, 2019; Helsley & Strange, 2008). The reason for this is the fact that the building's skeleton was formed entirely out of structural steel.

Historically, the first building that exceeded the height of 100 meters was Manhattan Life Insurance Building, built in New York, in 1894, with a height of 106m (348 feet) (CTBUH, 2019). Almost 15 years later, the height barrier of 150 meters was surpassed by the Singer Building, located in New York. Its construction was completed in 1908, having a height of 187 meters (Ali & Al-Kodmany, 2012). Since 2009 and until today, the throne of the tallest building in the world belongs to Burj Khalifa, located in Dubai, United Arab Emirates, with an architectural height of 828 meters (2717 feet).

1.1.2 Introduction to the development of Tall Buildings

At this moment, approximately 50% of the world's population is urban, meaning people are concentrated in cities. This number is expected to rise up to 60% by 2030 and 80% by 2050 (Ali & Al-Kodmany, 2012; United Nations, 2018). An indicative illustration of the past situation and future trends of urban populations per geographic region can be found in Figure 1.1. At a global scale, thus, cities tend to grow tremendously in terms of population, achieving high densities. This results in the need for accommodating large quantities of people in limited available space within urban locations. Due to the advanced building technology nowadays, particularly in developing countries, the construction of tall buildings seems a reasonable solution to this situation, satisfying both residential and commercial needs (Kheir, 2018a).

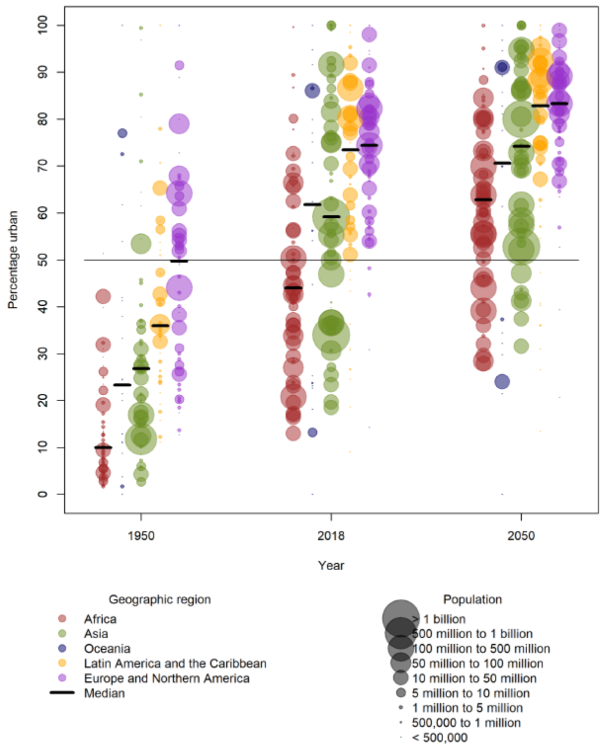


Figure 1.1 Percentage of population residing in urban areas for global regions per geographic region and population size, for the years of 1950, 2018 and 2050 (expected). Source: (United Nations, 2018)

During the 21st century, a boom in the construction of tall buildings has taken place globally (Honorée, Morgan, & Krenn, 2018). Tall buildings now represent a building typology with global use, common in regions with substantial economic development (Chiang, 2019). An overview of the annual number of tall buildings, above 150 meters, completed from 1909 until today can be found below in Figure 1.2, reaching a total figure of approximately 5000 completions. The blue dots represent the individual height of completed buildings and the grey bars the amount of completions per year.

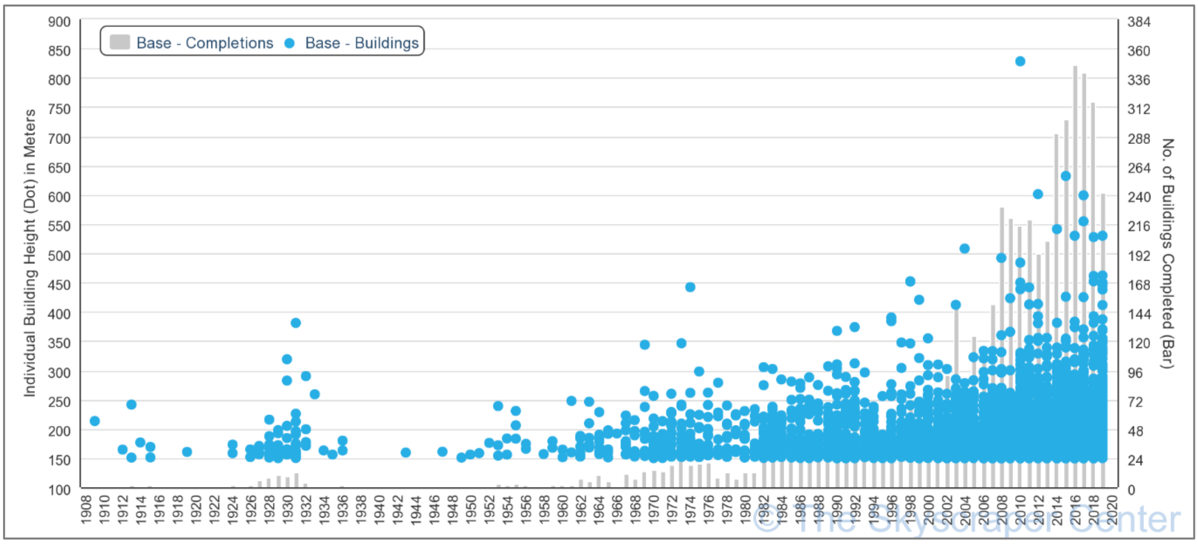


Figure 1.2 Overview of completions of tall buildings above 150m per year, time-range: 1909-2019. Source: Council of Tall Buildings and Urban Habitat (The Skyscraper Center, 2019)

According to data from the Council of Tall Buildings and Urban Habitat, between 2000 and 2009, a number of 1305 tall buildings over 150 meters were completed. Between 2000 and 2019, an approximate number of 4000 tall buildings over 150 meters were completed (81% of the total). Therefore, within the last decade, almost 2700 tall buildings have been completed, consisting of almost half of the total (The Skyscraper Center, 2019). The abovementioned numbers and facts regard projects that have been completed and documented by CTBUH until December 31st, 2019.

1.1.3 Driving forces of the development of Tall Buildings

A brief and preliminary discussion of certain suggested driving forces behind the development of tall buildings is presented in this sub-section. An elaborate approach is presented in the chapter of the Literature Study. In general terms, the development of tall buildings, especially during the 21st century, is suggested to be influenced by the location. For example, although tall buildings are structures of excessive construction costs, they can prove to be a low-cost solution in cases of developed countries, with efficient existing infrastructure (Ali & Al-Kodmany, 2012). National economic strength is also suggested to affect the way tall buildings develop (Barkham, Schoenmaker, & Daams, 2017; Barr, 2012). By 2030, 58% of the world's population is expected to be urban (United Nations, 2018). Land scarcity and the increasing urbanization rate, together with the forecasts for growing populations are factors to potentially contribute to the development of tall buildings in urban areas (Ali & Al-Kodmany, 2012; United Nations, 2019). The intention of the owners for maximizing his profits out of plots of land with certain dimensions is another factor that drives buildings reaching more floors and growing higher (Barr, 2010; Clark & Kingston, 1930). Cities tend to use their skyscrapers as a symbol of their economic robustness to attract more investment, an element that pushes the construction of tall buildings throughout time (Barr, 2013; Gluckman, 2003). Technological advancements and a race for the holder of title of the tallest buildings, encouraged by the vanity of the contractors and local governments, can also contribute to the growing of tall buildings (Helsley & Strange, 2008).

1.2 Problem field definition

A boom in the construction of tall buildings has been present, since the beginning of 21st century. Both the number and size of tall buildings have grown significantly, especially for heights above 200 meters. Approximately 75% of tall buildings worldwide have been constructed within the decade of 2010-2019 (The Skyscraper Center, 2019). This abrupt increase has ignited the interest of academics towards the field and to wider extent its economic aspects. Researchers began to realise that the drivers of the development of tall buildings have been understudied, although the building typology itself is unique in its nature and much more attention would have been expected (Ahlfeldt & McMillen, 2018; Barr, Mizrach, & Mundra, 2015; Helsley & Strange, 2008). Apart from the economic perspective which focuses on the amount and height of tall buildings, the respective vertical patterns have been neglected as well (Liu, Rosenthal, & Strange, 2018).

The first studies that dived deeper into the subject take place around 2007, in USA, having as starting point a city scale approach, with the focus on cities of North America, including Manhattan and New York. It was observed that in 2007 the tallest building in North America, at that time being, was located in Chicago, although in terms of population New York was a larger city. This rationale was extended, making similar observations for other regions worldwide, such as Kuala Lumpur and Taipei in comparison to Hong Kong and Singapore respectively.

As studies proceeded, it was marked that the development of tall buildings varies per location and inconsistencies were observed. The basic function of tall buildings is to accommodate large portions of people in densely populated cities, where land constraints do not allow (further) horizontal housing development (Helsley & Strange, 2008). This regards both populations and businesses. However, there are examples of tall buildings, the construction of which cannot be solely attributed to this need of accommodating excessive population demand in urban areas. For instance, cities tend to use their skyscrapers as a symbol of their economic robustness and growth and as a sign that they are ready to attract more investments (Barr, 2013; Gluckman, 2003).

Taking all the above into consideration, the understanding over what determines and pushes tall buildings to reach higher altitudes is deemed insufficient in terms of an overall global perspective, lacking support of respective empirical results. So far, different studies treated individual regions, focusing on different timeframes and different height ranges. Limited purposive conclusions have been drawn, too. Since tall buildings consist of a potentially efficient solution to overpopulation and increasing urbanization worldwide, its robust comprehension can benefit future urban planning policies.

1.3 Research objective and scope

1.3.1 Research objective

The research aims to expand the pool of existing knowledge around the subject of the driving forces behind the development of tall buildings, with emphasis on the drivers determining their height and delimiting their spatial distribution. So far, the majority of the studies have dealt with the subject by examining individual locations, mostly cities and to lesser extent countries. The major cities of North America, including

Chicago and New York, have been examined and recently the country of China as a whole. Therefore, the main objective of the specific research is to provide a global perspective of understanding, accompanied by qualitative data in order for a solid holistic overview to be achieved. Finally, a main contribution of this research is to include in the analysis tall buildings that have not been examined previously from a uniform perspective.

1.3.2 Research scope

The research examines the tall buildings with an architectural height of 150 meters and above at global scale. The selection of the specific height threshold is elaborately justified in the Chapter of Methodology and Data, Section 3.4. The chronological timeframe that is taken into account ranges from 1960 to 2019 and regards buildings that are constructed within period and still existing. The number of these buildings amounts to approximately 4800 (The Skyscraper Center, 2019). Although the year 1909 pinpoints the year of the oldest completed and still standing tall building surpassing the architectural height of 150 meters, the year 1960 is chosen as the lower threshold for the specific research timeframe, due to the availability of data for the most influencing factors, especially the ones related to economic aspects. Besides, only 85 tall buildings over 150 meters were built between 1909 and 1960. Therefore, compared to the total quantity of 4800 buildings to be examined, it is deemed that these buildings are a negligible quantity that cannot influence the quality and validity of the data used to provide results. For the purposes of this research, all tall buildings satisfying the abovementioned scope requirements are examined, regardless of their function, either this is residential, commercial or mixed.

1.4 Research questions

The problem definition and the research objective have led to the formulation of the main research question and respective sub-questions.

The main research question is formulated as follows:

" To what extent determinants influence the height and amount of tall buildings from a global point of view? "

In order for the answering of the main research question to be facilitated and explicitly treated, the following sub-questions have occurred:

1) Which factors are regarded as height determinants?
2) How does the distribution of tall buildings vary per region?

1.5 Conceptual research model

1.5.1 Methodology

The research employs a quantitative research strategy to approach the factors that influence the development of tall buildings globally. Descriptive statistics and regression analyses are designed to be the pillars of the research.

As a first step, the theories linked with the development of tall buildings are investigated in order for a more solid understanding of the research subject to be established. Emphasis is placed on the factors that affect the variations of tall buildings' height and the spatial distribution of the respective buildings. This is achieved through extended literature study. The main focus of this part of the research is to decode and identify the main height determinants that have substantial foundations in the literature. Potential height determinants are detected from relevant theories and studies related to urban economics. Once this first step is completed, a filtering of the determinants that are supported by empirical evidence will be performed, based on the research objective.

Suitable data reflecting the identified determinants will be collected and analysed through regression analysis. In order for the regression analysis to be executed, datasets are required to be created. These datasets will include the basic characteristics of the buildings under examination, such as height, completion date, floors, use, location, complemented with the selected determinants. The main source of the data needed will be the Council Tall Buildings and Urban Habitats (CTBUH). More specifically, The Skyscraper Center which is the database provided upon registration by the CTBUH. As far as economic indicators and data are concerned, the freely accessible database of the World Bank will be used. If needed, additional building, regional and national data will be collected from respective databases of (National) Bureaus of Statistics and Emporis.com.

The regression analyses will be conducted with the use of the SPSS software in order to look for correlations between the factors to be examined. The main goal will be the creation of a statistical model, having the height of the tall buildings as the dependent variable and the various determinants as the independent variables. The model should be able to depict the weight of each of the height determinants. The regression analysis will be accompanied by graphic representations, including relevant charts, histograms to illustrate in a clear manner the patterns and distribution of skyscrapers. The quantitative research approach is chosen as a clear way to depict the potentially investigated relationships between characteristics of the buildings and others selected to the influence it has on the height. The combination of literature theories, econometric characteristics and statistical analysis is deemed suitable for the purposes of the research(Knight & Ruddock, 2008; Verschuren, Doorewaard, Poper, & Mellion, 2010).

1.5.2 Expected outcome

The research intends to study the factors that influence the development of tall buildings within global regions. More specifically, the factors that determine the amount of buildings, their height patterns and spatial distribution. In terms of results, it is expected to find quantitative data that can prove or disprove the relationships between variables. Positive relationships are anticipated between the growth of tall buildings and the economic wealth, as well as increasing sizes of population of the location in examination. Extrapolating conclusions leading to findings depending on the function of the building are also anticipated. The end product of the research aims to be manifold. As a first step, constructive conclusions will be drawn to advance the current body of knowledge. They will be accompanied by informative illustrations to depict in a clear manner patterns of spatial distribution. Graphic representations including graphs, bar charts and histograms are intended to be created. Through the development of the statistical model, it is expected to confirm already detected determinants and others that prove to be influential according to region. For a better overview of the overall research design strategy, a simplified research design illustration can be found below in Figure 1.3.

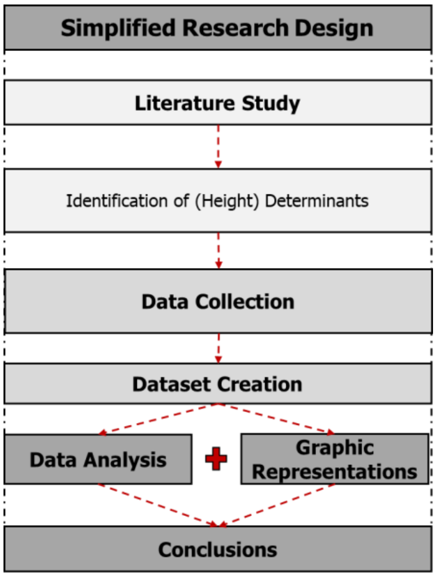


Figure 1.3 Simplified conceptual model of the research design process (Own illustration)

1.6 Research relevance

1.6.1 Scientific relevance

The research addresses a relatively recent architectural typology, the high-rise buildings (Douglas, 1996). The technological advancements on the construction industry have improved significantly. Buildings have reached the height of 828 meters and the height of 1km is about to be achieved in 2022.

It is understood that skyscrapers have extensive capabilities of accommodating people and their needs for housing. Therefore, the typology in question can act as an effective solution to the increasing urbanization. It is expected that in the following years, the main part of the population will be concentrated in urban cities, creating the so-called "global cities"(Sassen, 2005). Since skyscrapers are the dominating typology in this new type of cities, it imperative to conduct thorough research on the development of tall buildings and its implications.

The academic interest and research on the economics of skyscrapers began around 2007 and although it is expanding, the field is still regarded as understudied by academics (Ahlfeldt & McMillen, 2018; Barr, 2018; Barr et al., 2015; Helsley & Strange, 2008). This research aims to satisfy this call for contribution to the growing body of knowledge, and particularly its lack of quantitative data. The interest is admittedly growing but many studies stay at the qualitative dimension. Kheir and Mir (2012) have examined qualitatively the visual and cultural impacts of the tall building typology and Kheir (2018a) tried to identify spatial patterns. Both these studies were conducted for specific locations.

Quantitative research has been done for specific cities in North America, including New York, Manhattan and Chicago (Ahlfeldt & McMillen, 2018; Barr, 2010, 2012). Barr (2010, 2012) has examined height determinants for buildings exceeding the height of

100 meters for Manhattan and New York, while Ahlfeldt and McMillen (2018) have investigated relations between height, land values and construction costs for the city of Chicago.

Subsequently, until today, studies have been carried out mainly at city scale and to lesser extent at country scale. In addition to this, the research objective of these studies had certain factors in examination, and different ranges of building height and different timeframes were investigated. A recent research direction has been turned to relationships between rent prices and height determinants. Studies focus on the residential and office sector of the real estate market in Netherlands (van Assendelft, 2017; Westerhuis, 2019). Correlation between economic cycles and tall buildings' development for certain global regions was also investigated (Rovelli, 2017). The present research has a direct scientific connection with the research of Chiang (2019), in which tall buildings' height determinants and spatial patterns were studied for the country of China. The proposed research here aspires to act as a continuation to the research engaging China and to cover the rest of the world, similarly investigating height determinants.

1.6.2 Societal relevance

The constant growth of world population and increasing urbanization rates keep pushing cities to accommodate large amounts of population within the upcoming years and correspondingly societies need to adapt to this. The impact of tall buildings on the built environment spreads to multiple aspects, including economic, societal, technological, legal and environmental (Rovelli, 2017).

At the moment, populations are at the epicenter of attention among the sustainability goals set by the United Nations, especially the aspects of population growth and urbanization. Subsequently, a better understanding of the situation of building high will contribute to the need for efficient urban planning policies to achieve the Sustainable Development Goals (United Nations, 2019). Tall buildings are an efficient solution to the excessive urban population demand, due to phenomenon of urbanization. Building vertically is seen as the only choice in places where horizontal development is constrained by natural limits or existing structures (Ali & Al-Kodmany, 2012).

From the perspective of social sciences, the increasing development of tall buildings, leading to denser urban settings, can play significant role in the future urban lifestyle and quality of life (Glaeser, 2011). Cities are designed for people and society develops through the interaction between the people. It is argued that housing dynamics within a city influence people's behaviors, in terms of daily productivity and well-being (Glaeser, 2011; Ng, 2010). These effects are more intense in cities with high densities. Therefore, in such high densities the need for balance, regarding multiple socio-economic aspects is required.

Despite their size, tall buildings have also made steps towards being sustainable and contributing environmental benefits to their host cities (Kheir, 2018b). To have a valid proof for this, a customized sustainability certification has been developed for tall buildings. Opportunities for innovative and more sustainable solutions for construction projects can be expected to spawn through this obligation for tall buildings to reach certain sustainability standards (Bloomfield, 2011). Since tall buildings represent a unique, in its nature, typology, their visual impact in the urban skylines should not be neglected (Ahlfeldt & McMillen, 2018). It is also argued that traits of local identity and culture should be respected and incorporated in the design of this type of buildings due to this aesthetic impact (Kheir & Mir, 2012).

Taking into account the impact of tall buildings on diverse societal aspects, it is becoming evident that the amount of comprehension for the field is deemed insufficient and its significance for further understanding. The quantitative data and qualitative findings of this thesis can provide insights with added value towards the enhancement of the situation and leading to efficient city planning strategies and policies.

1.6.3 Practical relevance

The complexity and remarkable size of a skyscraper as a structure requires the involvements and collaboration of numerous stakeholders (Ali & Al-Kodmany, 2012). Both the quantitative and qualitative results of this research can prove to be beneficial for the stakeholders involved in the wider sector of real estate. The significance of solid understanding of the real estate markets and dynamics, in order for the corresponding stakeholders to achieve efficient decision making, is highlighted in literature. These stakeholders can vary from real estate valuers, brokers and investors to architects, urban planning developers and public policy makers (Ali & Al-Kodmany, 2012; Slade, 2000).

1.7 Summary of Chapter 1

In this first chapter, an introduction to the topic is provided. The main objective is to describe the skeleton of the specific research, before it is unfolded in the upcoming chapters. The research questions that are aspired to be answered through the research are formulated, based on the problem field definition. The research scope is also presented, yet parts of it are explained in more detail in Chapters 2 and 3, especially the rationale behind the height threshold of 150 meters. Chapter 1 closes with a brief reference to the intended methodology, and with the explanation of the relevance of the research. The methodology employed is more elaborately described in Chapter 3, together with the description of the phase of data collection.

2 Literature Study

This second chapter describes the theoretical background behind the determining factors that affect the development of tall building worldwide. In Section 2.1, the definition of a tall building and height measurement is introduced. Section 2.2 includes the presentation of relevant literature in total, while Section 2.3 focuses solely on previous studies of quantitative nature. A brief explanation of the way and process the literature was acquired is provided in Section 2.4 and finally, the key takeaways of the entire chapter are presented in Section 2.5

2.1 Basic features of Tall Buildings

2.1.1 Defining Tall Buildings

It is hard for an indisputable definition, of what a tall building is, to be established. Various approaches can be found in the literature, each one taking into account different criteria. The most common ones include setting a threshold either based on the height of the building or the number of floors. Additionally, others look into the relative size of the buildings among its surrounding ones and the use of advanced technological means (Ambrose, Harris, & Stone, 2008; CTBUH, 2017; Warszawski, 2003).

For the purposes of this research, the definition approach of the Council of Tall Buildings and Urban Habitat (CTBUH) will be adopted. This is based on the fact that CTBUH is the recognized arbiter on matters regarding the characteristics of tall buildings and also the body that attributes the title of "The World's Tallest Building" and rankings per city, country and global regions (Gerometta, 2009). This is enhanced by the fact that the databases of CTBUH for tall buildings will be the main source of data for this study and the respective definitions ensure consistency.

The tall building definition by CTBUH requires that the characteristics of a building belong to, at least, one of the three (3) following categories: 1) Height Relative to Context, 2) Proportion, 3) Embracing Technologies relevant to Tall Buildings. In more detail, a building should, respectively, 1) stand out among its surrounding buildings, 2) be adequately slender to give the appearance of a tall building and 3) employ advanced technologies, such as vertical transportation and structural wind bracing (CTBUH, 2017, 2019). A schematic depiction of these three criteria can be found below in Figure 2.1.

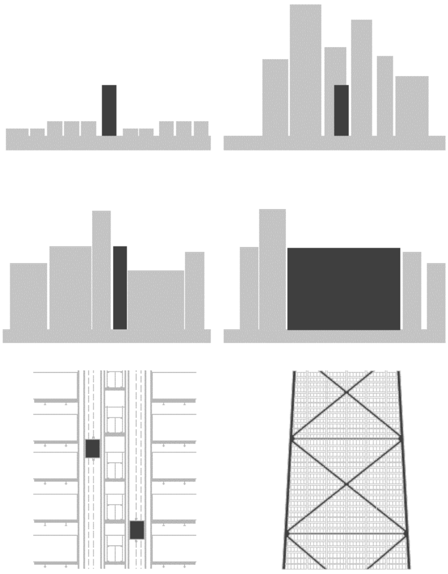


Figure 2.1 Simplified illustration of the three (3) criteria for defining tall buildings according to CTBUH. Source: (CTBUH, 2017)

Apart from setting the aforementioned three (3) criteria, CTBUH (2019) complementarily sets the threshold of 50 meters (165 feet) in order for a building to be defined as tall. Another point of attention is the separation between buildings and towers. There are numerous structures that serve as telecommunication and observation towers, thus, leaving a lot of their space unused. According to CTBUH (2019), in order for a structure to be considered a building, at least 50% of its height must be occupiable. Therefore, for this research, a building is defined as a tall building when it has a minimum height of 50 meters (165 feet), meets at least one of the three (3) criteria of CTBUH and more than 50% of its height is occupiable.

Certain, more precise, definitions also exist. A tall building exceeding the height limit of 150 meters (492 feet) is referred to as a Skyscraper (Kheir, 2018b). CTBUH (2019) has introduced two additional classifications in terms of height; the Supertall and the Megatall buildings. Supertall is a building that achieves the height of at least 300 meters (984 feet) and over a hundred of them have been completed until this day. Megatall is building that achieves the height of at least 600 meters (1968 feet), with only three (3) such impressive structures completed until today.

2.1.2 Measuring Tall Building Height

The main building characteristic that will be addressed in this thesis is the height of the buildings in examination. Thus, it is deemed necessary to specify the exact definition of the term that will be used for measuring height. Similar to defining tall buildings, the definition approach of CTBUH will be embraced for the case of tall building height.

CTBUH (2019) has proposed three (3) different categories for measuring tall building height; 1) Height to Architectural Top, 2) Height to Highest Occupiable Floor and 3) Height to Tip. All three categories have the same starting point for their vertical distance measurement, which is the level of the lowest, significant, open-air, pedestrian entrance of the building.

The Architectural Top of the building includes any spires belonging to the structure, yet excluding antennae, (flag)poles, signage, etc., the Highest Occupied Floor is defined as the finished floor level of the highest occupiable floor inside the building and the Tip is defined as the highest point of the building, regardless of material or function of the highest element (CTBUH, 2019). A visual representation of these three categories can be found in Figure 2.2, using the example of Willis and Petronas Towers height rivalry.

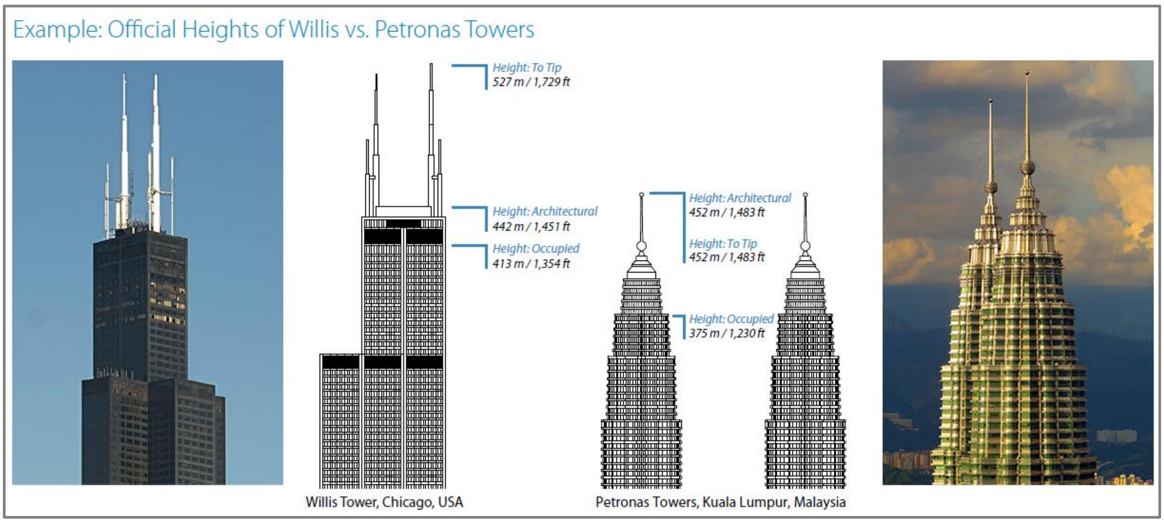


Figure 2.2 The three (3) different height definitions according to CTBUH, via the example of Willis and Petronas Towers. Source: (CTBUH, 2019)

For the purposes of this research, the height measurement category which is used is the Height to Architectural Top, also known as Architectural Height. This is justified by the fact that the upcoming analysis will address aspects mostly linked to the basic functions of the building. An additional height definition by CTBUH which should be mentioned at this point, regards the term of Vanity height. Vanity height is defined as the difference in height between Height to Tip and Occupied Height (CTBUH, 2019). This term is also used in the analysis phase of this study.

2.2 Overall overview of Height Determinants in Literature

The driving forces that influence and determine the fluctuation of tall buildings' height is the main point of attention of this research. Therefore, an extensive literature study on the particular direction is executed. Based on the performed literature review, the height determinants fall into four main categories. This division results in 1)economic, 2) location-related, 3) building-related and 4) other determinants. The fourth category mostly includes cultural, builders' ego aspects or factors of more abstract nature. The identification of height determinants below follows this division.

2.2.1 Economic determinants

According to literature, economic determinants have the most substantial influence on the development of tall buildings. This is introduced by the first study on the subject that took place after the boom of North American skyscrapers around 1930 and explored the linkage between building height and the economic benefits of adding more floors. Land prices, construction costs and rent prices were considered in the investigation. The main conclusion was that expanding upwards is a way of maximizing your potential profit out of a plot of land with specific horizontal boundaries (Clark & Kingston, 1930). The driver of profit maximization is also supported by recent studies (Barr, 2010; Helsley & Strange, 2008; Honorée et al., 2018; Kontokosta, 2013). The goal is to maximize the rentable area, being available to be offered by the developer of the building (Barr, 2010; Helsley & Strange, 2008; Willis, 1995). Moreover, it has been recorded that rent prices are higher in upper floors, as potential buyers link height with social status and stunning views (Barr, 2010). Empirical results supporting the influence of this determinant are derived from studies concerning mostly the region of North America. The elaborate structural systems required to withstand wind and bear huge loads are highly dependent on the prices/costs of construction materials. Therefore, the level of the prices of the materials during the time of the project execution has been observed as another height determinant (Barr, 2010, 2013, 2016; Warszawski, 2003). Similarly to the previous determinant, empirical evidence regarding this factor comes from studies focusing on the region of North America and a small sample of buildings within the country of Israel.

It has also been researched whether there is a relation between the height of tall buildings in Chicago and the business cycles (Hoyt, 1933). In this research, land prices and population size were factors that were considered influential and were examined. A recent continuation of this connection was the creation of Skyscraper Index in order to prove the connection of tall building height with business cycles (Lawrence, Hsu, Luo, & Chan, 2012; Thornton, 2005). In response to the Skyscraper Index, a recent study approached the linkage between business cycles and tall buildings height in a quantitative manner (Barr et al., 2015). Main goal of the study was to assess the credibility of the Skyscraper Index and the conclusion was to reject it (Barr et al., 2015; Thornton, 2005). According to the study, the fact that higher buildings are constructed during prosperous economic times is product of rising incomes and the general robust economic situation of the location in question (Barr et al., 2015).

The economic strength of cities is an important indicator that contributes to the development of tall buildings. In order for studies to decode and quantify this strength, the use of macroeconomic variables, such as real interest rate and Gross Domestic Product (GDP) growth is employed (Barkham et al., 2017; Barr, 2010, 2012; Barr et al., 2015; Honorée et al., 2018; Watts, Kalita, & Maclean, 2007). Studies have resulted to empirical evidence that a country's GDP has a positive relationship with tall buildings' height, while the real interest rate has a negative one (Barr, 2012; Barr et al., 2015; Garza & Lizieri, 2016). Both these macroeconomic variables are taken into consideration, by being calculated as the average value between the year when the project was proposed and the year when it was completed (Barr, 2012). The aforementioned evidence regards studies having mostly as scope tall buildings in North and South America. Regarding solely the positive relationship between GDP and building height, there is evidence supporting it via examination of tall buildings in the region of China (Barr & Luo, 2016). In close relation, the influence of Foreign Direct Investment (FDI) on the height of tall buildings was examined together with GDP in a recent academic study. Empirical evidence was provided supporting the positive relationship between this economic indicator and tall building's height, derived from an analysis of around 700 buildings over 200m, in a global level (Rovelli, 2017).

Another factor, likewise connected to the economic health of respective cities, that has been examined for its influence is the employment rate of a city. It was concluded in studies, having as target the cities of Chicago and New York, with empirical evidence supports that an increase in employment can lead to increase in the number of floors per tall building, and thus, their height. This is highly linked with the demand for additional office spaces, since labour volumes are higher within a city (Barr, 2012, 2013). Connected with the idea of employment rate, the economic indicator of income is examined in studies for its influence on building's height. Empirical results are included in a quantitative study for the buildings over 30 meters high of the city of Tel Aviv, Israel (Frenkel, 2007)

2.2.2 Building-related determinants

A common factor that has been considered important to dictating the height of tall buildings is the main use for which the building is constructed, also found as building function (Barr, 2012; CTBUH, 2019; Garza & Lizieri, 2016). It has been detected that buildings meant for residential purposes reach larger heights compared to buildings for office and commercial use. An interesting trend that has been dominant in the 21st century is the mixed use of tall buildings (Barr, 2012, 2016; Kheir, 2018a). The studies that investigated the influence of the building function explored the number of floors tall buildings have as a complementary determining factor. A remark should be made at this point, drawing attention to possible cause and effect relation between height and choice and of building function. Same applies to the choice of construction material. The size of the plot of land, that hosts a tall building, has been examined as a determinant in studies regarding cities in the United States of America (Barr, 2010, 2012, 2013). The size of the plot is an important part of the economic considerations for tall buildings, due to its impact to the height and to generating extra marginal costs. However, it is argued that taking it into account, as a determinant, might be redundant, since it goes without saying that developers choose large plots of land when it comes to the construction of tall buildings (Barr, 2013). It should be noted that the evidence for the significance of the specific determinant is limited to studies concerning cities in North America. In close relation to the size of the plot, the underground soil conditions and especially the bedrock depth has been regarded as a height determinant in studies, again focusing in cities of USA, New York in particular. Although engineering limitations regarding foundations have been eliminated, the consideration of cost is yet an important parameter, in case where it is needed to reach deep to find solid bedrock. Subsequently, additional costs occur for deep and complex foundations, which can have as a result the reduction of floors and hence affecting negatively the height of the buildings (Barr, 2012; Barr et al., 2015; Kheir, 2018b)

2.2.3 Location-related determinants

Looking back to the most basic purpose that tall buildings are designed for, which is accommodating large amounts of population, city size and the number of residents are certainly regarded as major height determinants. Given their capability of providing space in layers vertically, tall buildings can surely act as a favourable solution towards this excessive demand for increasing urban residents (Ali & Al-Kodmany, 2012). The size of the city that hosts tall buildings together with its population are directly influencing the number and size of tall buildings (Barkham et al., 2017; Helsley & Strange, 2008; Ibrahim, 2007). The size of city population is one of the most influential determinants in studies focusing on cities of North and South America as well (Barr, 2010, 2012, 2013; Barr et al., 2015; Garza & Lizieri, 2016; Honorée et al., 2018).

Empirical evidence concerning tall buildings in North and South America support the fact that height of tall buildings increases as population increases (Barr, 2012). Similar conclusions are drawn in studies investigating the case of China (Barr & Luo, 2016). As far as population is concerned as a determinant, there are studies that use urbanization to approach the connection. The excessive levels of urban population have led to extreme growth of cities, hence feeding the demand for tall buildings (Ibrahim, 2007; Kheir, 2018a; Trujillo & Parilla, 2016; Watts et al., 2007). One of the reasons for this is the massive immigration to urban centres in quest for job opportunities (Frenkel, 2007).

Another factor that has been known to negatively affect the development of tall buildings is the presence of land-use regulations, in most case at city level. Such a constraint for the height of tall buildings can be achieved by setting height limits on individual buildings and enforcing zoning (Ali & Moon, 2007; Barkham et al., 2017; Barr, 2010). Zoning is a quite common urban planning policy in cities of United States, such as New York and Chicago. It is highlighted that during the tall building boom in the early start of 20th century, no height restrictions were into effect, and the development of such buildings lived its glory days (Barr, 2010, 2012). This increasing tall building development, though, accompanied by overcrowding and casting shadows were the reasons for the creation of land-use regulations around 1920. Height restrictions per city district were introduced as a response and their effect to height was later found to have negatively affected height (Barr, 2013).

A less explored factor is whether a city acts as a harbour or port. Limited amount of studies have remarked that cities that have a harbour, host a significant amount of tall buildings (Ali & Al-Kodmany, 2012; Gottmann, 1966). However, there is lack of empirical evidence to support this observation securely. More targeted studies go even further and consider the distance to the city business district for the buildings in question (Barr, 2012). It has been observed that height can variate even within the same city, depending on how close to the core of a city's business activity a building is located. A city's business district is associated with agglomeration economies, a phenomenon which attracts taller buildings (Garza & Lizieri, 2016). The basic principle of agglomeration economies relies on the aggregation of economic activities and businesses in the same vicinity within urban settings, and tall buildings inherently enhance this phenomenon (Ali & Al-Kodmany, 2012; Helsley & Strange, 2008). Gathering tall buildings in close proximity, especially for business purposes, translates to gathering skilled businesspeople. Thus, knowledge transmission is encouraged and effectively achieved leading to enhancement of innovative activity (Audretsch, 1998).

2.2.4 Other determinants

A factor that has been considered to be a driving force for the development of tall buildings and their height is the height competition among builders (Barr, 2010). It is argued that being accountable and renowned for the tallest buildings on earth brings benefits to the builders and respectively pushes the height limits of buildings (Helsley & Strange, 2008). Supportive empirical evidence for the influence of builders' rivalry on height competition are found in a comparative study between New York and Chicago (Barr, 2013). It is also observed that this competitive phenomenon takes place during prosperous periods for the corresponding local economies (Barr, 2012). Through this interaction, it has been also examined whether a strategic interaction among builders of neighbouring cities can occur and guide tall buildings' development and height. The study which treated this research objective came up with limited evidence to draw secure conclusions, but even if strategic interaction is plausible, it remains a local phenomenon (Barr, 2013). Regarding the region of China, there are controversial conclusions on whether height competition exists, a fact that can be attributed to the difficulty of this determinant to be quantified. More specifically, studies have provided evidence supporting excessive development and presence of height competition for buildings over 200 meters in China, whereas other studies focusing on a larger sample of buildings exceeding 100 meters in height find no evidence, especially as far as inter-city competition is concerned (Barr & Luo, 2016; Li & Wang, 2018). In order for studies to attempt to quantify whether height competition has basis, another potential determinant came into light and this was the number of already completed tall building projects and their height, also known as previous completions (Barr, 2013; CTBUH, 2019).

Although difficult to be quantified and hence assessed, it is argued that the government of cities exploit the symbolic nature of tall buildings in order to create a robust economic appearance and social status. It can serve as a visual proof that these cities are ready to accept and welcome investments (Barr et al., 2015; Kheir & Mir, 2012; Parker, 2015). Having a plethora of tall buildings can act as a way to gain value of status (Barr, 2012). For instance, the development of iconic tall buildings facilitated the entry of various Asian cities, such as Kuala Lumpur, Singapore and Shanghai to the ranks of upper global cities (Vanolo, 2017). It is argued that attractive new-built tall buildings can aesthetically rejuvenate "dull" urban neighbourhoods (Ali & Al-Kodmany, 2012). This effect can be enhanced even more when ensuring cultural integration to the location the building is placed (Kheir & Mir, 2012). The city in which tall buildings are located and especially its importance as a business centre is regarded as another determinant. This factor is observed in numerous studies, emphasizing on cities that play an important role in global trade and commerce, having global connectivity (Ali & Al-Kodmany, 2012; Barkham et al., 2017; Barr, 2012).

The abovementioned realization that cultural integration is needed for tall buildings as well led to focus of a study towards cultural aspects. A visual and cultural integration of this modern building typology to the particular characteristics of each location is essential (Al-Kodmany, 2013; Kheir & Mir, 2012). Consequently, within a recent study the influence of cultural determinants is examined, being ignored so far. That is why it is attempted to evaluate their impact by using Hofstede's cultural dimensions and specifically, power distance, individualism and masculinity. For instance, a hypothesis that high individualism is linked with aiming for taller buildings is formulated (Honorée et al., 2018). In this research, the height of the tallest building, of each country that was examined, is used. Indeed, the analysis indicated that height is consistent with Power distance primarily, which is relevant to other theoretic studies that suggest that tall buildings are associated with the need of certain cultures to symbolise their domination (Honorée et al., 2018; Parker, 2015).

A conclusive and clear overview of the various height determinants and their frequency in literature can be found below in Table 2.1. A remark should be made here that the discussion in this section and hence Table 2.1 regard a mixture of determinants that are either evidence-based or stated in the literature through observations and based on educated suggestions.

Table 2.1 Overview of the various height determinants and their frequency in literature, regardless of type of study (quantitative or not) (Own illustration)

Height Determinants	(Clark & Kingston, 1930)	(Hoyt, 1933)	(Gottmann, 1966)	(Warszawski, 2003)	(Thornton, 2005)	(Watts et al., 2007)	(Frenkel, 2007)	(Ibrahim, 2007)	(Helsley & Strange, 2008)	(Moon et al., 2010)	(Barr, 2010)	(Al-Kodmany, 2011)	(Ali & Al-Kodmany, 2012)	(Barr, 2012)	(Barr, 2013)	(Ding, 2013)	(Kontokosta, 2013)	(Parker, 2015)	(Barr et al., 2015)	(Barr, 2016)	(Garza & Lizieri, 2016)	(Barr & Luo, 2016)	(Barkham et al., 2017)	(Rovelli, 2017)	(Kheir, 2018a)	(Kheir, 2018b)	(Ahlfeldt & McMillen, 2018)	(Li & Wang, 2018)	(Honorée et al., 2018)	(Chiang, 2019)	**Count (out of 30)**
Economic																															
Profit Maximization	✓								✓		✓						✓											✓	✓		**6**
Business Cycles		✓			**X**	✓													**X**		✓			✓							**2**
GDP (City)												✓		✓					✓			✓	✓	✓				✓		✓	**8**
GDP (Country)						✓					✓				✓						✓			✓					✓		**6**
Real interest rate						✓					✓			✓	✓									✓					✓		**6**
FDI							✓																	✓				✓			**3**
Employment rate											✓			✓	✓													✓			**4**
Income							✓												✓				✓								**3**
Real Estate Loans											✓				✓																**2**
Stock volume											✓				✓																**2**
Construction costs	✓			✓							✓	✓	✓	✓						✓				✓			✓				**9**
Building-related																															
Building use/function							✓			✓		✓		✓						✓	✓			✓	✓		✓	✓	✓	✓	**12**
Plot size											✓			✓	✓																**3**
Rent price	✓			✓						✓										✓											**4**
Material	✓			✓							✓	✓		✓	✓					✓				✓		✓		✓		✓	**11**
Bedrock depth														✓																	**1**

Height Determinants	(Clark & Kingston, 1930)	(Hoyt, 1933)	(Gottmann, 1966)	(Warszawski, 2003)	(Thornton, 2005)	(Watts et al., 2007)	(Frenkel, 2007)	(Ibrahim, 2007)	(Helsley & Strange, 2008)	(Moon et al., 2010)	(Barr, 2010)	(Al-Kodmany, 2011)	(Ali & Al-Kodmany, 2012)	(Barr, 2012)	(Barr, 2013)	(Ding, 2013)	(Kontokosta, 2013)	(Parker, 2015)	(Barr et al., 2015)	(Barr, 2016)	(Garza & Lizieri, 2016)	(Barr & Luo, 2016)	(Barkham et al., 2017)	(Rovelli, 2017)	(Kheir, 2018a)	(Kheir, 2018b)	(Ahlfeldt & McMillen, 2018)	(Li & Wang, 2018)	(Honorée et al., 2018)	(Chiang, 2019)	**Count (out of 30)**
Location-related																															
Land area (city)								✓	✓							✓					✓		✓						✓	✓	**7**
Population						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓			✓	✓		✓	✓	✓	**18**
Urbanization rate						✓	✓	✓	✓	✓						✓					✓				✓	✓		✓	✓	✓	**12**
Land value	✓			✓								✓	✓	✓									✓		✓		✓				**8**
Land-use regulations (Zoning)						✓					✓			✓	✓	✓	✓			✓			✓								**8**
Floor Area Ratio														✓																	**1**
Purchased Air rights														✓						✓											**2**
Located in Capital city								✓																✓					✓		**3**
Located in CBD							✓			✓				✓		✓					✓		✓				✓				**7**
Harbour/ Port			✓																											✓	**2**
Other																															
Business city								✓													✓		✓	✓							**4**
Global city connectivity			✓																				✓								**2**
Height competition			✓					✓	✓				✓	✓									✓		✓			✓			**8**
Builders' strategic interaction									✓						✓											✓			✓		**4**
Past Completions											✓				✓					✓		✓								✓	**4**
Cultural																		✓											✓		**2**

2.2.5 Frequency of height determinants in explored studies

Based on the existing findings of the literature review, it is inferred that the development of tall buildings is mainly influenced by the characteristics of the corresponding location. Similarly, the economic factors are suggested to significantly affect but to lesser extent, judging by the frequency of the respective determinants. Building-related determinants rank third in terms of influence, followed by other determinants. For a better overview, the top-ranking determinants are gathered per category in the following Table 2.2.

Table 2.2 Most frequent height determinants for tall buildings per category based on the literature review

Determinant	Category	Frequency (out of 30)
Population size	Location-related	18
GDP	Economic	14
Urbanization rate	Location-related	12
Building use	Building-related	12
Construction material	Building-related	11
Construction costs	Economic	9
Land values	Location-related	8
Land-use regulations	Location-related	8
Height competition	Other	8
Located in CBD	Location-related	7
Land area size	Location-related	7

Looking into the frequency of the determinants individually, the population size of the location is the factor with the most references in current bibliography. In close relation to population size, and ranking third in literature appearances, the urbanization rate of a location is also regarded as one of the most significant determinants. As far as the aspect of location is still concerned, local land values and existing land-use regulations are deemed as influential factors, followed by land area size and distance to the business district of the city in question.

Regarding the determinants of economic nature, the Gross Domestic Product (GDP) and costs required for overall construction are the two most common factors found in literature. The use that tall buildings are designed to serve and the chosen material for their construction elements are the two most frequent factors found in literature. However, it should be noted here that the existence of the cause and effect relationship should be taken into consideration in the process of this research. The phenomenon of height competition also appears quite often, as a driving force that pushes the height of tall buildings to the maximum.

2.3 Quantitative studies providing empirical evidence for height determinants

2.3.1 Overview of evidence-based studies

The process of literature review resulted in an amount of 30 publications, relevant to the specific research. However, only 16 of them employ a quantitative methodology. In this section, a targeted review on these studies, that have provided empirical results, is presented. This is deemed relevant to the present research, as it is a quantitative study, aiming foremost to provide supporting empirical evidence. Emphasis is placed on the variables, location and height of the buildings that were examined and a concise gathering of them is presented in Table 2.3 below. The full version of this Table, including all key elements per publication, can be found in the Appendix. Following this table, a detailed presentation of the relevant quantitative studies is described in chronological order.

Table 2.3 Overview of quantitative studies on tall buildings' development and height

Author	Study area	Study period	Heights examined	Dependent variable	Independent/ Examined variables	Model
(Clark & Kingston, 1930)	Manhattan	1929-1930	-	-	-Construction costs -Land values -Rent prices	Cost-Benefit Analysis
(Frenkel, 2007)	Tel Aviv, Israel	Until 2001	>27m	-Amount of buildings	-Building use -District located within city -Income	Multinomial Logit Model/ Regression
(Helsley & Strange, 2008)	-	-	-	-	-Height competition -Strategic interaction between developers	Game-theoretic model
(Moon et al., 2010)	Seoul, South Korea	-	>100m	-Rent price	-Height -Gross building space -Number of households -Avg. surrounding heights -Years to completion -Uniqueness of appearance	Multiple Regression
(Barr, 2010)	Manhattan	1895-2004	>100m	-Number of completions -Average height	**Building-related:** -Avg. (skyline) height -Avg. plot size **Economic-related:** -Real construction costs index (national) -Inflation, GDP deflator % (national) -Value of real estate loans (national) -F.I.RE/total employment (national) -Real interest rate (national) -Avg. daily traded stock volume -Population (city) -Dow Jones industrial index -City's economic volatility **Topical:** -Zoning regulations	Regression /OLS

(Barr, 2012)	New York	1895-2004	>100m	-Height	**Building-related:** -Plot size & shape -Depth to bedrock -Distance to Central business core -Building use (residential, office, etc.) **Economic-related:** -Real interest rate -Real construction cost index -City population -National F.I.RE/ Employment -Equalized land assessed value **Topical:** -Zoning regulations -Floor Area Ration -Purchased air rights	Decision theory game/(Spatial) regressions
(Barr, 2013)	Chicago & New York	1885-2007	>80m (for Chicago buildings) >90m (for New York buildings)	-Number of completions per city -Maximum height	**Building-related:** -Avg. Height -Avg. & max. plot size **Economic-related:** -GDP (national) -F.I.RE/ Employment rate (National) -Real material cost index (national) -Real estate loans (national) -Real interest rate (national) -Population size (city) -NYSE/CSE stock volume **Topical:** -Zoning regulations	Regressions
(Barr et al., 2015)	USA, Canada, China, Hong Kong	1885-2009 (USA), 1922-2008 (Canada), 1972-2008 (China), 1950-2008 (Hong Kong)	Tallest completed per year		-Height -GDP	Vector AutoRegressions
(Barr & Luo, 2016)	China	1970-2014	>183m	-Annual completions -Max. height	-Height -Population -GCP (city GDP) -Government revenues -Government expenditures -Relative distance	(Spatial Autocorrelation) Regression

(Garza & Lizieri, 2016)	Latin America (29 cities from 10 countries)	2000-2012	>65m	-Height	-Building use -District within city -completion date -GDP (national) -Area size (city) -UNESCO Global Heritage Site -Population -Urbanization -Business cycle -City Ranking (GaWC)	Regression / OLS
(Barkham et al., 2017)	Global	2000-2015	>200m	-Number of floors	-GDP -Income -Land area -CBD distance -Global connectivity	Regression
(Rovelli, 2017)	Global	1909-2016 (building-related), 1960-2015 (GDP),1970-2015 (FDI), 2009-2017 (construction costs)	>200m	-	**Building-related:** -Height -Number of floors -Building use -Material -Date of proposal -Date of completion **Economic-related:** -GDP growth -Real interest rate -FDI -Construction costs (residential or office) -City Ranking **Topical:** -Location (city, country)	Correlations
(Ahlfeldt & McMillen, 2018)	Chicago	1870-2010	>17m	-land prices/values	-Height -Land use (commercial or residential) -Distance to CBD -Floor space/area (limited data) -Construction costs (limited data)	Spatial/ Micro-geographic analysis and correlations
(Honorée et al., 2018)	Global/ 90 countries	Until 2008	Tallest building per country	-Height	**Cultural (Hoftstede's dimensions):** -Power Distance -Individualism -Uncertainty Avoidance -Masculinity **Building-related:** -Height -Building use **Economic-related:** -GDP growth -Real interest rate **Topical:** -Urbanization rate -Located in capital city	Regression
(Li & Wang, 2018)	China	2003-2015	>200m	-Cumulative Height per city	-Height -Population -Urbanization rate -GDP -FDI -Employment rate	Regression

(Chiang, 2019)	China	1980-2018	>200m	-Height (Architectural, Occupied, Vanity)	**Building-related:** -Number of floors -Building use -Material -Type of finishing (roof) -Date of proposal -Date of start -Date of completion **Economic-related:** -GDP (city) -Industrial size **Topical:** -City size -Population -Population density -Government control -Completions	Linear Regression

The first quantitative study towards investigating the height and economics of tall buildings dates back to 1930 (Clark & Kingston, 1930) . The intention of this specific study was to assess whether building high could be regarded as a financially rational investment, contrary to the common belief back then that skyscrapers were solely a result of height competition. The analysis was performed using a Cost-Benefit Analysis approach. The case study involved the hypothetical development of a tall office building on an existing plot of land, located in the business district of Manhattan. The basic conclusion drawn was that height is consistent with profit maximization. A certain number of floors is required to be constructed in order for the developer to break even and as moving upwards additional profits could be generated (Clark & Kingston, 1930; Helsley & Strange, 2008). Specifically, the optimal number of floors to reach the highest return was estimated to be 63 floors. The variables examined in this early study were land prices, construction costs and expected rent revenues. All three variables were based on local data for the year 1929 (Clark & Kingston, 1930).

Insisting on the notion of height competition, another study handled the phenomenon of strategic interaction between builders (Helsley & Strange, 2008). A game-theoretic model was designed to assess the behavior between 2 rival developers within the same city. It was concluded that if one of the developers is in possession of a more favourable location, they will act strategically by adding additional height in order to pre-empt the other developer of attempting to surpass their height. Therefore, evidence for strategic interaction between developers and hence, height competition is provided by this study (Helsley & Strange, 2008). Additional variables that are believed to affect the height of tall buildings are discussed as indicative in the respective publication, such as local population and urbanization rate, but due to the nature of the analysis no concrete evidence is provided to quantitatively support their influence.

In an early, and limited to the region of Tel Aviv in Israel, Frenkel (2007) investigated the spatial distribution of high-rise buildings within the wider urban area. The database used included 1506 buildings, taller than 27 meters and the dependent variable was the amount of buildings. The main factors that were examined for their influence were the proximity of the building to the Central Business District (CBD), building use and to lesser extent the income of residents. The empirical results suggest that there is higher concentration of tall buildings closer to city centre and that a trend towards residential and mixed building use is marked. The author also predicts that in the future it is highly possible to have suburban areas, solely dedicated to residential purposes (Frenkel, 2007).

Another early, for the field, study in South Korea investigated the connection between rent prices and the uniqueness of the building's appearance (Moon et al., 2010). The research concerned 30 residential buildings over 100m for the city of Seoul in South Korea and the dependent variable was the rent price per m2. The limited sample and the fact that the dependent variable is not the height makes the specific research partially relevant to the present one, but the positive relationship between higher rent prices for higher floors should be noted.

Moving to a more recent study, more related to the present research due to the use of multiple regression as analysis model, Barr (2010) examined quantitatively tall buildings over 100m in height, between 1895-2004, for the region of Manhattan. The objective of the specific study was to investigate the influence of suspected determinants to the average height of tall buildings and their number of completions. Hence, these two factors were handled as the dependent variables for the analysis. The examined determinants were divided into categories in order to depict their nature more accurately. These categories mostly include building-related determinants and economic ones, which are further divided into national and city-related. The main conclusion of the research is that economic factors, especially the ones reflecting the economic robustness of the city in question, are more consistent to influence height and number of completions. Delving deeper, the size of the city's population and employment rate are the two strongest determinants, having a positive relationship to both dependent variables, followed by construction costs and presence of zoning regulations, which affect negatively (Barr, 2010). Additionally, the study does not support the idea of height competition for the region of Manhattan, based on the findings and correlations occurring for the number of past completions and trends in height. As far as limitations are concerned, the author uses the national real construction costs index to depict construction and material costs for the investigated buildings but points out a reluctancy to whether this approach is the best measurement available.

Expanding the study area to the whole city of New York, Barr (2012) attempts to evaluate the influence of quest for status together with economic factors, for buildings reaching over 100m and between the timeframe 1895-2004. As far as regression analysis is concerned, the dependent variable is only one, height, for this study and the examined variables are again divided into building-related and economic. The study provides evidence for height competition between builders, with the use of spatial econometric models, a phenomenon especially encouraged during boom periods. Digging deeper into the results of regressions, zoning regulations and construction costs act as major determinants, having a negative influence in height. City's employment rate and population size are the two most positively influential factors towards height, similar to previous studies including only the sub-area of Manhattan (Barr, 2010, 2012). Plot size is also supported by evidence for having a positive relationship with tall buildings' height. An innovative element of this particular study is the consideration of purchasing air rights as a height determinant and including it in the regression analysis. Although, instinctively, it makes sense that by acquiring surrounding air rights, developers are able to reach higher altitudes, this study for the case of New York supports it with quantitative data.

The need to further enhance the pool of empirical evidence regarding strategic interaction between developers ignited another study, in which buildings of Chicago and New York are examined for potential interurban competition (Barr, 2013). The research concludes that there is mediocre evidence for interurban competition and strategic interaction between developers. Although the main focus of this research lies in strategic interaction, still fruitful key takeaways can be extracted by critically isolating results from the regression analyses. The size of the city's population is again the most influential factor regarding height. Employment rate, GDP growth and stock volume are less influential factors, yet with solid positive effect on height increase. On the other hand, based on the analysis performed, cost of materials and zoning regulations indicate a negative relationship with height (Barr, 2013). A remark should be made at this point that the sample of buildings that were taken into account in this study was relatively small, 113 for each city, and including buildings lower than 100 meters high.

In 2012, an economist of Barclay's Bank conducted research and came up with a indicative timeline, depicting world's tallest buildings completions in comparison to business cycles, especially crisis times. The end product of this research was an Index, called Skyscraper Index and the main suggestion was that the development and height of tall buildings is dictated by the fluctuation of business cycles (Lawrence et al., 2012). A follow-up study to further investigate whether the Index is well-founded took place (Barr et al., 2015). Although the focus of the research was on validating the significance of Skyscraper Index, collateral evidence can still be drawn in connection to the current research, due to its quantitative nature. The main conclusions based on quantitative results indicate that height of tall buildings is heavily driven by GDP and to a lesser extent by high-income levels, while the driver of height competition is not systematic.

Barr and Luo (2016) investigated certain factors that affect tall buildings development in China, in order to determine whether the excessive boom in the country represents a rational response to demand. A database of tall buildings, over 183 meters tall, across 74 different cities within China was created, taking into consideration completions for the period between 1970 and 2014. For the analysis, regression and spatial autocorrelation models are employed with two dependent variables; annual completions per city and tallest building height per city as well. The size of cities' population, GDP and government's revenues and expenditures were the basic independent variables. GDP and population were found to have the strongest influence on height and number of completions, which is positive, as expected. For the specific study, a trend towards gradually increasing heights is noticed, while no evidence is found to support the presence of interurban height competition. An interesting fact about the real estate market of China is also highlighted in the publication in question. China does not have a free market in terms of land, land is owned by the government in almost every case (Barr & Luo, 2016, 2018).

Directing attention to Latin America, in another attempt to test theories regarding record breaking buildings' height, Garza and Lizieri (2016) used regression models providing additional empirical evidence related to the present research. Height was selected as the dependent variable and the scope included 377 buildings over 65 meters tall, across 10 different countries in Latin America for the timeframe of 2000-2012. The main variables that were taken into account are height, building use, GDP, location within the city itself, population size, city ranking and whether the location is associated with UNESCO heritage. As far as results are concerned, GDP proves to be the most positively influential factor, the size of the city area affects negatively the height of tall buildings and the study is inconclusive for the influence of business cycles. Ranking of cities also proved a good predictor for height, meaning that it is expected for buildings to be taller in cities that are considered well developed and of economic importance. The height of buildings with proximity to UNESCO protected sites are affected negatively. The researchers call for extending the research to a wider range of cities and regions, which is also considered a limitation at the same time.

Barkham et al. (2017) conducted a research concerning tall office buildings globally between 2010 and 2015, with the intention to prove the importance of four specific factors. These four factors were: GDP, size of land area, global connectivity of city examined and existence of land-use regulations. After the regression analysis, the significance of the first three aforementioned factors was supported quantitatively and characterized by a positive relationship to tall buildings development, while the presence of land-use regulations had a negative influence.

Rovelli (2017) researched, with a quantitative approach, the relationship of tall buildings with economic cycles. GDP in different variations, Foreign Direct Investment (FDI) and real interest rate were the main variables, on which emphasis was placed on. Regression analyses were conducted using a database of approximately 1600 buildings, mostly for the period of 1960-2015. Data for construction costs was also obtained for the time period between 2009-2017, regarding buildings for residential and office use. The results of the analyses concluded that the amount of new built tall buildings globally is highly and positively linked with the GDP level and FDI, while real interest rate affects negatively, having less influence though.

The excessive concentration of tall buildings in Chicago and observed trend for taller heights drew the attention of another study, mainly focused on interrelating height and land values this time. Ahlfeldt and McMillen (2018) employed a spatial, micro-geographic approach to examine such relationship and provide additional empirical evidence to the field. Their research scope involved 1737 buildings, taller than 17meters in the city of Chicago, built between 1870 and 2010. Height, exact location and year of completion were the main variables used for the analysis. The key conclusions provide strong positive correlation between height increase and proximity of the location to Central Business District (CBD) and negative effect of construction costs to height rising. Positive, but less strong, relation is indicated between land price and height. The fact that the specific study also includes buildings having height lower than 50 meters should be noted and taken into account.

In an alternative direction other than economically related determinants, Honorée et al. (2018) performed research on variables affecting tall building's height with special focus on incorporating cultural variables, based on Hofstede's cultural dimensions. Despite the clear focus on cultural factors, building- and economic-related determinants were also taken into consideration and the dependent variable of the analysis was architectural height. However, the sample is deemed as limited as it only includes 1 building (the tallest one) out of 90 countries in order to cover as many countries as possible to serve its multicultural research purpose. Another limitation, as suggested by the authors, is the omission of material costs variables. The results of the analysis showed that the economic variables have the strongest influence in height increase, especially real interest rate, GDP growth and urbanization, with cultural ones being limitedly influential.

Li and Wang (2018) focused their study on the evolution of Chinese skyscrapers for the timeframe of 1990-2016. Main objectives were to test the presence of height competition between cities and provinces, and find evidence for potential overbuilding. The authors make a remark to explain why the height competition exists in China, attributing it to the intention of province governments to increase land value, and hence attract foreign investments, while satisfying their ego at the same time. Through the descriptive statistics, a trend for a transition to mixed use tall building function is noticed and through regression, interurban height competition, increasing urbanization and GDP are supported by empirical results, having positive influence on height. Into more depth, regarding the regression analysis, the dependent variable was the cumulative height of the buildings per city and the main examined variables were urbanization rate, GDP and FDI. Database consisted of 722 Chinese buildings, exceeding height of 200 meters, between 2003 and 2015 (Li & Wang, 2018).

To the knowledge of the writer, the most recent relevant study on height determinants of tall buildings concern the country of China, examining tall buildings over 200 meters high. More specifically, Chiang (2019) investigated the height patterns and height determinants for the country of China, excluding Hong Kong and Macau, due to the difference of governing system. Over 600 buildings were included in the dataset, with their completion ranging from 1980-2018. Regarding the regression analyses, the dependent variable is height, in three variations, namely architectural, occupied and vanity. The specific study places less attention to economic variables, focusing on building and city-level related ones. The general conclusion is that building-related factors have stronger influence than the city-level ones, and once again city GDP is the most significant determinant for height. Certain examples that dictate city advertisement purposes, to attract foreign investments, through building skyscrapers are detected. The author additionally remarks that China has large portions of land inefficiently exploited, fact that does not correspond with the popular theory of building tall in cases of land scarcity. Digging deeper into the regression results, GDP is the strongest determinant to height, followed by size of city population and density, with all of them affecting positively. The use of the buildings and the existing amount of tall buildings are also significant, again influencing height in a positive way (Chiang, 2019).

2.3.2 Confirmed Height Determinants

In this section, the determinants that have been confirmed to have correlation with the height and amount of tall buildings are presented. The confirmed correlations result from empirical findings of the studied publications. A concise overview can be found in Table 2.4 below.

Table 2.4 Overview of height determinants, confirmed by empirical results

Height Determinants (supported by empirical evidence)	(Clark & Kingston, 1930)	(Frenkel, 2007)	(Helsley & Strange, 2008)	(Moon et al., 2010)	(Barr, 2010)	(Barr, 2012)	(Barr, 2013)	(Barr et al., 2015)	(Garza & Lizieri, 2016)	(Barr & Luo, 2016)	(Barkham et al., 2017)	(Rovelli, 2017)	(Honorée et al., 2018)	(Ahlfeldt & McMillen, 2018)	(Li & Wang, 2018)	(Chiang, 2019)	**Count (out of 16)**
Economic																	
Profit Maximization	✓				✓												**2**
Business Cycles								X									**0**
GDP (City)					✓		✓	✓		✓	✓				✓	✓	**7**
GDP (Country)									✓				✓				**2**
Real interest rate					✓	✓	✓						✓				**4**
FDI															✓		**1**
Employment rate					✓	✓	✓										**3**
Income																	**0**
Real estate loans					✓												**1**
Stock volume							✓										**1**
Construction costs					✓	✓								✓			**3**
Building-related																	
Building use/function		✓							✓				✓	✓		✓	**5**
Plot size						✓											**1**
Rent price				✓													**1**
Material					✓	✓	✓									✓	**4**
Bedrock depth					✓												**1**
Location-related																	
Land area (city)									✓		✓		✓			✓	**4**
Population					✓	✓	✓		✓	✓			✓			✓	**7**
Urbanization rate									✓				✓		✓	✓	**4**
Land value														✓			**1**
Floor Area Ratio																	**0**
Purchased Air rights						✓											**1**
Located in Capital city																	**0**
Located in CBD		✓							✓					✓			**3**
Harbour/ Port																	**0**
Other																	
Business city									✓								**1**
Global city connectivity											✓						**1**
Height competition			✓			✓	✓								✓		**4**
Strategic interaction between builders			✓				✓										**2**
Past Completions																✓	**1**
Cultural													✓				**1**

Summarising the findings of Table 2.4, the category of economic determinants has the most confirmed determinants, with the location-related ones coming second. Compared to the general findings of Table 2.1, where location-related determinants were the dominant category, a shift takes place. This can be attributed to the fact that economic indicators are easier to be included and measured in quantitative studies. Building-related and other determinants follow correspondingly, in a similar manner as observed in the general findings of Section 2.2. A comparative overview of the findings of this Section and Section 2.2 is presented in Table 2.5 below. This comparison regards the frequency of the determinants individually.

Table 2.5 Comparative table of determinants based on mixed literature findings and quantitative studies

Based on quantitative studies:			**Based on mixed literature findings:**		
Determinant	**Category**	**Frequency** (out of **16**)	**Determinant**	**Category**	**Frequency** (out of **30**)
GDP	Economic	9	Population size	Location-related	18
Population size	Location-related	7	GDP	Economic	14
Building use	Building-related	5	Urbanization rate	Location-related	12
Real interest rate	Economic	4	Building use	Building-related	12
Construction material	Building-related	4	Construction material	Building-related	11
Land area size	Location-related	4	Construction costs	Economic	9
Urbanization rate	Location-related	4	Land values	Location-related	8
Land-use regulations	Location-related	4	Land-use regulations	Location-related	8
Height competition	Other	4	Height competition	Other	8
Located in CBD	Location-related	3	Located in CBD	Location-related	7
Construction costs	Economic	3	Land area size	Location-related	7

Comparing the findings, it is understood that the majority of determinants that are also evidence-based coincide with the ones that are found in the mixed literature, as discussed Section 2.2. There are three exceptions, though. The first exception regards the construction costs. Although, in the mixed presentation of height determinants, construction costs are identified as the fifth most influential factor, when checking its frequency in empirical studies, this has an appearance rate of 3 out of 16 publications. This fact can most likely be attributed to the difficulty of acquiring data for such costs, especially for a variety of countries and cities, and for large timespans. It is also noted that land values are ignored in the majority of quantitative studies, possibly again due to the availability of data. Thirdly, the relationship between height and proximity to CBD is found in limited evidence-based studies. This can be attributed to the complexity regarding this factors, which includes acquiring coordinates. Another interesting observation is the fact that height determinants that are widely discussed in the literature, have not been examined at all in quantitative studies, such as income.

2.3.3 Coverage of geographical regions by quantitative studies

Since the objective of this study is to provide a holistic understanding of the development of tall buildings at a global scale, gaps for underexamined geographical regions are identified. Thus, a relevant evaluation is provided in this section as follows.

The region of Northern America is mainly investigated by one researcher with emphasis on the cities of New York and Chicago. The tall buildings that are examined have height over 100 meters and the studies include the relevant buildings that are built until 2004. The region of South America has been mainly investigated by one study (Garza & Lizieri, 2016). The study included buildings with height above 65 meters, being completed from 2000 to 2012. The region of Asia has attracted the attention of recent studies due to the increasing amount of newly built tall building the last two decades. All related studies have examined buildings with height over 200 meters and the timeframe between 1970 and 2018 has been covered (Chiang, 2019; Li & Wang, 2018). The rest global regions have not received similar attention so far. The rest of the studies included in this section had a global scope, and thus partially included and examined the rest regions of the world. However, this has been the case for different ranges of height and determinants, without providing a unified gathering of findings.

Based on the above facts, certain gaps can be detected. First of all, the newest tall buildings of North America, between 2005 and 2019, have not been investigated. Additionally, the region of Middle East, despite the concentration of numerous tall buildings in short time period, have not been examined quantitatively. Although the region of Asia, and specifically China, has been examined in recent studies, it is detected that the tall buildings with architectural height between 150 and 200 meters have been neglected. This marks a substantial amount of buildings, possibly leading to more concrete conclusions if included. Lastly, certain regions have not been included at all, namely Oceania.

2.4 Selection criteria for literature study

In order for the literature study to be as explicit as possible, a brief description of the process of selecting the relevant literature is described (van Wee & Banister, 2016). The publications reviewed were acquired with the use of the online tool of the TU Delft Library, WorldCat Discovery Database (connected with results of worldwide libraries), and Google Scholar. Into more detail, regarding the online research, certain examples of keywords and Boolean operators used for search follow. The main keywords used include the terms of "tall buildings", "skyscraper", "high-rise", "development"," construction", "factors" and the use of facilitating clauses also took place. A specific example comprises as follows: "tall buildings AND construction industry", "skyscrapers AND factors AND development", accompanied by regional specifications. As a last remark, papers and bibliography used by examined papers were also scanned and the ones relevant were included in the literature study.

2.5 Key takeaways of Literature Study

Summarising the findings of literature study, it is suggested that the decision behind the proposition and construction of a tall building is affected by the specific location. The relevant determining factors can be divided into national scale and a city scale. More precisely, the development of tall buildings is impacted by the demographic characteristics of the city in terms of city scale and, likewise by the economic strength of a country in terms of national scale. As far as city scale is concerned, the dominant determinants have been documented to be population size and urbanization rate, restricting land-use regulations and proximity to central business district. In terms of national scale, the dominant determinants regard economic indicators and include mostly GDP, FDI, Real interest rate and construction costs.

To lesser extent, it is suggested that factors related to the characteristics of the building itself have an influential effect to development. These factors mainly concern the use the building is designed to serve and the selected construction material. Although such factors are treated in certain previous studies as influential forces on the height of tall buildings, it should be marked that there is a potential case of cause and effect relation. For instance, it could be the case that the height of a tall building is defined by the intended uses or the opposite. Therefore, this potential cause and effect relation concerning similar factors should be further investigated in the course of this research and clarified. A separate underlying factor that is popular in the literature is the height competition between developers. This factor does not fall under the aforementioned categories. It is suggested that the desire of developers to be accountable for the highest buildings regionally and worldwide pushes the development and maximum heights of tall buildings.

All the above determinants are the result of the scouring of mixed-type previous studies, others being quantitative, others discussion oriented. Either derived from quantitative studies or not, the major height determinants mostly coincide in terms of suggested influence. More recent studies have quantitative direction with focus on substantiating the strength of relationships between the height of tall buildings and suggested determinants. The majority of studies use the (multiple) regression analysis as the research tool.

Regarding geographic coverage of studies, tall buildings appear nowadays in every global region in various quantities. The regions of North America and Asia have attracted the main attention of studies, and other regions have been neglected or investigated to lesser extent. Thus, inconsistencies are detected in terms of geographic coverage. Inconsistencies are also detected in terms of the height of examined buildings. Different studies investigate different height ranges, others including heights taller than 100 meters and others taller than 200 meters. Thus, it is concluded that, despite the existing studies, there is significant research gap, still to be filled, and lack of homogeneity.

3 Methodology and Data

This third chapter elaborates on the methodology used for the present research and the data collection phase. To begin with, the basic outline of the research design is described in Section 3.1 and the complete research strategy is unfolded in Section 3.2. The basics of the main research tool, which is regression analysis, are introduced in Section 3.3 and the phase of data collection is described in section 3.4, together with respective rationale regarding choices. In section 3.5, the variables to be used in the analysis phases are provided and a remark about the classification of determinants is realized in section 3.6.

3.1 Research Design

A simplified outline of the research design has been already presented in Chapter 1. In this section, a more elaborate and in-depth description of the research design is provided.

3.1.1 Research approach

The present research employs a quantitative research strategy. The intention is to identify and quantify the factors that influence the development and height of tall buildings at a global scale. Both theoretical and empirical studies and findings have been researched. This direction makes descriptive statistics and regression analyses the pillars of the research analysis. In the following sections, the overall research procedure is unfolded with the ultimate goal to provide answers to the posed research questions. The regression analyses will be conducted with the use of the SPSS software in order to look for correlations among determining factors. The quantitative research approach is chosen as a clear way to depict the potentially investigated relationships between characteristics of the buildings and others selected to the influence it has on the height. The combination of literature theories, econometric characteristics and statistical analysis is deemed suitable for the purposes of the research (Knight & Ruddock, 2008; Verschuren et al., 2010).

3.1.2 Research steps

In order for the formulation of the overall research process and respective research questions to be clearly constructed, a number of successive logical steps were introduced at the initial stage of the exploration of the research topic. Despite the seemingly brief verbiage of these steps, their contribution to the solid understanding and research progress is critical. These research steps are expressed as follows and can be found in the following Figure 3.1.

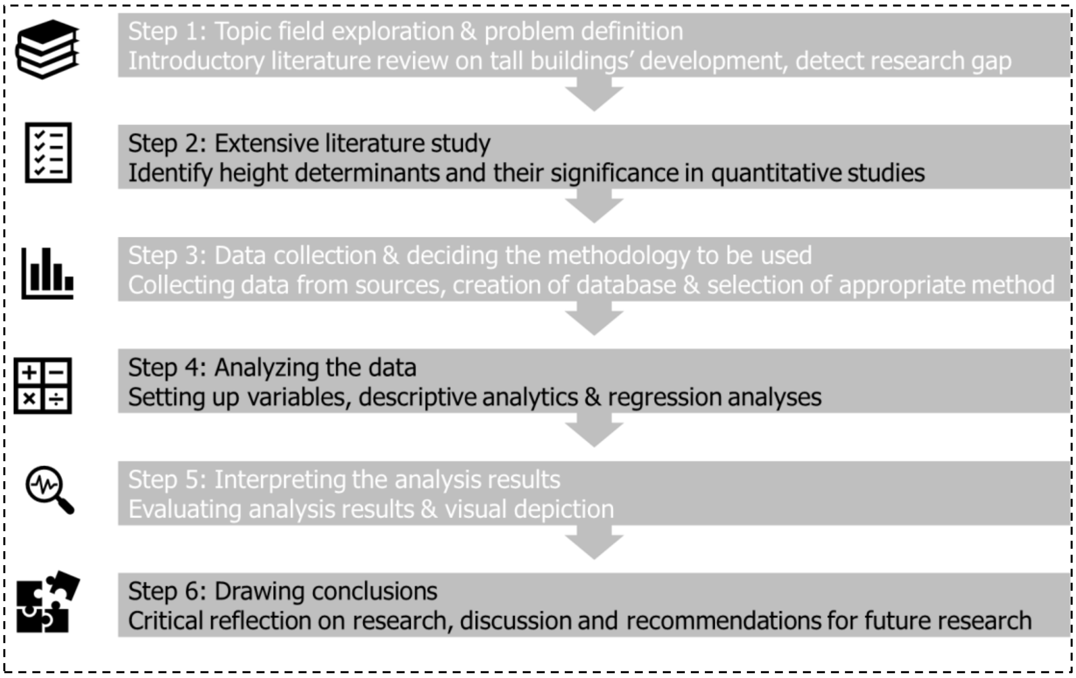


Figure 3.1 Logical successive steps to aid research process (Own illustration)

As a first step, the wider subject field of tall buildings and their development is explored through a preliminary literature review. By examining what studies have been already executed and what still requires further investigation, the research gap is detected, and the problem is defined. As a second step, a deeper dive into the factors that influence the development and height of tall buildings is made. Links between theories and quantitative studies providing empirical results are being investigated. This is achieved through extended literature study. Main focus is placed on identifying the most influential height determinants. As a third step, the creation of a solid dataset is intended through the collection of relevant data. The data collected derive from a combination of the conclusions of literature study and the accessibility to data. Main sources of data include the Council Tall Buildings and Urban Habitats (CTBUH), the freely accessible database of the World Bank and respective databases of (National) Bureaus of Statistics. Depending on the final form of the database, the suitable methodology to be used is selected. As a fourth step, the actual processing of the data is performed. The analysis mostly relies on descriptive statistics and regression analyses. As a fifth step, the outcome of the analysis requires to be interpreted. This is achieved based on statistical principles and depicted through clear illustrations. Ultimate purpose of the research is to answer the research questions. As a sixth and final logical step, the ultimate conclusions and answer to the main research question are intended to be presented. Critical reflection on the outcome of the research and recommendations for future research are also part of this step. In order for the abovementioned research steps to be linked with the main and sub research question for purposes of a clearer overview, the following Table 3.1 is additionally provided.

Table 3.1 Linkage among research phases, logical steps and research questions

Research Phase	Research Objective	Research Steps	Research questions	Research Method
Introduction	Topic exploration and problem definition	Step 1		Literature Review
Literature Study	Identification of determinants	Step 2	**Sub-1**: Which factors are regarded as height determinants?	Literature Review Deductive Analysis
Data collection & Methodology	Creation of database and selection of method	Step 3		Data collection
Data Analysis	Providing proof for relationships amongst determinants	Step 4	**Sub-2**: How does the distribution of tall buildings vary across regions?	Descriptive statistics Correlations Regression analysis
Data evaluation & Conclusions	Interpretation of empirical results	Step 5 Step 6	**Main:** To what extent determinants influence the height and amount of tall buildings from a global point of view?	Deductive analysis

3.2 Research method

3.2.1 Analysis procedure

The core part of this research is the understanding of the influencing factors that determine the development of tall buildings worldwide. Therefore, the theoretical study on these height determinants is the primary phase of the procedure of the analysis. Once the theoretical comprehension is completed, the next phase consists of the formulation of relevant research questions and data collection accordingly. Both these stages of this second phase are described in a detailed manner in the following sections. The empirical analysis is the last phase, where the variables are constructed, the analysis and the statistical models of the regression are made. The graphic depiction of this analysis procedure is found in the Figure 3.2 below.

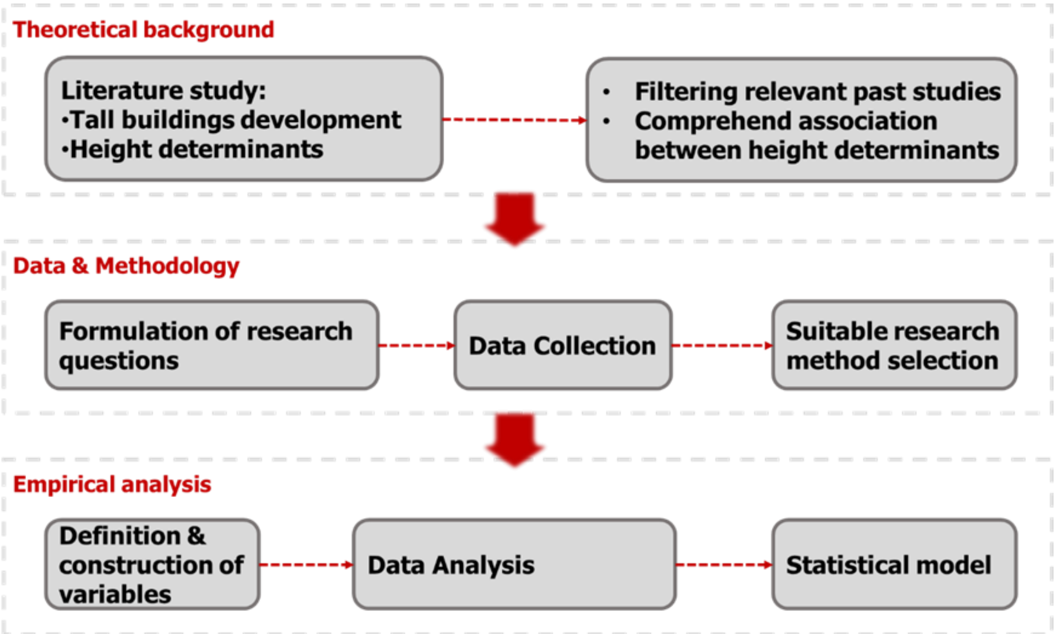


Figure 3.2 Analysis process of research structure (Own illustration)

3.2.2 Answering the Research Questions

In this subsection, a more precise linkage between the research questions and their corresponding tools for answering are described. In reverse order, the first research sub-question, "Which factors are regarded as height determinants?", will be answered using partially the findings of the literature review and accompanied by the results of the relevant regression analysis. The second research sub-question, "How does the distribution of tall buildings vary per region?", will be answered mostly with the descriptive statistics on the data collected.

In order for the main research question to be answered, "To what extent determinants influence the height and amount of tall buildings from a global point of view? ", several regression models will be employed. The approach of the main research question is divided into separate perspectives to facilitate the research and the clarity in the presentation of the results. These perspectives are elaborated below and are accompanied by the respective variables to be used with.

Building related perspective

Placing emphasis on the construction and design aspect of a tall building, it became evident throughout the literature study that the use, the building is designed to serve, plays an important role to the range of the final height that will be reached. Since population increases and cities are already densely occupied, need for additional room for accommodation is generated. Therefore, it is suggested that there is increased need for taller buildings and serving residential and professional purposes. Studies expect a transition to tall buildings of mixed use, to accommodate multiple needs under the same roof (Kheir, 2018a). In the same direction, in order for larger heights to be achieved, the advancements in technology play their role as well. Concrete and steel are the most common materials, but according to studies the use of composite materials can lead to higher altitudes (Al-Kodmany, 2011).

Therefore, it is suggested that building attributes, such as use and construction material, affect the height of tall buildings. The extent to which such factors influence will be tested during analysis. This part of the analysis phase will use relevant variables that depict the building characteristics of the structures examined. Such factors include individual height of buildings and count of them, building use and construction material. The use of building is also connected with the population size and urbanization rate, and thus respective variables will be used for the analysis.

Location and economic related perspective

According to the literature study, the overall prosperity of a particular location is a significant driving force behind tall buildings' development. The well-being of a location attracts more residents, due to the increase of career opportunities. Therefore, in such location the size of population and urbanization rate increases, creating excessive demand for building facilities to accommodate people, both for residential and professional purposes.

Therefore, it is suggested that demographic and economic characteristics of a specific location affect the height and development of tall buildings. Their influence will be assessed in the upcoming analysis. This suggestion will be tested during the empirical analysis phase, with the use of the relevant variables that depict the well-being of a location. Such factors are the population size and urbanization rate, together with the economic indicators that are present in the region. Such economic factors consist of GDP, FDI and real interest rate. In addition to this, to reflect the geographic influence, special dummy variables will be created for continental and national purposes. The exact breakdown of these two dummy variables is provided in the section of data collection.

Height competition perspective

Height competition between builders is an influential factor, that is quite popular especially in qualitative studies. This is attributed to the fact that it is a factor difficult to be measured. The theory behind this suggests that builders pursue building taller than what already exists, for reasons of status and reputation. An approach for analysing this aspect enables looking the connection of the heights of previous buildings and amount of them, while focusing on individual locations.

The suggestion is that height competition influences the increase of (maximum) height of tall buildings. This will be tested with the use of variables, such as average and maximum height, amount of completions and location. More precisely, the evolution of the maximum between regions and cities will be examined, and the variable for vanity height for each building will be used.

3.2.3 Additional research directions and general overview

Apart from the research questions, additional complementary research directions will be introduced in this section. To begin with, although the scope of the research is global, productive findings isolated per regions will be checked and reported accordingly. Moreover, there is a number of previous studies that examined buildings with heights over 200 meters. Therefore, where deemed rational, the analysis phase can be performed in three divisions: 1) the sample as a whole, 2) the sample for heights 150-200 meters and 3) the sample for the heights of 200 meters and above. Comparisons with previous studies, having treated samples of 200+ meters, will be facilitated. A further breakdown for the height range of 300 to 600 meters is planned, especially for the investigation of existence of height competition. The number of tall buildings located in Asia, and especially China, consist of a staggering proportion of the sample. Therefore, the possibility of bias is highly likely, and the analysis is aimed to be executed for the whole sample and the sample without Asia or China. Comparisons with the findings of Chiang (2019) could be easily made this way. A graphical depiction of the connection between research questions, respective methodology and research directions is presented in the Figure 3.3 below.

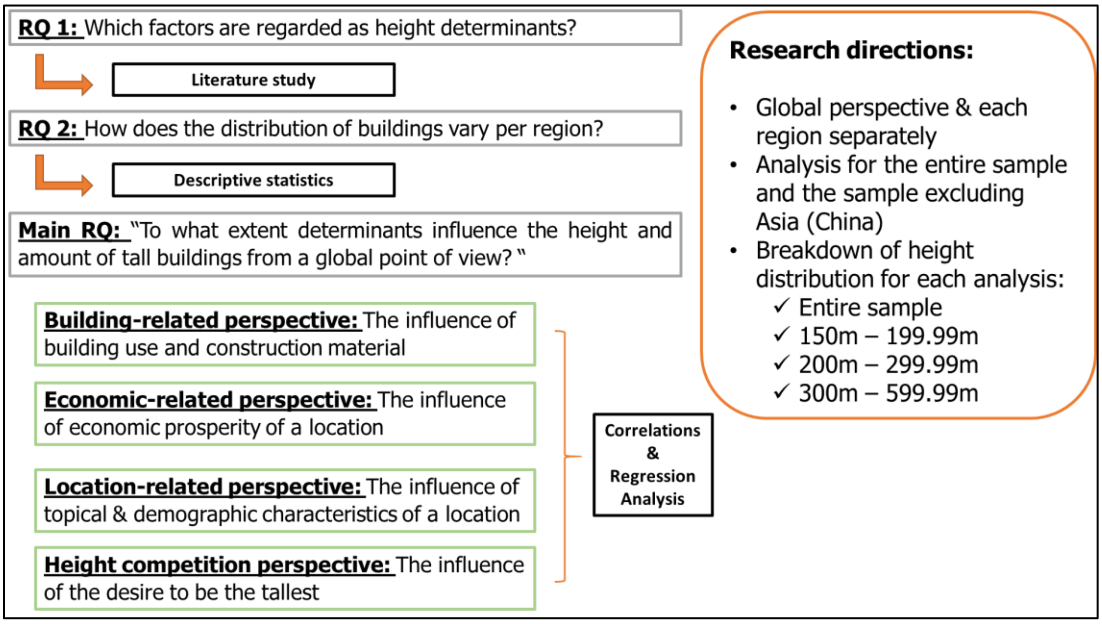


Figure 3.3 Detailed depiction of the answering of posed research questions (Own illustration)

3.3 Basics of Regression Analysis

The main goal of the present research is to assess the level of influence of certain variables upon others. For this purpose, the main research tool to be used is the regression analysis. Therefore, a brief overview of the basic principles of this statistical procedure is provided.

Regression analysis is based on the equation below, in which it is indicated that an outcome can be predicted through a selected model plus a certain amount of error. The model is selected based on its suitability to fit the respective data and the error is calculated by the difference between the observed values of the model and the estimated outcome. The outcome corresponds with the so-called dependent variable and the model incorporates the chosen independent variables to be examined, alternatively called predictors (Field, 2009).

$$outcome_i = (model) + error_i$$

The most basic type of regression analysis is the simple regression. This type is characterized by one (1) independent variable and the model employs a linear approach with a straight line to achieve the best fitting to the data (Field, 2009). The respective equation can be found below (Field, 2009).

$$y_i = (a_0 + a_1 X_i) + \varepsilon_i$$

Breaking down the elements of the equation, y_i represents the outcome, the variable to be predicted, and X_i is the i-th value of the predictor variable. Furthermore, coefficient a1 represents the gradient or slope of the straight line fitted to the data and a0 is the intercept of that line, corresponding to the value of Y-axis, through which the straight regression line crosses. The parameters a_0 and a_1 are known as the regression coefficients. There is also the residual term, ε_i, being the difference between the score predicted by the line for participant i and the score that participant-i actually obtained (Field, 2009). The basic idea is that each coefficient depicts how much the value of y_i increases, while X_i is increased by one unit, assuming the rest of independent variables remain constant.

A more intricate type of regression is the multiple regression. In multiple regression, an outcome variable is predicted by numerous variables, contrary to simple regression, where the prediction is made using one predictor variable. The respective equation is found below.

$$y_i = (a_0 + a_1X_1 + a_2X_2 + \ldots + a_nX_n) + \varepsilon_i$$

Each predictor variable, Xi, has its own coefficient. The value of a coefficient indicates the gravity of each predictor variable to the dependent or outcome variable. R^2 is a value that reflects the credibility of the regression analysis. It is known as the coefficient of determination and explains to what extent (in percentage) the variance in the dependent variable is accounted by the used regression model. As a general rule, the more independent variables are included in a regression model, the more accurate the prediction is. However, attention should be paid in order for issues like overfitting to be avoided.

As it has been highlighted in Chapter 2, the Literature Study, the height and amount of tall buildings is influenced by more than one factors. Therefore, the type of regression that is used in this research is the multiple regression. The analysis of the specific study is performed with the aid of the statistical software SPSS (Statistical Package for the Societal Sciences). The use of this particular software regards mainly the needs of the regression analysis, and further statistical analyses and graphs.

3.4 Data Collection

In this section, the collection of data is elaborated, the sources and the basic features of the created dataset are presented.

3.4.1 Selection of building sample

The objective of the research is to investigate the drivers that determine the development of tall buildings from a global angle. The ideal scenario would be to have data for every building taller than 50 meters and meeting the criteria to be characterised as a tall building, as it was defined in Chapter 2, Section 2.1. It was decided to set the threshold of 150 meters, for the respective buildings to be included in the data collection. This is based on the quality of the data, while ensuring at the same time that the scope of the research is not compromised, and literature review. First of all, the main scope of the study is height and what drives it. As a result, the interest is placed on the highest buildings. Complete information for the building aspects relevant to this research is not available for buildings lower than 100 meters, and while the case for the height range between 100 and 150 meters is better, still numerous buildings have incomplete data. More specifically, the main missing data regard the dates for start of construction works, structural material, occupied height and therefore vanity height. Even for the selected sample, it was detected proactively that certain case would require additional research from various sources in order to acquire complete information for them. As a result, it was concluded that the lowest threshold in order to ensure the quality and completeness of the data sample is 150 meters and above. At the same time, the size of the sample is sufficient for a quality study. It should be also marked that this sample size already provides added value to the pool of research, since previous studies have focused on building samples, with 200 meters as threshold.

The source regarding the building data is the Council of Tall Buildings and Urban Habitat (CTBUH). As already explained, CTBUH is the official and accredited body that handles the characteristics and definitions concerning tall buildings worldwide. Thus, CTBUH can be acknowledged as an accredited source of data.

Apart from the height threshold, another threshold was decided regarding the timeframe in which the data sample would be included. This threshold is a more straightforward one, since it is linked with the availability of data. The chronological timeframe that is decides to be investigated ranges from 1960 to 2019. The reason for this threshold derives from the fact that data regarding economic indicators, as well as demographic data, are available after the year of 1960 by the World Bank. This resulted into a database of 4826 buildings, exceeding the height of 150 meters and being built between 1960 and 2019. A concise visual overview of the geographical distribution of the buildings is found in Figure 3.4 below.

Figure 3.4 Geographical distribution of the buildings, for which data is collected. Source: (OpenStreetMap, (The Skyscraper Center, 2019))

As far as basic figures of the data sample are concerned, the mean value of the building height is 193 meters having a standard deviation of 47 meters, with a maximum value of 828 meters. In terms of floors, the average value is measured at 48, with a standard deviation of 11 and the building with the maximum number of floors being 163. A complete presentation of the descriptive statistics for all included variables follows in Chapter 4.

It should be noted that all buildings included in the data sample concern exclusively buildings that are defined as "Completed" by the CTBUH. A "Completed" building corresponds to a building that is topped out structurally and architecturall, fully cladded and open for its prescribed function (CTBUH, 2019). The building use and the building material are another two additional indicative categories that characterise the buildings of the sample. The building use is divided into: Residential, Office, Hotel, Mixed and Other. A mixed-use tall building consists of two or more building uses, each of which occupies a significant proportion of the building's total space (CTBUH, 2019). The building material is divided into: Steel, Concrete, Composite, Mixed and Precast. According to CTBUH, a structural material is characterised as Composite when a combination of two or more materials are used together in the main structural elements. For example, a building with steel columns with a floor system of reinforced concrete beams. A mixed one uses distinct systems, one on top of the other. For example, a steel structural system located on top of a concrete structural system, and the opposite (CTBUH, 2019).

3.4.2 Selection of sample of determinants

The development of tall buildings is influenced by various factors, ranging from an economic aspect to location related. As it came to light through Chapter 2, the Literature Study, there are determinants that have been documented to have stronger or lesser influence. However, results of previous studies are limited to certain regions of the world and performed for different time periods.

The intention of this research is to include as many as determinants as possible in order to be investigated. This depends on the availability of the data of the corresponding influential factor. Based on this availability and in combination of the findings of the literature study, data for the following determinants were collected, apart from the building-related ones that were collected from CTBUH. These correspond to the Population and Urbanization rate of each Country, the Gross Domestic Product (GDP) of each country, the Real Interest Rate of each country and the Foreign Direct Investment (FDI) regarding each country. The data for these factors concerns the time period between 1960 and 2019, with the exception of FDI, for which the available data starts from 1970. The source for the abovementioned data is the World Bank database. As an accredited international financial institution, its reliability is deemed validated. Furthermore, the coordinates of each city were collected for every single building using the data provided by Google maps. The coordinates are deemed as an auxiliary set of parameters to further assist the analyses.

3.5 Specification of variables

3.5.1 Dependent Variables

The main focus of the research is the architectural height of a tall building and to what extent it is affected by relevant factors. Therefore, the main dependent variable for the regression analysis is the architectural height. In addition to this, due to the data that have been collected, regression analyses having the amount of buildings and vanity height as dependent variables will be considered to be performed. Additional details are provided in Chapter 4, regarding the variations of the analysis.

3.5.2 Overview of independent variables

In this section, the grouping of the variables to be used for the database and regression analysis is presented. The variables are divided into three categories: 1) building related, 2) location related and 3) economic. This division is based on the findings of the literature study and availability of data.

As far as the first category is concerned, the variables are selected with the intention to best depict the aspects of the buildings themselves. First of all, the city, the country and the wider geographical region for each building is included. The architectural height and number of floors for each building is used, along with its functional use, material for construction and the year of the completion of the project. The longitude and latitude of each city that hosts at least one tall building are also included. As far as the locational characteristics are concerned, the population and urbanization percentage for each country have been collected. As far as the economic variables are concerned, variables depicting GDP, FDI and Real interest rate per country are specified. Regarding the aspect of height competition, the variable of vanity height is calculated, and additional variables will be employed accordingly. A concise overview of the variables can be found in the Table 3.2 below.

Table 3.2 Overview of the basic figures of the data sample collected

Category	Variable	Measurement Unit	Timeframe	Observations	Source
Building related	Building name	-	1960-2019	4826	CTBUH
	City	-	1960-2019	4826	CTBUH
	Country	-	1960-2019	4826	CTBUH
	Region	-	1960-2019	4826	CTBUH
	Coordinates	Latitude & Longitude	1960-2019	4826	Google maps
	Arch Height	Meters (m)	1960-2019	4826	CTBUH
	Occ Height	Meters (m)	1960-2019	1241	CTBUH
	Height to Tip	Meters (m)	1960-2019	4780	CTBUH
	Vanity Height	Meters (m)	1960-2019	1224	Calculated
	Number of floors	Amount	1960-2019	4807	CTBUH
	Building use	-	1960-2019	4811	CTBUH
	Material	-	1960-2019	3709	CTBUH
	Completion Date	Year	1960-2019	4826	CTBUH
	Proposed date	Year	1960-2019	1267	CTBUH
	Construction start date	Year	1960-2019	3668	CTBUH
	Completions per year	Amount	1960-2019	4826	CTBUH
Location related	Population (country)	Amount	1960-2019	4826	World Bank
	Urbanization percentage (country)	Percentage	1960-2019	4826	World Bank
Economic	GDP	Amount	1960-2019	4826	World Bank
	Real Interest Rate	Percentage	1961-2019	4826	World Bank
	FDI	Amount	1970-2019	4826	World Bank

3.5.3 Space and time effect

The effect of space and time is a factor that is examined in the analysis phase of this research. In order for the time effect to be reflected, two divisions are created; one per decade and another one for every 5 years. These two divisions are applied within the timeframe of 1960-2019.

As far as the space effect is concerned, two separations are selected. The first one is used to reflect the regional effect and the second one to reflect the country effect. Regarding the division in regions, the continent of America is divided in three parts; North, Central and America, while the continents of Europe, Africa and Oceania stay as they are. Middle East is treated as a separate region, following the categorisation by CTBUH, and the continent of Asia is divided in the part of China on its own and the rest. This regional division is presented in Table 3.3 as follows, with a total of 9 separate categories.

Table 3.3 Division of data sample in geographical regions

Geographic Region	Amount of buildings
North America	866
Central America	54
South America	76
Europe	198
Africa	12
Middle East	373
Asia (excluding China)	1075
China (as separate region)	2060
Oceania	112

Apart from the effect of the regions, based on the needs of this research, the influence in country level is required to be reflected. Therefore, a deeper division at country level is executed. It should be marked that certain countries have single digit amount of buildings and this can influence the significance of this division. As a result, certain groupings are created for the cases with negligible amount of completions, also based on geographic proximity. In North America, there are three countries with presence of tall buildings and the division stays as it. In Central America, the majority of tall buildings is concentrated in Panama, and two additional buildings are located in Dominican Republic. Therefore, Dominican Republic is integrated to Panama, as one country grouping. In South America, Brazil hosts a substantial number of tall buildings compared to th rest of the other countries combined, and therefore a division into Brazil and into rest of the south American countries is selected. Regrading Europe, four divisions are selected based on geographic proximity; Northern European countries, Central, South and Eastern. Additional to these four subcategories, the region of Europe includes separately the countries of Russia and Turkey. These two countries do not belong into one of the four subregions, due to their significance number of tall buildings. Oceania and Africa are treated as countries themselves. This is because Africa only has 12 tall buildings, while Oceania has the 99% of its buildings located in one country, Australia. Moreover, Middle East is divided into the four countries with the most completions and one fifth subcategory is added with the grouping of the rest of the countries, with insignificant amount of buildings. The region of Asia is divided almost purely per country, apart from few exceptions, such as Cambodia being grouped with Vietnam. A clear picture of the 30 divisions into countries and country groups are available in Table 3.4 as follows.

Table 3.4 Division of data sample for the space country effect purposes

North America	**Central America**	**South America**
• USA (722) • Canada (108) • Mexico (36)	• Panama (52) + Dominican Republic (2)	• Brazil (35) • Rest S. American countries* (41) *Argentina, Chile, Colombia, Uruguay, Venezuela
Europe	**Middle East**	**Africa**
• Turkey (60) • Russia (42) • Central European countries[1] (73) • Northern European countries[2] (26) • South European countries[3] (16) • Eastern European countries[4] (3) [1] DACH, Poland, France [2] Sweden, UK, NL [3] Italy, Spain [4] Ukraine, Georgia	• UAE (251) • Qatar (35) • Saudi Arabia (33) • Israel (19) • Rest countries of M. East* (35) *Kuwait, Bahrain, Lebanon, Jordan, Iran, Iraq	• African countries* (12) *South Africa, Tanzania, Kenya, Algeria, Nigeria
Oceania	**Asia**	
• Australia (110) + New Zealand (2)	• China (2060) • Japan (251) • South Korea (220) • Thailand (105) • Indonesia (102) • Malaysia (91) • Philippines (87)	• Singapore (85) • India (71) + Sri Lanka (8) + Bangladesh (1) • Vietnam (29) + Cambodia (1) • Kazakhstan (4) + Azerbaijan (4)

3.6 Classification of determinants

Based on the overall research design and in combination with collected data, the classification and presentation of determinants is selected to be done following the categories of building aspects, economic factors, location-based elements and height competition aspects.

It is acknowledged that an alternative and more well-rounded classification could consist of: i) Realisation aspects, ii) Real Estate aspects and iii) Ambition aspects. Regarding realisation aspects, an identification of the determinants required for the developers in order to construct would be optimal, such as possible restrictions due to regulations and area. For the real estate aspect, the determinants could have been broken down based on their contribution to demand and supply, in order to understand if a specific location needs a tall building. Regarding ambition aspects, it would be optimal to identify the reasons that potentially cause height competition phenomena, such as political interests.

However, due to the nature of collected data this classification could not be done in a satisfactory manner. The aspect of real estate could be approached, but no variables to depict regulations or political motives are into the disposal of the writer.

3.7 Summary of Chapter 3

This chapter describes the basic outline of the initial research steps and rationale, and the foundations for a solid research strategy are established. Regression analysis is the main tool to be used for the phase of the analysis and a brief explanation of it is provided. Furthermore, the stage of data collection is described in detail and educational choices made throughout the process are sufficiently justified. It is also made clear that the main dependent variable for the following analysis is architectural height. Finally, the various divisions regarding time and space are explained in depth, to facilitate the comprehension of their usage in the regression analysis.

4 Empirical Analysis

This fourth chapter presents the findings of the analysis phase for the present research. In Section 4.1, a detailed distribution of tall buildings globally and their characteristics is provided. Section 4.2 presents the variables used in regression analysis and a correlation analysis is done among these variables. In Section 4.3, the findings of the regression analysis are described, and a comparative discussion of them against similar studies is provided in Section 4.4. The chapter ends with a summarization of the main points.

4.1 Global distribution and characteristics of tall buildings

In this section, the results of the analysis that are relevant to answering the second research sub-question are presented. The respective question is: "How does the distribution of tall buildings vary per region?". These findings are also auxiliary in the answering of the main research question.

4.1.1 Distribution of tall buildings per geographic region

For the purposes of this research, data regarding every building taller than 150 meters worldwide are gathered. This corresponds to an amount of 4826 buildings, completed between the years of 1960 and 2019. A division of the amount of completed projects, for every 5-year period since 1960, is presented in the Figure 4.1 below.

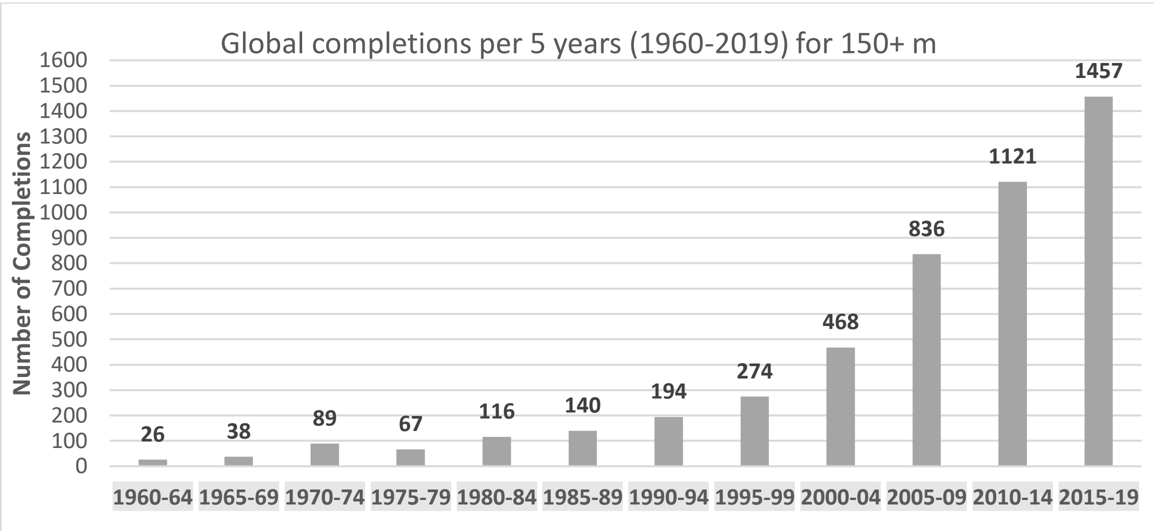


Figure 4.1 Global completions of 150m+ tall buildings, divided in 5-year time-periods

It is observed that a significant increase in construction of tall buildings took place at the beginning of 21st century. Striking is that more than half of the completed projects ever in history have been developed within the last decade. Between 2000 and 2004, an impressive total of 468 projects were completed, exactly the same amount of the previous decade, yet in half the time. Since then, there has been a constant increase in completed projects per 5 years, ending up with a number of 1457 buildings, exclusively constructed within the last 5 years. For the record, the year 2016 is highlighted as the one with the most completions, with 328 buildings taller than 150 meters, followed by the year of 2017, with 324 completed projects. A breakdown of tall buildings' completions per year is available in the Appendix. Zooming into the geographic distribution of the aforementioned buildings, it is observed that the geographic region in which the development of tall buildings was born is North America. A detailed breakdown of the completions per decade and per global region is presented in the Table 4.1 below.

Table 4.1 Completions of tall buildings per region, divided per decades

Completions per region per decade	**1960-69**	**1970-79**	**1980-89**	**1990-99**	**2000-09**	**2010-19**	Subtotal
Africa	-	4	-	-	-	8	**12**
Asia	1	17	53	332	888	1844	**3135**
Central America	-	-	-	4	19	31	**54**
Europe	-	8	6	18	47	119	**198**
Middle East	-	-	-	5	151	217	**373**
North America	59	112	181	87	155	272	**866**
Oceania	1	8	10	20	28	45	**112**
South America	3	7	6	2	16	42	**76**
Subtotal	**64**	**156**	**256**	**468**	**1304**	**2578**	4826

Between the years of 1960 and 1989, the staggering majority of tall buildings constructed had been located in North America, especially in New York and Chicago. During the same 30-year time-period, minor construction activity of tall buildings is noticed in Asia, Oceania and South America. Throughout the decade of 1990-1999, an abrupt shift is marked. The region of Asia took the lead in the amount of completed projects, and kept doubling their completions per decade till today. This resulted in a total count of 3135 buildings for the region of China, with North America coming second with only 866 completions. In general terms, since 2000, increased activity is observed in all regions of the world. Apart for Asia, North America and Middle East are seen as the regions with the higher tendency to build high, with Europe starting to increase its pace since 2010. Regarding the region of Asia, a striking fact is that the two thirds of the constructed buildings are located in China. This is visible in the Table 4.2 below, in which the top-10 of countries and top-10 cities with the most completions of tall buildings are presented.

Table 4.2 Top-10 for most completions per country and per city

Top-10 Countries			**Top-10 Cities**		
		Completions			**Completions**
1	China	2060	**1**	Hong Kong (China)	352
2	USA	722	**2**	New York (USA)	234
3	Japan	251	**3**	Shenzhen (China)	226
4	UAE	251	**4**	Dubai (UAE)	198
5	S. Korea	220	**5**	Shanghai (China)	163
6	Australia	110	**6**	Tokyo (Japan)	155
7	Canada	108	**7**	Chongqing (China)	125
8	Thailand	105	**8**	Guangzhou (China)	114
9	Indonesia	102	**9**	Chicago (USA)	113
10	Malaysia	91	**10**	Bangkok (Thailand)	92

China is by far the country with the most completed projects, followed by USA, with almost 70% fewer completions though. The countries of Japan, United Arab Emirates and South Korea come next, hosting over 200 buildings. At city scale, the dominance of China is subsequently impressive, having five cities in the top-10. Hong Kong is the city with the most completions, scoring 352 buildings. In terms of other regions, New York, Dubai and Tokyo score numerous completions as well. The prevalence of China becomes even more striking when realizing that nearly every tall building in Asia is built later than 1990.

4.1.2 Distribution of tall buildings per height range

In this section, the distribution per height range of tall buildings is described. As stated in Chapter 2, buildings taller than 600 meters are characterized by CTBUH as "Megatall" and buildings with height between 300 and 600 meters as "Supertall" (CTBUH, 2019). The division in height range is using these 2 categories, accompanied by two additional sub-divisions; one including buildings below 200 meters and another including the interval height between 200 and 300 meters. A detailed breakdown of the examined global completions per height range within the decades is presented in the Table 4.3 below.

Table 4.3 Completions of tall buildings per height category, divided per decade

Completions per height range per decade	**1960-69**	**1970-79**	**1980-89**	**1990-99**	**2000-09**	**2010-19**	Subtotal
150-200 m	54	115	194	359	1002	1513	**3237**
200-300 m	9	39	59	95	283	936	**1421**
300-600 m	1	2	3	14	19	126	**165**
>600 m	-	-	-	-	-	3	**3**
Subtotal	**64**	**156**	**256**	**468**	**1304**	**2578**	4826

It is observed that buildings with heights between 150 and 200 meters have been the dominant category since 1960. Since 2000, the category of 200-300 meters has been showing rapid increase. The category of Supertall (300-600m) buildings has also increased significantly since 2010, growing its completions by over than 6 times in amount. The increased popularity for taller buildings is directly attributed to the technological advancements in the field of construction or functionality purposes (Ali & Moon, 2007). This tendency for taller buildings is more evident when examining the share of height ranges per decade, as found in the Figure 4.2 below.

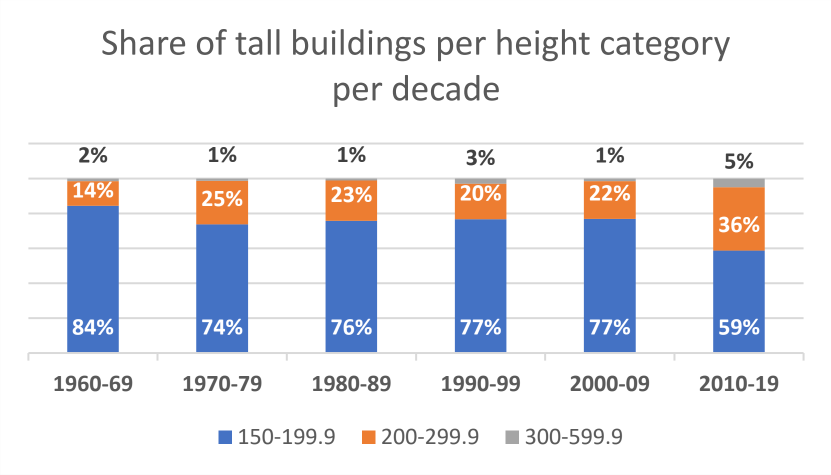


Figure 4.2 Share of tall buildings per height category, divided per decade

During the last decade, an increase in the 200-300m category is marked reaching the 36% of the share of completions between 2010-2019, although ranging from 14% to 25% for all the past years. Supertall buildings show increased development since 2010, reaching 5%. Therefore, a growth in the share of buildings taller than 200 meters is observed, since 2010. This marks a trend towards higher buildings, with the starting point placed in 2010.

4.1.3 Evolution of height in time and per region

Based on the data collected, a timeline of the evolution of average and maximum height per year is constructed from a global perspective. This is illustrated in the Figure 4.3 below.

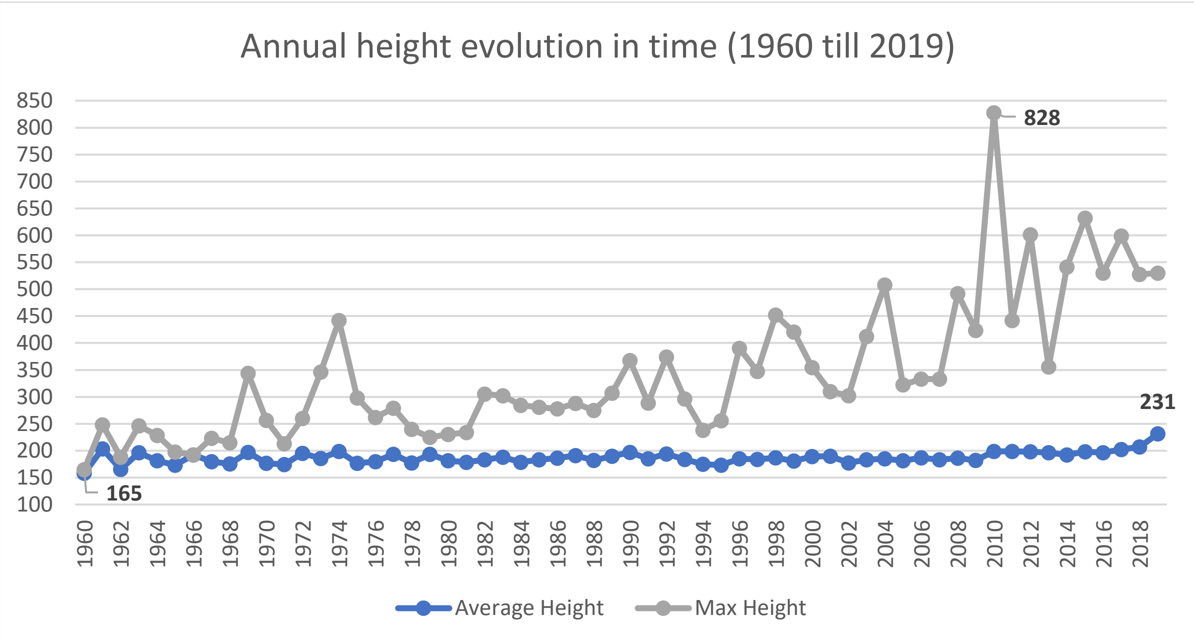


Figure 4.3 Global annual evolution of tall buildings' height from 1960 till 2019

Regarding the average height, it scored around 165 meters starting in 1960,and remained at this figure till 1968. Afterwards, it is observed to be fluctuating between 175 and 190 meters, until the year of 2009. For the next 8 years, the average height is stabilized at 200 meters and then increasing at around 205 meters in 2018, ending at 231 meters for 2019. The annual maximum height shows an overall, but not constant, increase throughout the years, and especially after 2010, when almost every year at least one building over 400 meters is built. For the record, the tallest completion corresponds to the Burj Khalifa building, located in Dubai, completed in 2010, with the impressive architectural height of 828 meters. Looking at each global region individually, the same two values are examined. In the Figure 4.4 below, the existing maximum height and the all-time average per global region is presented.

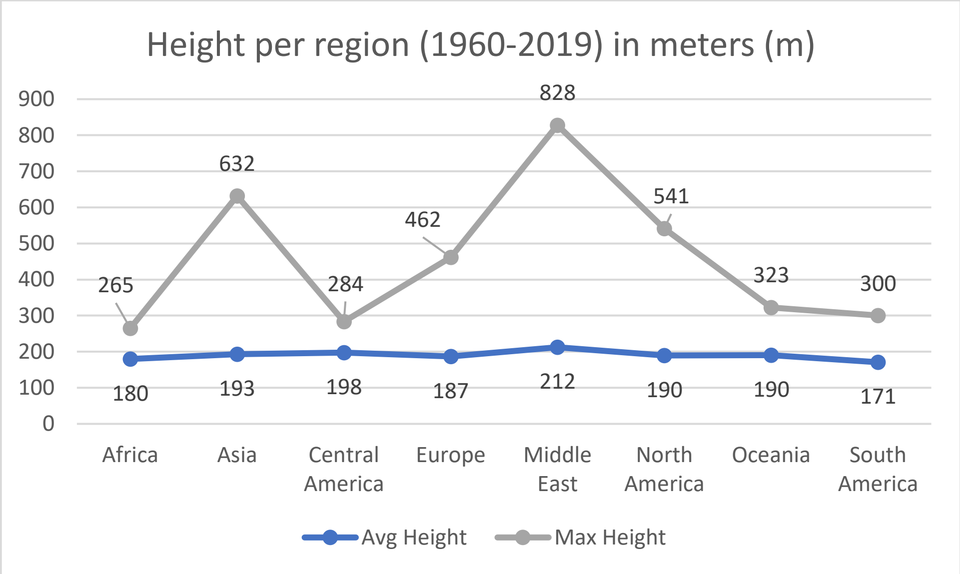


Figure 4.4 Average and maximum height per geographic region

At a first glance, Middle East is the geographical region with both the highest average (212 meters) and maximum height (828 meters), for the 60-year timespan between 1960-2019. The region of Asia also scores high for average and maximum height as well. In general terms, it is marked that the regions of Asia, Middle East and North America have the tendency to construct extreme heights. On the other hand, the regions of Africa and South America tend to host the lowest buildings. Focusing more into the evolution of record height per region in time, a complete illustration for each region is presented in Figures 4.5 and 4.6. In these figures, the annual maximum height per region and for how many years this height was maintained is identified. This more detailed investigation is performed, based on the fact by literature that height competition is detected to be present among regions, and to lesser extent at a global scale.

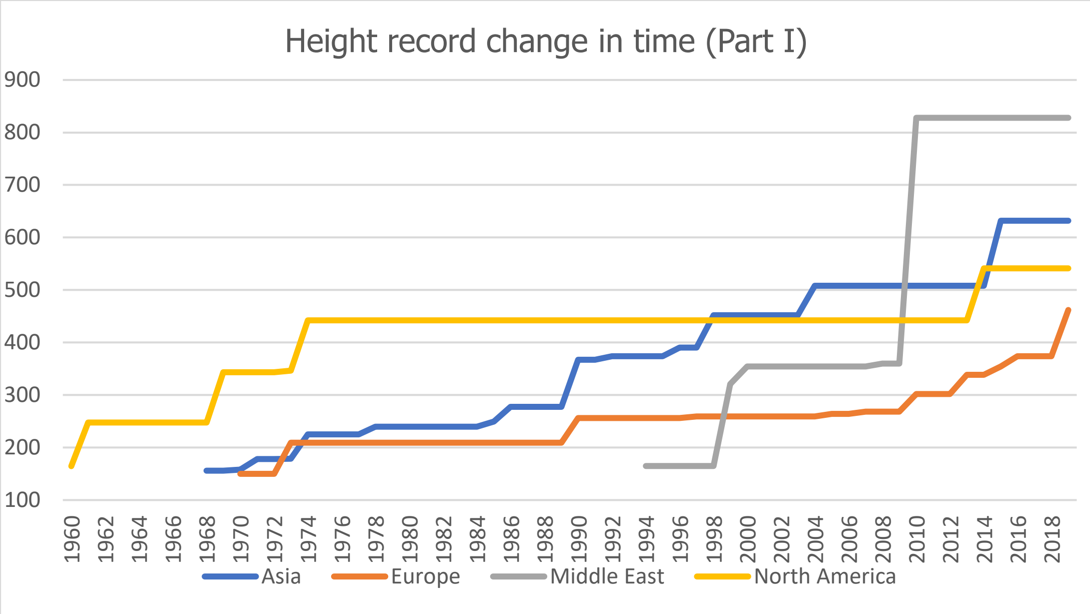


Figure 4.5 Maximum height evolution in time for Asia, Europe, Middle East and North America

By visually examining the graph in Figure 4.5, it is evident that there is a constant chase for surpassing the existing maximum height for the region of Asia throughout the years. Similar situation is observed for the region of Europe, but since the year of 2006. Regarding Middle East, no clear conclusions can be drawn, since within the first 14 years of tall buildings' existence in the region, the tallest building was built, preempting further attempts for exceeding. In North America, despite their high amount of completions, no indications for constantly reaching higher altitudes are found. The second graph treats the regions with the lower heights and amount of global completions. More specifically, there is no evidence for the region of Africa. Both for Central and South America, there is limited evidence for tendency to exceed past maximum heights, solely for the early time-period of building high and till the limit of 200 meters is surpassed. Only Oceania provides more consistent indication for height competition, throughout the years.

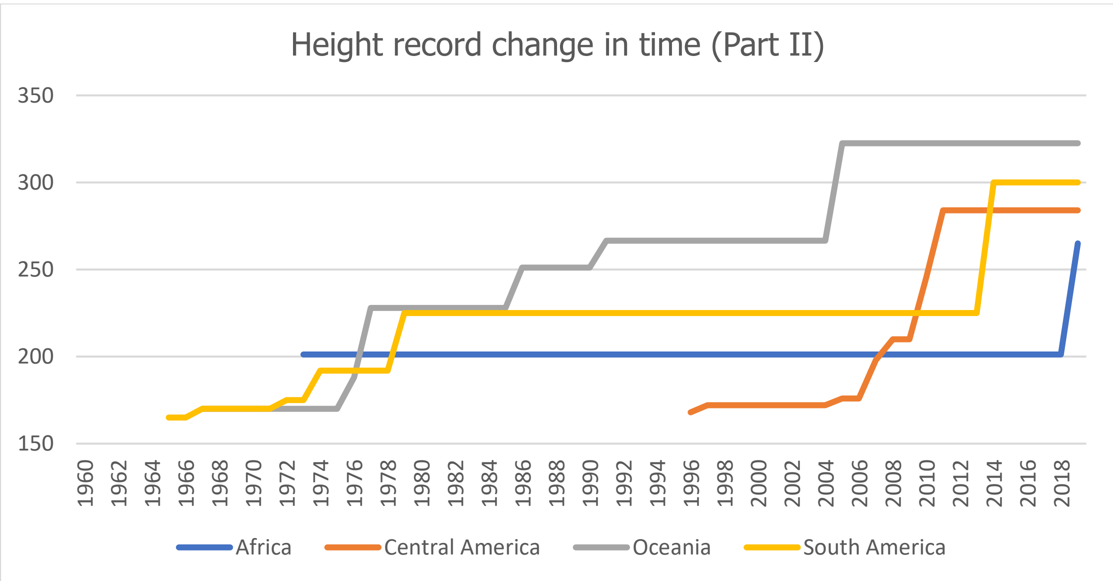


Figure 4.6 Maximum height evolution in time for Africa, Central America, Oceania and South America

Summarizing, after examining visually the height progressions per region, reserved conclusions for height competition can be drawn for the regions of Asia, Europe (after 2006) and Oceania.

Another indicative factor of height competition is the Vanity height of a tall building. According to CTBUH, Vanity height is defined as the difference in height between Height to Tip and Occupied Height. An overview of the cases, average and maximum vanity height per region is presented in the Table 4.4 below. However, due to not fully available information, the data used for the brief analysis of the vanity height is limited to 1200 cases. A more detailed approach for the variable of vanity follows in section 4.3. It can be inferred that there is the tendency to use Vanity height for tall buildings in the regions of Middle East, Europe and Oceania. This observation is based on the proportion of vanity cases per region, in combination with the value of average regional vanity height. Further analysis on vanity height is presented additionally in section 4.3.

Table 4.4 Overview of vanity height and its cases per geographic region

	Average of Vanity height (m)	Number of vanity cases per region	Maximum of Vanity height (m)
Africa	39.86	5/12	79.6
Asia	23.78	696/3135	190.1
Central America	30.13	7/54	60.5
Europe	26.83	80/198	110
Middle East	35.33	130/373	244.4
North America	23.00	246/866	159.7
Oceania	25.96	41/112	92
South America	15.52	19/76	39
Grand Total	25.09	1224	244.4

4.1.4 Building use and structural material

A key characteristic of a building is the use it is designed to serve. As seen in the Table 4.5 below, the residential and office type of building use are the 2 dominant ones. These two types of use together comprise of almost 80% of the total amount. Hotel, mixed-use and other complete the other 3 types of categorization, with mixed type consisting of a proportion of 17%. Regarding mixed-use type, the building that fall in this category consist of at least two of the rest of the categories, e.g. Office & Residential.

Table 4.5 Overview of tall buildings use types divided per decade

	1960-69	1970-79	1980-89	1990-99	2000-09	2010-19	Subtotal	Share
Office	53	129	206	298	408	859	**1953**	**40%**
Residential	4	8	20	89	617	1066	**1804**	**38%**
Mixed	4	13	17	47	204	518	**803**	**17%**
Hotel	1	6	13	32	64	123	**239**	**4%**
Other	2	0	0	2	11	12	**27**	**1%**

Delving into the timeline of construction, it is observed that the initial use of tall buildings over 150 meters was for office spaces. This was the situation until 1999. Since 2000, the primary use has shifted to Residential purposes, with Mixed-use type gaining ground from 2010 and on. Regarding height range, the distribution of building use, shown in the Figure 4.7 below, results in more insights.

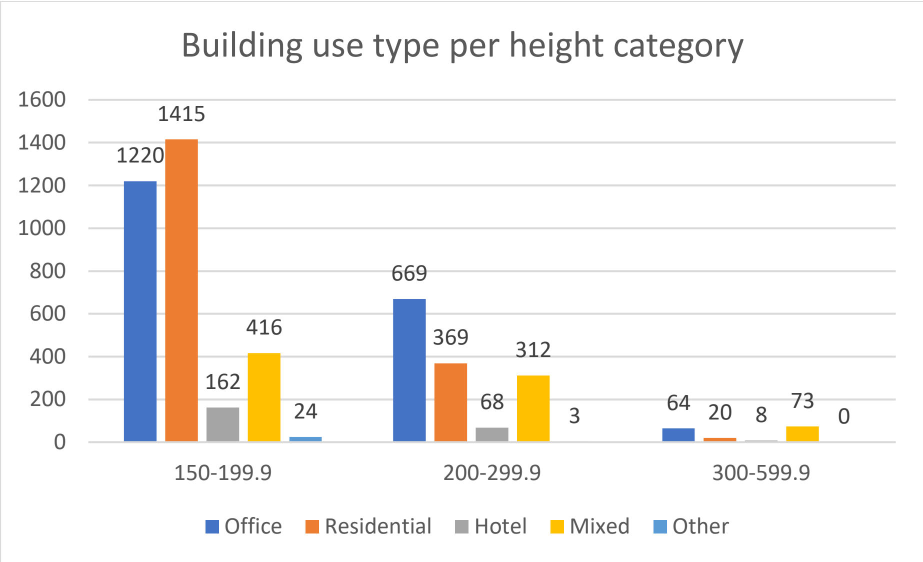
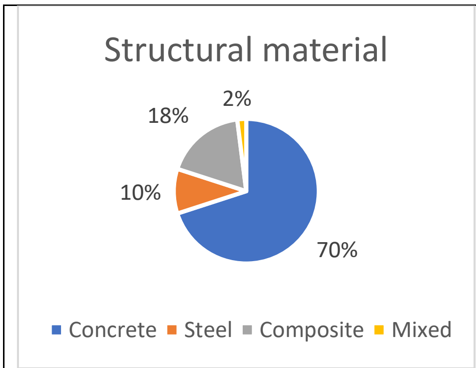


Figure 4.7 Bar chart of types of tall building uses per height category

It is observed that as height increases, buildings for residential purposes decline, while mixed-use increases, from the perspective of proportion. In fact, the majority of Supertall buildings is of mixed-use, while the residential type is quite low in share. This could be a minor indication of building higher, for reasons other than the demand for space for population increase.

In terms of the selected material for structural elements of tall buildings, 70% of them have used Concrete as the basic material for their construction. Composite and steel follow correspondingly, as seen in the combined Figure 4.8 below. Concrete is the dominant material for the height ranges of 150-200 meters and 200-300 meters. However, it is observed that for heights above 300 meters, composite is the most used material.



	150-200 m	200-300 m	300-600 m	>600 m	**Subtotal**
Composite	**205**	**397**	**98**	**1**	701
Concrete	**1808**	**780**	**52**	**0**	2640
Mixed	**34**	**33**	**4**	**2**	73
Steel	**249**	**120**	**11**	**0**	380
Precast	**14**	**1**	**0**	**0**	15

Figure 4.8 Combined figure with global distribution of structural material for tall buildings

4.1.5 Project dates & construction duration

This specific research focuses on the driving forces behind the development and height of tall buildings globally. This part dives deeper in the timeline of the construction of the buildings, examining the year the project was proposed, the year the construction started and the year of the final completion. In addition to this, the results of this section are used later in the regressions analyses, since not all proposal dates are known for the buildings of the database. When a tall building is decided to be proposed for construction, the involved parties base their decision, mostly on the current economic situation and demographic characteristics of the location. Therefore, the year of proposal concerning a building is of outmost importance for the research to follow.

Starting construction date & overall duration

The database of this research consists of 4826 buildings worldwide. Although the completion dates are known for all of them, the dates for starting construction are available for 3668 of them, out of 4826. Using the available data and comparing them with the respective completion dates, findings regarding their average construction duration are presented as follows. Regardless of region and height range, the average construction duration of buildings over 150m is calculated at 3.6 years. In the following Table 4.6, a more detailed breakdown of the average construction duration per region and height range is presented.

Table 4.6 Average construction duration in years, per region & height range

Avg. construction duration in years	**150-199.9**	**200-299.9**	**300-599.9**	Average per region
Africa	3.8	5.3	-	**4.4**
Asia	3.4	4.1	5.1	**3.7**
Central America	3.3	4.0	-	**3.6**
Europe	3.8	3.8	6.7	**3.9**
Middle East	3.9	4.5	5.4	**4.3**
North America	2.8	3.3	4.0	**3.0**
Oceania	2.8	3.2	3.0	**2.9**
South America	3.6	7.0	8.0	**4.1**
Average per height	**3.3**	**4.0**	**5.1**	**3.6**

Proposal date and overall duration for construction

The economic and demographic conditions existing when a tall building is about to be proposed for construction paly significant role. From the 4826 buildings of the database, information about the proposed year exists for only 1267 of them, almost 25% of total buildings examined. Based on these, a brief breakdown for the average duration between proposal and construction start & between proposal and completion is presented. Regardless of region and height range, the average duration between proposal and completion is calculated at 5.9 years. In the following Table, a more detailed breakdown of the average duration per region and height range is presented.

Table 4.7 Average duration from proposal to completion in years, per region & height range

Avg. duration in years (proposal-completion)	150-199.9	200-299.9	300-599.9	Average per region
Africa	6.5	8.3	-	**7.6**
Asia	5.2	6.0	7.0	**5.7**
Central America	6.0	5.8	-	**5.9**
Europe	6.9	8.1	9.4	**7.3**
Middle East	6.5	5.7	6.9	**6.2**
North America	5.1	6.8	7.8	**5.8**
Oceania	5.5	5.9	-	**5.6**
South America	6.1	6.5	9.0	**6.3**
Average per height	**5.5**	**6.2**	**7.2**	**5.9**

Regardless of region and height range, the average duration between proposal and construction start is calculated at 1.9 years. In the following Table, a more detailed breakdown of the average duration per region and height range is presented.

Table 4.8 Average duration from proposal to starting construction in years, per region & height range

Avg. duration in years (proposal to start)	150-199.9	200-299.9	300-599.9	Average per region
Africa	2.0	3.33	-	**2.8**
Asia	1.4	1.78	2.0	**1.6**
Central America	2.3	1.83	-	**2.0**
Europe	3.2	4.22	3.0	**3.4**
Middle East	1.8	1.40	1.4	**1.5**
North America	2.0	2.92	3.3	**2.4**
Oceania	2.6	2.63	-	**2.6**
South America	2.1	0.75	1.0	**1.8**
Average per height	**1.8**	**2.0**	**2.0**	**1.9**

Summarizing the outcome of this subsection, it is concluded that the average construction duration is 3.5 years, irrespective of height range and geographical region. More specifically, tall buildings below 200 meters require approximately 3 years to be built, buildings between 200 and 300 meters require around 4 years and supertall buildings around 5 years in average. Additional to this construction duration, an average duration of 2 years is added to the completion of the building since its proposal, which does not increase based on height range. During this 2-year timespan, all necessary actions required regarding acquiring permits and design finalizations are included. Regarding the regions, it is observed that Asia and Middle East expedite the construction start after the proposal is made. This is consistent with earlier findings, indicating that the tendency to build higher in these two regions.

4.1.6 Economic Indicators per region

FDI and GDP are two economic indicators that are suggested to be linked with the amount and height of tall buildings. In this section, the total received sum of FDI per region is presented in the Figure 4.9 below, in comparison with the height of the tallest existing building of the respective region. The similar comparison is made between GDP level per region and maximum height.

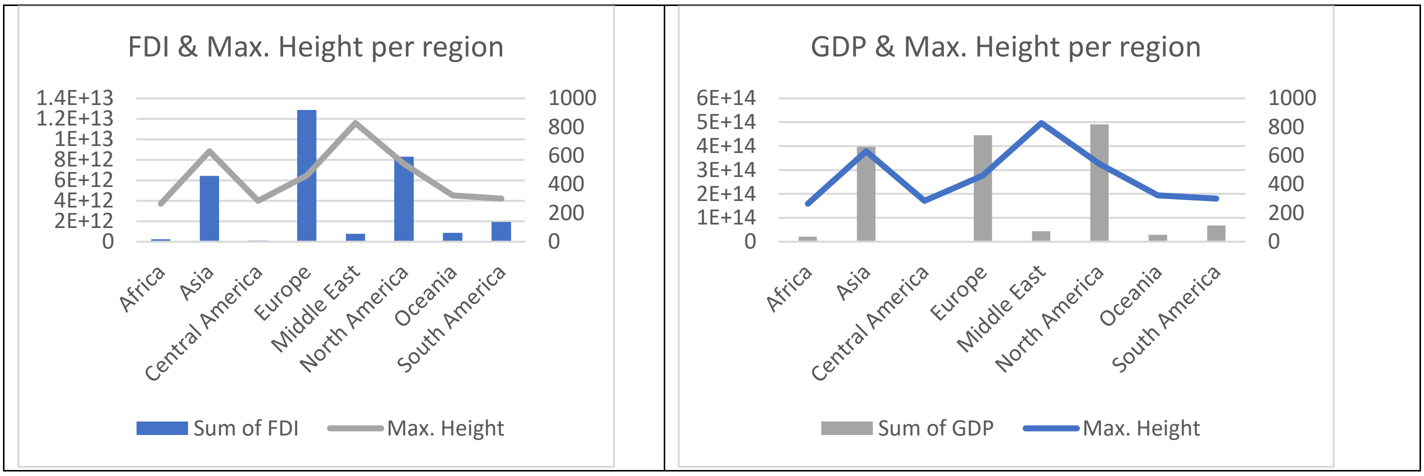


Figure 4.9 Comparison between FDI, GDP and maximum height per region

An initial observation is that GDP and FDI are strongly related per global geographic region, with certain minor deviations. For instance, for both indicators, the case is that Asia, Europe and North America score higher compared to the other regions. Regarding FDI, Europe shows the higher inflows, whereas for GDP, North America has the lead. In general terms, comparing maximum height to both indicators, consistency is observed between the two values. Middle East is an interesting case, showcasing extreme heights with minimal FDI and GDP compared to the other regions. On the other hand, despite having the largest FDI and high GDP, Europe hosts moderate amount of completions and moderate heights.

4.1.7 Key takeaways of characteristics and global distribution of tall buildings

A total amount of approximately 5000 tall buildings over 150 meters have been built in the last 60 years, 80% of which during the 21st century. The region of North America maintained the title with the most buildings until 1990, and since then and until today the region of Asia hosts the majority of tall buildings over 150 meters. In terms of countries, China and USA lead the race with most completed such buildings, and in terms of specific cities, Hong Kong, New York and Shenzhen are the top-3. In terms of height range, from 1960 till 2009, 75% of the buildings have heights up to 200 meters with the rest 25% of them being higher. The last decade, a shift occurred and the new-built tall buildings over 200 meters consist of the 40% of the total share. The current global average height is around 230 meters, while the last 20 years has been fluctuating between 170 and 200 meters. Concerning geographic regions, Asia, Middle East and North America show the tendency to build higher. The most popular building use consists of Office use (40%) and Residential use (38%), followed by Mixed-use type (17%). The last two decades, a shift towards Residential type of building use being the most popular occurred, although the Office use was the dominant type until 2000. The residential type is more common in lower heights and as heights increase mixed and office use gains ground in terms of amount. The dominant structural material is concrete, counting to 70% of the total buildings, followed by steel and composite materials to lesser extent. It is found that as height increases, the use of composite materials becomes more common. It is also concluded that the average construction duration is 3.5 years, irrespective of height range and geographical region. This regards mostly the category of buildings up to 200 meters. It is found that an additional year of construction is required for every 100 meters added to these 200 meters. As far as the time required between project proposal and start of construction works is concerned, it is found that 2 years are necessary, regardless of region and height. A subtle positive relationship between economically strong regions and extreme heights is also detected, based on the regional breakdown of maximum height, GDP and FDI. This applies to limited regions only.

4.2 Correlations of Variables

4.2.1 Presentation of Variables

Tall buildings' height is suggested to be determined by diverse factors, related to the building itself, to the demographic characteristics of their location and to the economic strength. Based on this outcome of the literature, the database was created, and the descriptive statistics of the variables are presented in the Table 4.9 below. The amount of observations per variable is documented, together with the minimum and maximum value, as well as the average and the standard deviation. The division of the two dummy-categories regarding the space fixed effect have been described in detail in section 3.5.

Table 4.9 Overview of descriptive statistics for constructed variables

Variables	**N**	**Min**	**Max**	**Mean**	**Standard Deviation**
Height					
Arch Height	4826	150	828	193.41	47.381
Vanity Height	1224	0	244	25.09	21.776
Numerical Variables					
Completions per year	4826	1	328	192.42	103.873
Longitude (x)	4826	-123.118451	174.7652231	65.81912789	81.71800494
Country Population	4815	36460	1,378,665,000	643,770,941.27	599,305,165.674
Country Urbanization rate	4815	17.18 %	100.00 %	61.43 %	19.61 %
Country GDP	4815	0	1.87*10^13	4.02*10^12	4.50*10^12
Country Real interest rate	4815	-18.30 %	77.62 %	2.96 %	4.56 %
Country FDI	4715	-2.2*10^10	7.34*10^11	1.00*10^11	1.17*10^11
Structural material dummy					
Concrete	3809	0	1	-	-
Steel	3809	0	1	-	-
Composite	3809	0	1	-	-
Mixed	3809	0	1	-	-
Precast	3809	0	1	-	-
Building use dummy					
Office	4826	0	1	-	-
Residential	4826	0	1	-	-
Hotel	4826	0	1	-	-
Mixed	4826	0	1	-	-
Other	4826	0	1	-	-

Time dummy 1 – per Decade					
1960-1969	4826	0	1	-	-
1970-1979	4826	0	1	-	-
1980-1989	4826	0	1	-	-
1990-1999	4826	0	1	-	-
2000-2009	4826	0	1	-	-
2010-2019	4826	0	1	-	-
Time dummy 2 – per 5-year					
1960-1964	4826	0	1	-	-
...					
2014-2019	4826	0	1	-	-
Space dummy 1 – per Region (9 dummies)					
Africa	4826	0	1	-	-
China (alone)					
Asia (without China)	4826	0	1	-	-
Central America	4826	0	1	-	-
Europe	4826	0	1	-	-
Middle East	4826	0	1	-	-
North America	4826	0	1	-	-
Oceania	4826	0	1	-	-
South America	4826	0	1	-	-
Space dummy 2 – per Country (30 dummies)					
China	4826	0	1	-	-
...					
USA	4826	0	1	-	-

As a brief summary of the descriptive values of the Table 4.9 above, the architectural height has a mean value of 193 meters, deviating by ±47 meters. This reflects that the majority of global buildings range between 150 and 240 meters. The minimum value is 150 meters, due to the on purpose imposed lower boundary and the maximum is 828 meters, which is the Burj Khalifa building in Dubai. Economic and demographic drivers are also examined with the use of the Numerical variables. The effect of building use and structural material is also investigated with the use of two respective dummies. In addition to this, the effect of the time and space is aspired to be tested. Regarding time, the examination is performed with the relevant dummies, either for a breakdown per decade or into 5-year timeframes. As far as the space or location is concerned, the examination is done either with the numerical variable of longitude, or with the use of corresponding regional and national dummy variables, depending on the outcomes of the analysis.

4.2.2 Correlations of variables with Architectural height

In this section, the preliminary examination of the relationship between basic variables is presented. The linkage of the variables with the architectural height is explained. This is achieved through correlation analysis and presented in the Figure 4.10 below. Variables having a bivariate correlation bigger than 0.70 are prone to raising multicollinearity issues and should be handled and interpreted carefully in the part of the regression analysis. Attention should be also pointed out to variables that do not show statistical significance, as this is an early indicator for them not to be included or treated carefully in the following stages of analysis.

Correlations[b]

		Arch Height (m)	Longitude (x)	Year's completions	Population Lag-3	Urbanization Lag-3	GDP current Lag-3	FDI Net inflows Lag-3	Real interest rate Lag-3
Arch Height (m)	Pearson Correlation	1	.025	.119**	.040**	.040**	.095**	.096**	-.046**
	Sig. (2-tailed)		.081	.000	.006	.006	.000	.000	.002
Longitude (x)	Pearson Correlation	.025	1	.189**	.442**	-.429**	-.172**	-.021	-.127**
	Sig. (2-tailed)	.081		.000	.000	.000	.000	.154	.000
Year's completions	Pearson Correlation	.119**	.189**	1	.190**	.070**	.422**	.501**	-.051**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000
Population Lag-3	Pearson Correlation	.040**	.442**	.190**	1	-.730**	.377**	.552**	-.101**
	Sig. (2-tailed)	.006	.000	.000		.000	.000	.000	.000
Urbanization Lag-3	Pearson Correlation	.040**	-.429**	.070**	-.730**	1	.062**	-.122**	.093**
	Sig. (2-tailed)	.006	.000	.000	.000		.000	.000	.000
GDP current Lag-3	Pearson Correlation	.095**	-.172**	.422**	.377**	.062**	1	.882**	.009
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.559
FDI Net inflows Lag-3	Pearson Correlation	.096**	-.021	.501**	.552**	-.122**	.882**	1	-.060**
	Sig. (2-tailed)	.000	.154	.000	.000	.000	.000		.000
Real interest rate Lag-3	Pearson Correlation	-.046**	-.127**	-.051**	-.101**	.093**	.009	-.060**	1
	Sig. (2-tailed)	.002	.000	.000	.000	.000	.559	.000	

**. Correlation is significant at the 0.01 level (2-tailed).

b. Listwise N=4715

Figure 4.10 Correlations among height and basic variables

At a first glance, high correlation occurs between FDI and GDP, as well as Population and Urbanization rate. Therefore, it is expected for them to raise multicollinearity issues, and being excluded from certain models as analysis proceeds. An important observation is the fact that the variable of longitude is not statistically significant, since its significance value is 0.081. As a result, the specific variable is not included in the following regression analyses. Instead, the element of space is tested through the dummy variables of geographic regions and the ones for countries. The variables of population size and urbanization rate also show signs of limited statistical significance with height and this should be checked in the analysis to follow.

In general terms, it is observed that the architectural height has weak correlations with all other numerical variables. The strongest correlation appears with the amount of completions of the same years, but even this one scores 0.119, which is low. The nature of relationship occurs as expected, based on the literature findings. All variables have a positive influence on the architectural height, except for real interest rate, bearing negative influence. Higher, still quite low though, correlations are observed between urbanization rate and population size, which is negative, and between GDP and FDI, which is positive. These conclusions derive from a sample of 4715 buildings globally. A correlation value is missing from the table and regards the relationship between architectural and vanity height, with a correlation of 0.559. This derives from a smaller sample of 1141 observations, a point that should be taken into account for regression analysis.

4.2.3 Correlations of variables with amount of completions

In this section, the relationship between the amount of completions with the economic and demographic indicators is presented, from a global perspective. The linkage of the variables with the amount of completions is achieved through correlation analysis and presented in the Figure 4.11 below. The results concern the years of the period between 1960 and 2019, except for FDI, for which data is available from 1970 and afterwards.

Correlations							
		Completions	World GDP	World FDI	World Real interest rate	World Population	World Urbanization rate
Completions	Pearson Correlation	1					
	Sig. (2-tailed)						
	N	59					
World GDP	Pearson Correlation	.948**	1				
	Sig. (2-tailed)	.000					
	N	59	59				
World FDI	Pearson Correlation	.854**	**.899****	1			
	Sig. (2-tailed)	.000	.000				
	N	49	49	49			
World Real interest rate	Pearson Correlation	.474**	.549**	.532**	1		
	Sig. (2-tailed)	.000	.000	.000			
	N	58	58	49	58		
World Population	Pearson Correlation	.851**	**.951****	.863**	.610**	1	
	Sig. (2-tailed)	.000	.000	.000	.000		
	N	59	59	49	58	59	
World Urbanization rate	Pearson Correlation	.891**	**.974****	.879**	.607**	**.996****	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	59	59	49	58	59	59

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4.11 Correlations among global variables and amount of completions

It is evident that, from a global point of view, the number of completed projects per year are highly correlated with economic indicators and demographic characteristics. This regards especially the value of World GDP and world's urbanization rate, followed by FDI and population. World real interest rate appears to have weaker correlation with the amount of completions, yet a significant one. It should be noted that particularly high correlations are measured between the examined variables themselves. For instance, World population size has a correlation of 0.996 with the World's urbanization rate. This observation should be taken into account, for future regression analyses involving these figures.

4.3 Multiple regression analysis

Tall buildings' height is suggested to be determined by diverse factors, either related to the building itself, to the demographic characteristics of their location and to the economic strength. When a tall building is decided to be proposed for construction, the involved parties base their decision, mostly on the current economic situation and demographic characteristics of the location. Therefore, the year of proposal concerning a building is of outmost importance for the research to follow.

4.3.1 Introduction

The moment when the decision for a tall building to be proposed is made is of critical importance. This decision is linked with the growth of the respective locations, both demographically and economically. Therefore, it is crucial for which year(s) the suggested influential factors are taken into account. However, the proposal date is not known for every building of the dataset and this has to be compensated for. This is based on the analysis of identifying the duration of the construction of section 4.1.6, in combination with the fact that there is data of the completion date for the entire dataset. Since in most studies only the data for completion date is available, the most common practice is to lag the factors to be investigated by a certain amount of time, usually in years. More specifically, in studies regarding North America, the respective factors were lagged by 1 to 3 years from the year of completion of the buildings (Barr, 2012, 2013), and in another one by 5 years (Barr, 2010). In their research for South America, Garza and Lizieri (2016) lagged their variables by 2 years. In a more complex approach, the mean values of the factors for the timespan between completion and 1 year minus the proposal date were considered in a more recent study with limited data sample (Honorée et al., 2018). Based on this school of thinking and the findings of section 4.1.6, that result in the fact that the average construction duration of a tall building is approximately 3.5 years, it is decided to lag the relevant factors by 3 years, prior to completion date. The respective determinants are examined based on their value 3 years prior to the completion of the projects. Since the average construction duration is 3.5 years, the prosperity of a location can be reflected sufficiently when lagging 3 years from the completion, together with the conditions present when construction is on initial stages.

4.3.2 Dependent variable & transformations

The present study employs the Multiple Linear Regression as the fitting model for the data collected. The outcome of this part of analysis aims to answer the main research question, directly linked with the height of tall buildings. The variable of architectural height is the dependent variable for the regression analysis to follow. The specific variable is characterized by positive skewness, as it can be seen in the Figure 4.12 below, which present the Frequency Histogram for the variable. For this reason, it is transformed using the Logarithmic transformation for the purposes of the analysis in SPSS.

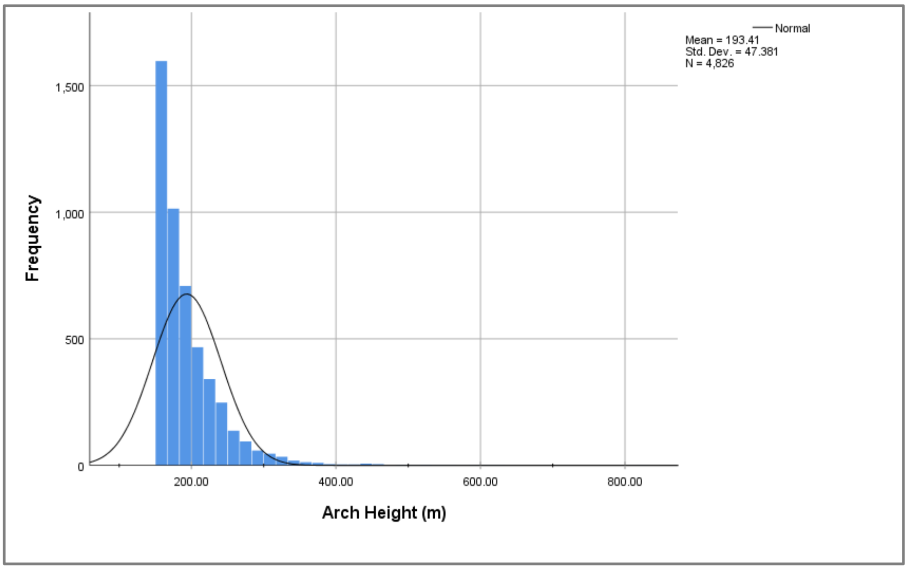


Figure 4.12 Frequency histogram for Architectural height, with normal distribution bell

For reasons of consistency and further convenience, various numerical variables were transformed as well. The form of the transformed variables is found in the Table 4.10 below. The following transformation are used in order for issues of linearity and skewness of the respective variables to be resolved as much as possible.

Table 4.10 Detailed transformations of variables regarding regression models

Variables	Initial Form	Transformed Form	Transformation
Dependent Variables			
Arch Height	Linear	Logarithmic	LN (Arch Height)
Vanity Height	Linear	Logarithmic	LN (Vanity Height)
Numerical Variables			
Longitude (x)	Linear	Logarithmic	LN (Longitude+200)
Country Population	Linear	Logarithmic	LN (Population)
Country GDP	Linear	Logarithmic	LN (GDP+1)
Country FDI	Linear	Logarithmic	LN (FDI+1)

4.3.3 Regression models – Architectural height the dependent variable

In order for the level of influence of the determinants to be evaluated, numerous multiple regression models are developed. The dependent variable is the architectural height, in logarithmic form. The economic and demographic variables are used in linear and logarithmic form, and dummy variables are used to represent the building use, structural material and time effect. The influence of the space is tested with the use of dummy variables for region and country, divided as explained in detail in Chapter 3. The ENTER method is used for all models, in which all variables are inserted into the model, regardless of their significance and adjustments are made based on findings throughout the process. The regression models are presented in two batches below and elaborately described afterwards. In the first batch, presented in Figure 4.9, four initial models are used to detect multicollinearity issues among the variables.

Variables	Dependent Variable: LN Architectural Height			Dependent Variable: LN Architectural Height			Dependent Variable: LN Architectural Height			Dependent Variable: LN Architectural Height		
	Model 1.1			Model 1.2			Model 1.3			Model 1.4		
	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF
Constant	5.441	90.377	-	5.447	90.390	-	5.430	90.263	-	5.477	96.798	-
Amount of year's completions	0.0001	3.010	1.513	0.0002	4.572	1.309	0.0002	4.115	1.374	0.0002	4.125	1.242
Population size (country)	-0.0259	-3.404	21.490	-	-	-	-0.0042	-1.650	2.411	-0.0137	-5.030	2.748
Urbanization rate (country)	-0.0016	-3.025	9.579	0.0001	0.542	1.075	-	-	-	-0.0008	-3.144	2.242
GDP (country)	0.0118	1.718	12.751	-0.0101	-4.079	1.630	-0.0064	-1.919	2.985	-	-	-
FDI Net Inflows (country)	0.0020	1.674	1.498	0.0021	1.721	1.497	0.0023	1.855	1.492	0.0024	2.027	1.446
Real interest rate (country)	-0.0015	-2.043	1.038	-0.0019	-2.628	1.011	-0.0018	-2.609	1.007	-0.0016	-2.319	1.016
Residential	-0.062	-7.276	1.704	-0.062	-7.308	1.703	-0.062	-7.298	1.704	-0.062	-7.285	1.704
Hotel	-0.026	-1.522	1.102	-0.025	-1.483	1.102	-0.025	-1.485	1.102	-0.026	-1.507	1.102
Other	-0.116	-1.659	1.007	-0.120	-1.721	1.006	-0.120	-1.720	1.006	-0.118	-1.684	1.006
Mixed	0.069	7.014	1.323	0.069	7.015	1.323	0.068	6.989	1.323	0.069	7.050	1.322
Office	-	-	-	-	-	-	-	-	-	-	-	-
Steel	0.033	2.402	1.350	0.031	2.258	1.348	0.029	2.147	1.340	0.034	2.495	1.347
Composite	0.166	17.170	1.370	0.164	16.985	1.366	0.165	17.028	1.367	0.166	17.214	1.369
Mixed	0.113	4.783	1.032	0.115	4.864	1.031	0.113	4.788	1.032	0.114	4.853	1.030
Precast	-0.028	-0.551	1.022	-0.034	-0.658	1.021	-0.036	-0.693	1.019	-0.028	-0.553	1.022
Concrete	-	-	-	-	-	-	-	-	-	-	-	-
Observations	3703			3703			3703			3703		
Fixed effect	No			No			No			No		
R^2/ Adjusted R^2	0.182/0.179			0.180/0.177			0.180/0.177			0.182/0.179		
F-value	58.775			62.226			62.454			63.035		

Figure 4.13 Models 1.1-1.4 with architectural height as dependent variable, no fixed effects applied

In the first model, Model 1.1, the architectural height is associated with the number of completed buildings during the year of completion, national population size and urbanization rate, national GDP, FDI and real interest rate, together with the effect of building use and structural material. No fixed effects regarding space or time are applied. The model results in a low R^2 of 0.179, indicating that there are still variables missing in order for the height to be more efficiently explained. An important remark is that the variables of population size in particular, and to lesser extent urbanization rate and GDP score quite high in collinearity diagnostics. They present VIF scores of 21.490, 9.579 and 12.751 respectively. For linear regression, VIF can be tolerated for values under 10.0, yet any result exceeding 4.0 should be treated as alarming, regarding multicollinearity issues (Field, 2009). These three variables in question are highly correlated with each other. This is also supported by the correlations found in Section 4.3.2, especially between GDP and FDI. In the same section, the variable of GDP is suggested to be more statistically significant compared to population size and urbanization rate. In Model 1.2, the variable of national population size is not included, having the largest VIF value. All variables have now VIF values below 4.0, signalling no issues of multicollinearity and a slight decline in R^2 is marked. Although Model 1.2 was adequate in terms of multicollinearity, Models 1.3 and 1.4 are also constructed to examine the impact of removal the other two variables, high in VIF, urbanization rate and GDP respectively. Among all three models, namely 1.1-1.4, the F-value and R2 have almost identical values. Additionally, there is no clear indication to exclude on of them, based on statistical significance. Therefore, it is not evident which independent variable to eliminate, at this point, and more models, accompanied by time and space effects, are examined to end up with the optimal models.

All tested models are included in the Appendix, with the variables of population, urbanization and GDP being removed per case.

The best performing models in terms of both collinearity and statistical significance are presented in Figure 4.10, below, accompanied by the contribution of space and time fixed effects. Starting with the fixed effect of time, two possible scenarios are examined, breaking down the period or 1960-2019 into decades and smaller periods of 5 years. However, after testing various models, their influence was almost identical to the explanation of the dependent variable, with the 5-year breakdown showing a slight increase in explanatory power. Thus, the effects of time per 5-year period are presented and discussed moving forward.

	Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height		
Variables	**Model 1.5**			**Model 1.6**			**Model 1.7**			**Model 1.8**		
	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF
Constant	5.4272	95.462	-	5.510	73.375	-	5.204	461.000	-	5.433	51.403	-
Amount of year's completions	0.0002	5.129	1.357	-	-	-	0.0001	3.578	1.273	-	-	-
Population size (country)	-	-	-	-	-	-	-	-	-	-	-	-
Urbanization rate (country)	-	-	-	-	-	-	-	-	-	-	-	-
GDP (country)	-0.0075	-3.529	1.241	-0.0114	-5.317	1.283	-	-	-	-0.009	-2.406	3.647
FDI Net Inflows (country)	-	-	-	-	-	-	-	-	-	-	-	-
Real interest rate (country)	-0.0017	-2.488	1.005	-0.0023	-3.197	1.085	-	-	-	-	-	-
Residential	-0.062	-7.298	1.704	-0.0623	-7.3008	1.7916	-0.062	-7.371	1.775	-0.060	-6.988	1.852
Hotel	-0.025	-1.485	1.102	-0.0305	-1.8309	1.1043	-0.034	-2.068	1.105	-0.037	-2.212	1.109
Other	-0.120	-1.720	1.006	-0.1143	-1.7525	1.0116	-0.122	-1.880	1.007	-0.107	-1.648	1.013
Mixed	0.068	6.989	1.323	0.0635	6.55949	1.3384	0.066	6.917	1.317	0.063	6.585	1.341
Office	-	-	-	-	-	-	-	-	-	-	-	-
Steel	0.023	1.795	1.393	0.041	3.031	1.611	0.024	1.871	1.461	0.039	2.849	1.724
Composite	0.164	17.074	1.371	0.161	16.923	1.378	0.162	17.094	1.366	0.160	16.693	1.414
Mixed	0.115	4.912	1.027	0.116	4.989	1.029	0.106	4.552	1.033	0.107	4.613	1.038
Precast	-0.043	-0.842	1.003	-0.032	-0.637	1.006	-0.047	-0.940	1.014	-0.023	-0.458	1.029
Concrete	-	-	-	-	-	-	-	-	-	-	-	-
Observations	3789			3789			3789			3789		
Fixed effect	No			Time			Space (Regions)			Time+Space (Regions)		
R^2/Adjusted R^2	0.178/0.176			0.194/0.190			0.197/0.193			0.211/0.205		
F-value	74.462			43.218			54.464			35.823		

Figure 4.14 Best performing models with architectural height as dependent variable (fixed effects)

Models 1.5-1.8 are the best performing models, based on collinearity and statistical significance. All additional models used to this outcome are presented in Appendix. As a general remark, it was concluded that the variable of amount of completions was highly correlated with the time fixed effect, and when the fixed effect is applied the amount turns out statistically insignificant. The variables of FDI, population size and Urbanization rate proved to be not statistically significant, thus, not affecting the architectural height. A last remark regards the space fixed effect. When it is applied, it renders the previously significant variables of GDP and real interest rate as insignificant.

Model 1.5 turned out to be best one, where no fixed effects are applied. The significant independent variables for this model are the amount of completions, GDP and real interest rate, together with building use and structural material. It has the highest F-value (74.462) among all models, but its explanatory power is quite low, with R^2 being 0.178. In Model

1.6, the first application of the fixed effect of time (5-year periods) is employed. The explanatory power increases from 17.8% to 19.4%, but the F-value drops to 43.218. Apart for use and material, GDP and real interest rate are again the two significant factors.

In Model 1.7, the individual fixed effect of space (regions) is examined. A slightly improved explanatory power is observed compared to the individual time effect of Model 1.6, while the F-value increases. However, GDP and real interest rate become insignificant, being overlapped by the effect of the effect of space. In the Appendix, models with the space fixed effect at country level can be found. The reason why it is not included here is that it resulted in overfitted models with really low F-values (between 15.000-25.000), and raising multicollinearity issues significantly. At the same time, the increase in explanatory was trivial, with the maximum value being 22.8%, compared to Model 1.8 with R^2 0.211.

The final model, 1.8, included both space (regions) and time fixed effects and as already mentioned R^2 0.211, the highest of the models, but with the lowest F-value (35.823). Except for building use and material and fixed effect, only the factor of country GDP remains significant statistically. Since there is no model with both the highest R^2 and highest F-value, in a middle ground solution, the results of Model 1.6 will be presented in more detail moving forward, supported by the fact that two of the economic variables are also significant. The explanation is also complemented by the relative findings of Model 1.7 for the space fixed effect. The explanatory power of the selected model is regarded as low, since the value of adjusted R^2 is 0.194. Interpreting this value, the included independent variables have the ability to compensate and express 19.4% of the variance of the dependent variable. This means that there are more variables, not included in the model, to explain the height variable. The full results of the statistical model 1.6 can be found in Appendix.

Using model 1.6, the architectural height can be expressed with the following function:

LN (Arch Height) = c + b1*LN(GDP) + b2*(Real interest rate%) + b3*(Building use) + b4*(Structural material) + b5*(Time/5-year periods) + error

To begin with, for model 1.6, the constant value of c is equal to 5.510 and when removing the logarithmic nature, this is interpreted to 247 meters. Both national economic variables, GDP and real interest rate, have negative coefficients, b1=-0.00114 for the former and b2=-0.0023 for the latter. A 10% increase in GDP, results in a 0.01% drop in Architectural height, and a 10% increase in real interest rate results in a decrease of 0.02% for the dependent variable. Regarding building use, the refence point variable is the Office use. Compared to this use, statistically significant results occurred for the Residential and Mixed use. The coefficient b3 for residential use is -0.0623 and for mixed use +0.0635. Subsequently, when a tall building is built for residential use, a 6% drop in height is marked, while a 6.5% increase for mixed use. Both findings are relative to the office building use. Regarding the structural material, the refence point variable is Concrete. Compared to this, statistically significant results occurred for the Composite and Mixed materials. The coefficient b4 for Composite is +0.161 and for mixed +0.116. Subsequently, a tall building with composite materials can result in a 17% increase in height and in a 12% increase for mixed use. Both findings are relative to the concrete material.

As far as the time fixed effect is concerned, it is observed that architectural height increases as time progresses. Having the 5-year period of 1960-1965 as the baseline, an increase of 8% in architectural height is observed for completions between 2010-2014, and 11% increase for the period of 2015-2019. Since the regional space effect was not incorporated in Model 1.6, the partial results of Model 1.7 are described to identify the related effect between regions. The full model 1.7 and its results can be found in Appendix. The baseline region for this comparison is the region of North America, and it is also noted that the variables for the regions of Oceania and Africa bore statistically insignificant coefficients. Compared to North America, it is found that Central America, Middle East, China and the rest of Asia individually are associated with taller buildings. Instead, South America, Africa and Europe build have lower buildings than North America. In figures, a tall building in Middle East is by 10.6% taller and 2.5% in Asia than in N. America, whereas 8% lower in South America and 3% lower in Europe. For reasons of completeness, a modified version of model 1.7 is run with the space fixed effect of countries instead of regions, also available in Appendix. Regarding useful observations, compared to the country of USA, buildings located in UAE, Saudi Arabia and Malaysia are 11% higher, while buildings in countries of Azerbaijan, Kazakhstan, Brazil are around 10% lower. As an overall remark, the influence of economic variable is evaluated as quite low compared to the rest variables. Another remark regarding the fixed effects used in the models is that the element of space is more influential than the one of time. Therefore, it enhances the argument that the development of tall buildings and extreme heights are highly linked with their location.

A second set of models is constructed, including the independent variable of vanity height, with the size of the sample being reduced to 1141 observations, from 3703. The outcome of this approach results in higher R^2, with values of 0.38-0.42. A strong influence of vanity height on architectural height is marked. Building type and structural material contribute to increasing the R^2. The best performing models are presented in the Figure 4.11 and explained in more detail below. To avoid misunderstanding, these models are numbered as 2.i, compared to the initial models, excluding vanity height in the variables, that are numbered as 1.i.

	Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height		
Variables	Model 2.1			Model 2.2			Model 2.3			Model 2.4			Model 2.5		
	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF
Constant	5.050	37.983	-	5.060	41.186	-	5.028	29.033		4.749	134.096		4.660	36.795	-
Vanity Height	0.182	17.909	1.157	0.181	18.095	1.129	0.184	18.313	1.150	0.176	17.869	1.146	0.179	17.967	1.179
Amount of year's completions	0.00003	0.380	1.339	-	-	-	-	-	-	-	-	-	-	-	-
Population size (country)	0.011	0.693	25.603	-	-	-	-	-	-	-	-	-	-	-	-
Urbanization rate (country)	0.001	0.829	11.412	-	-	-	-	-	-	-	-	-	-	-	-
GDP (country)	-0.019	-1.408	12.335	-0.011	-2.663	1.101	-0.015	-3.401	1.233	-	-	-	-	-	-
FDI Net Inflows (country)	-0.001	-0.488	1.510	-	-	-	-	-	-	-	-	-	-	-	-
Real interest rate (country)	-0.005	-3.642	1.161	-0.004	-3.571	1.017	-0.005	-3.751	1.059	-0.004	-2.716	1.689	-0.005	-3.039	1.827
Residential	0.003	0.168	1.725	0.004	0.241	1.711	0.010	0.601	1.744	0.001	0.063	1.781	0.009	0.494	1.822
Hotel	-0.049	-1.495	1.099	-0.048	-1.467	1.096	-0.046	-1.429	1.107	-0.063	-1.966	1.104	-0.062	-1.927	1.115
Other	-0.036	-0.291	1.019	-0.036	-0.289	1.018	-0.028	-0.224	1.021	-0.042	-0.345	1.020	-0.030	-0.242	1.023
Mixed	0.130	7.523	1.324	0.130	7.577	1.312	0.127	7.346	1.342	0.121	7.207	1.315	0.121	7.131	1.351
Office	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Steel	0.076	2.301	1.203	0.077	2.466	1.124	0.088	2.699	1.227	0.092	2.969	1.139	0.088	2.763	1.216
Composite	0.151	8.712	1.400	0.153	8.881	1.384	0.154	8.935	1.393	0.156	9.258	1.379	0.156	9.228	1.390
Mixed	0.063	1.828	1.082	0.066	1.949	1.065	0.070	2.050	1.083	0.036	1.069	1.087	0.039	1.151	1.102
Precast	-0.112	-0.729	1.020	-0.096	-0.632	1.009	-0.094	-0.618	1.010	-0.104	-0.696	1.016	-0.107	-0.719	1.016
Concrete	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Observations	1141			1147			1147			1147			1147		
Fixed effect	No			No			Time (5 year)			Space (Regions)			Time + Space		
R^2/Adjusted R^2	0.383/0.375			0.382/0.376			0.391/0.379			0.412/0.402			0.420/0.405		
F-value	46.551			63.885			32.853			43.892			27.949		

Figure 4.15 Models 2.1-2.5 with architectural height as dependent variable, including vanity height as independent variable

Starting with Model 2.1, the issue of multicollinearity remains present between the three variables of Population, urbanization and GDP and on top of that the majority of economic variables occurs as statistically insignificant. Another remark to be noted is that the variable of national real interest rate remained significant through all models with a negative coefficient. Model 2.2 is the best performing one, eliminating all issues of stat. insignificance and multicollinearity. With no fixed effects applied, the R2 value is 0.382 and the following variables are significant: vanity height, GDP, real interest rate, building use and structural material. In Models 2.3 and 2.4, the time and space effect is examined for its influence individually. Applying the fixed effect of space (regions) has more influence on the robustness of the model, both in terms of F-value and R^2, compared to the fixed effect of time. It is also noted the when the space fixed effect is applied, the variable of GDP gets redundant, as insignificant. Lastly, the combined fixed effect of time and space is examined, resulting in an increase in R2, but with significant decrease in the overall model significance, as F-value drops. As a result, the best performing model with fixed effects is Model 2.4 and it is described in depth below. The full model 2.4 can be found in Appendix.

Using model 2.4, the architectural height can be expressed with the following function:

LN (Arch Height) = c + b1*LN (Vanity Height) + b2* (Real interest rate%) +b3*(Building use) + b4*(Structural material) + b5*(Space/regions) + error

To begin with, for model 2.4, the constant value of c is equal to 4.749 and when removing the logarithmic nature, this is interpreted to 115 meters. The variable of vanity height in logarithmic nature has a large positive coefficient of 0.176, meaning that an increase of it by 10% will result in an increase of 1.7% in architectural height. Regarding national economic variables, in this model only real interest rate is significant, with a negative coefficient of -0.005. a 10% increase in real interest rate results in a decrease of 0.05% for the dependent variable. Regarding building use, the refence point variable is the Office use. Compared to this use, statistically significant results occurred only for the Mixed use. The coefficient b3 for mixed use is +0.127. This means that when a tall building is built for mixed use, a 13.5% increase in the dependent variable is detected. Regarding the structural material, the refence point variable is again Concrete. Compared to this, statistically significant results occurred for the Composite, Steel and Mixed materials. The coefficient b4 for Composite is +0.154, for steel is +0.088 and for mixed +0.070. Subsequently, a tall building with composite materials can result in a 17% increase in height, with steel in a 9% increase and in a 7% increase for mixed use. Both findings are relative to the structural material of concrete.

As far as the space fixed effect is concerned, the following are observed for the geographic regions included in the model. The baseline region for comparison is the region of North America. Significant findings concern the regions of Middle East and Europe. In comparison with North America, height in Europe are lower by 7.4%, while in Middle East larger by 16%.

After completing the presentation of model 2.4, an additional analysis takes place with special emphasis on the variable of vanity height. The findings on the specific variable are employed to treat the height competition aspect of the research scope. Therefore, it is important to detect whether the presence of vanity height is stronger, in terms of height range, location or time. As a result, three variations of Model 2.3 are developed. In variation 2.3a, the variable of vanity height in two subcategories, one including the buildings of 150-300 meters and another consisting of the rest, over 300 meters. For the second variation, Model 2.3b, the variable is divided into 9 subcategories based on the geographic regions and for the third one, Model 2.3c, the vanity height variable is interacted with time decade variables. The outcome of these three models are presented in the Figure 4.12 below.

		Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height		
	Variables	Model 2.3a (height range)			Model 2.3b (regions)			Model 2.3c (time effect)		
		Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF
	Constant	5.299	38.111	-	4.733	22.123	-	5.078	40.400	-
	GDP (country)	-0.012	-3.495	1.234	-0.002	-0.275	3.414	-0.012	-2.813	1.177
	Real interest rate (country)	-0.003	-3.218	1.063	-0.004	-2.240	1.906	-0.004	-3.422	1.027
	Residential	-0.023	-1.652	1.760	0.006	0.373	1.823	0.007	0.402	1.728
	Hotel	-0.087	-3.326	1.111	-0.069	-2.167	1.120	-0.048	-1.476	1.099
	Other	-0.025	-0.251	1.021	-0.028	-0.226	1.024	-0.028	-0.221	1.020
	Mixed	0.062	4.403	1.388	0.119	6.998	1.356	0.130	7.482	1.342
	Office	-	-	-	-	-	-	-	-	-
	Steel	0.041	1.559	1.233	0.088	2.742	1.252	0.079	2.420	1.220
	Composite	0.084	5.986	1.449	0.154	9.010	1.430	0.152	8.799	1.387
	Mixed	0.063	2.297	1.083	0.026	0.763	1.119	0.069	2.028	1.074
	Precast	-0.059	-0.487	1.010	-0.100	-0.670	1.025	-0.100	-0.659	1.010
	Concrete	-	-	-	-	-	-	-	-	-
VANITY HEIGHT INTERACTIONS	Vanity H.*(150-300m)	0.091	10.247	3.816	-	-	-	-	-	-
	Vanity H.*(>300m)	0.211	25.974	4.009	-	-	-	-	-	-
	Van H.*Central America	-	-	-	0.180	6.607	1.276	-	-	-
	Van H.*North America	-	-	-	0.172	15.123	5.132	-	-	-
	Van H.*South America	-	-	-	0.167	6.458	2.071	-	-	-
	Van H.*Africa	-	-	-	0.132	4.570	1.226	-	-	-
	Van H.*Europe	-	-	-	0.145	11.823	2.527	-	-	-
	Van H.*Middle East	-	-	-	0.217	19.108	3.937	-	-	-
	Van H.*Oceania	-	-	-	0.169	11.605	1.823	-	-	-
	Van H.*CHINA	-	-	-	0.175	16.482	6.699	-	-	-
	Van H.*REST ASIA	-	-	-	0.175	15.547	5.067	-	-	-
	Van H.* Decade 60-70	-	-	-	-	-	-	0.156	5.531	1.134
	Van H.* Decade 70-80	-	-	-	-	-	-	0.192	8.583	1.239
	Van H.* Decade 80-90	-	-	-	-	-	-	0.203	9.109	1.346
	Van H.* Decade 90-00	-	-	-	-	-	-	0.183	14.965	2.336
	Van H.* Decade 00-10	-	-	-	-	-	-	0.173	16.317	4.606
	Van H.* Decade 10-20	-	-	-	-	-	-	0.186	18.076	5.599
	Observations	1147			1147			1147		
	Fixed effect	Time (5 year)			Time (5 year)			NO		
	R^2/Adjusted R^2	0.610/0.602			0.424/0.408			0.387/0.378		
	F-value	76.502			27.383			44.584		

Figure 4.16 Model 2.3 variations, with different interactions for the predictor variable of vanity height

The purpose of this sub-analysis is the relative difference among the coefficients of vanity height. Therefore, no further remarks regarding the overall performance of the models are made.

Focusing on the height range, it is identified that the impact of vanity height on architectural height is twice as much for the building category of over 300 meters. Regarding the regional division, the findings are not as clear. The main remark is that the impact of vanity height is higher for the region of Middle East, with Africa and Europe providing the lower impact. Regarding the evolution of vanity height through time, there are indications that the phenomenon of height competition is not a recent phenomenon, which coincides with the literature suggestions, placing it since 1920 for North America (Gottmann, 1966). Higher impact is detected between 1970 and 1990. A slight decrease of vanity's height impact is marked for the decade of 2000-2010. This is perhaps linked with the fact that Burj Khalifa was already under construction in 2003, with Taipei 101 almost completed at the same time, thus preempting other potentially ambitious developers. Summarizing, the strongest model is Model 2.3a, with the height range interaction, both in terms of significance and explanatory power. Thus, it can be inferred that vanity height is more consistent with the buildings of the highest tier. In terms of impact on architectural height, the influence of region follows. Judging by the constant values from all these three models, the interaction of vanity height with regions explains the value of architectural height, and specifically its increase, more intensively.

4.3.4 Regression models – Vanity height as dependent variable

In order for the phenomenon of height competition to be further investigated, a regression analysis with vanity height as the dependent variable is performed. Three models, 3.1 to 3.3, are constructed and presented in the Figure 4.13 below.

	Dependent Variable: Ln Vanity Height			Dependent Variable: Ln Vanity Height			Dependent Variable: Ln Vanity Height		
Variables	Model 3.1			Model 3.2			Model 3.3		
	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF
Constant	4.915	13.600		4.728	12.573		4.286	8.995	
Amount of year's completions	-0.001	-3.639	1.323	-0.001	-1.758	2.689	-0.001	-2.064	1.335
Population size (country)	-0.206	-4.387	25.173	-	-	-	-	-	-
Urbanization rate (country)	-0.015	-4.645	11.197	-0.001	-1.249	1.143	-0.004	-3.277	1.772
GDP (country)	0.113	2.800	12.250	-0.049	-3.223	1.680	-0.037	-2.034	2.525
FDI Net Inflows (country)	0.002	0.260	1.510	-0.001	-0.127	1.529	0.005	0.688	1.540
Real interest rate (country)	0.003	0.694	1.160	-0.003	-0.757	1.032	0.009	1.935	1.678
Residential	-0.302	-6.066	1.670	-0.310	-6.160	1.689	-0.277	-5.534	1.710
Hotel	0.149	1.565	1.097	0.136	1.421	1.100	0.133	1.398	1.103
Other	-0.583	-1.592	1.017	-0.626	-1.697	1.018	-0.558	-1.527	1.019
Mixed	-0.025	-0.500	1.324	-0.034	-0.655	1.345	-0.036	-0.712	1.332
Office	-	-	-	-	-	-	-	-	-
Steel	0.110	1.138	1.202	0.081	0.819	1.228	0.130	1.337	1.210
Composite	0.222	4.391	1.376	0.204	4.023	1.366	0.229	4.497	1.412
Mixed	0.343	3.433	1.070	0.358	3.553	1.075	0.290	2.887	1.090
Precast	-0.152	-0.338	1.020	-0.262	-0.580	1.018	-0.101	-0.224	1.028
Concrete	-	-	-	-	-	-	-	-	-
Observations	1141			1141			1141		
Fixed effect	No			Time (Decade)			Space (Regions)		
R^2/Adjusted R^2	0.136/0.125			0.128/0.115			0.147/0.133		
F-value	12.623			9.718			37.216		

Figure 4.17 Models 3.1-3.3 with vanity height as dependent variable

In general terms, all examined models show low R^2 values. Significant contribution to the significance of the models had the application of the space fixed effect for regional level. This means that vanity height is affected by the effect of the location, as similarly proved in the previous subsection. There is only one region, being significant and with a positive effect on vanity height, with a coefficient of +0.300, and this is Middle East. The use of composite and mixed materials also favors substantially the value of vanity height, while buildings of residential type appear to decrease the existence of vanity height, while hotels are linked with vanity height. Economic and demographic variables show trivial influence on vanity height, as well as time progression.

4.3.5 Supplementary findings including interactions between variables

Based on the previously performed analysis and models, certain connections and suggestions among variables have occurred. A more targeted investigation for certain of them follows in this sub-section, supported by the respective explanation.

As proved, the residential type of building use is quite significant and influential upon architectural height. Theoretical findings suggest that residential tall buildings are needed due to the demand for increasing populations and high urbanization rates (Ali & Al-Kodmany, 2012; Barr, 2012). Since population size and urbanization rate turned insignificant in the majority of the models, this interactive relationship could not be tested. Therefore, two additional interactions are created, with the use of the cross products of population size and urbanization size with the variable of building use, respectively. These findings, with their significance and coefficients are presented in the Table 4.18 below, in two isolated models with architectural height as the dependent variable.

Model 4.1	Unstandardized Coefficients				Model 4.2	Unstandardized Coefficients			
	B	Std. Error	t	Sig.		B	Std. Error	t	Sig.
(Constant)	5.260	0.033	160.536	0.000	(Constant)	5.263	0.012	451.577	0.000
LN Population size * Office Use	0.003	0.002	1.513	0.130	Urbanization rate * Office Use	**0.001**	0.000	**2.998**	**0.003**
LN Population size * Residential Use	**-0.003**	0.002	**-1.980**	**0.048**	Urbanization rate * Residential Use	**-0.001**	0.000	**-4.453**	**0.000**
LN Population size * Hotel Use	0.000	0.002	-0.087	0.931	Urbanization rate * Hotel Use	0.000	0.000	0.671	0.502
LN Population size * Other Use	-0.004	0.004	-0.995	0.320	Urbanization rate * Other Use	-0.001	0.001	-1.171	0.242
LN Population size * Mixed Use	**0.006**	0.002	**3.372**	**0.001**	Urbanization rate * Mixed Use	**0.001**	0.000	**6.486**	**0.000**
a. Dependent Variable: LN Arch Height					a. Dependent Variable: LN Arch Height				

Figure 4.18 Models 4.1 and 4.2 including the interaction of building use with population size and urbanization rate, respectively.

As far as national population size is concerned, it is observed that it is solely significant when interlinked either with the residential or with the mixed type building use. This finding enhances the suggestion that population size is linked with the residential needs of a location in terms of function. In addition to this, around 40% of the mixed type buildings examined serve partially residential functions. From the qualitative perspective, strictly residential buildings push heights lower, while mixed type enjoy larger heights. The existence itself of a tall building turns out to be sufficient to satisfy the need for increasing populations, while tall building of mixed functions can be associated with other reasons, such as causing sensation, apart from accommodating diverse functions. Comparatively, the influence of mixed buildings on height is double than residential, yet low in magnitude.

Regarding urbanization rate at country level, the findings showcase similarities with the population size. The interconnection of urbanization rate with residential and mixed type provides again statistically significant results, having the same signs for coefficients as in Model 4.1. The magnitude of impact is equal for this case, though. Different from the results with population size, the impact of the interaction of urbanization with office use is also contributing positively to height. This indicates that taller office buildings are existent in locations with high urbanization rates, where people are concentrated, and agglomeration economies are developed.

The economic indicator of Foreign Direct Investments (FDI) also ended up not to be impacting architectural height in the majority of the models. Thus, its impact interacted with time effect and space effect is briefly examined at this point. The two corresponding models are presented in Figure 4.19 below.

Model 4.3	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	5.228	0.027	194.021	0.000
FDI*TIME (1970-80)	-7.380E-05	0.002	-0.042	0.966
FDI*TIME (1980-90)	0.001	0.001	0.858	0.391
FDI*TIME (1990-00)	0.001	0.001	0.606	0.545
FDI*TIME (2000-10)	0.000	0.001	-0.429	0.668
FDI*TIME (2010-20)	**0.003**	0.001	2.668	**0.008**
a. Dependent Variable: LN Arch Height				

Model 4.4	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	5.210	0.029	182.604	0.000
FDI*REGION (Central America)	0.003	0.002	1.577	0.115
FDI*REGION (North America)	0.001	0.001	1.119	0.263
FDI*REGION (South America)	-0.003	0.002	-1.928	0.054
FDI*REGION (Africa)	-0.002	0.003	-0.512	0.609
FDI*REGION (Europe)	0.001	0.001	0.372	0.710
FDI*REGION (Middle East)	**0.005**	0.001	3.804	**0.000**
FDI*REGION (Oceania)	0.001	0.002	0.949	0.343
FDI*REGION (China only)	**0.004**	0.001	3.086	**0.002**
FDI*REGION (Rest of Asia)	0.002	0.001	1.182	0.237
a. Dependent Variable: LN Arch Height				

Figure 4.19 Models 4.3 and 4.4 including the interaction of FDI with time(decade) and space(regions), respectively.

Again poor results occur regarding the impact of FDI on height. In terms of its interconnected impact with time, a positive, yet low influence, is detected only for buildings constructed in the last decade, from 2010 to 2019. Interlinked with location, in particular region, FDI impacts height positively for the cases of Middle East and China, in almost equal terms. Regarding Middle East, the need for external funding for such costly structures is reasonable, since its GDP level is low as described in section 4.1.6, with certain exceptions for countries. An interesting fact is that FDI is contributing to height for tall buildings in Asia, but not for the rest of the Asian countries combined.

The combined effect of urbanization rate and population with time and space effects are also examined, as they both ended up insignificant in the main models of the analysis. Population size in all combinations turned out insignificant again. However, the findings for the interaction of urbanization rate with time and space are presented in the Figure 4.20 below.

Model 4.5	Unstandardized Coefficients			
	B	Std. Error	t	Sig.
(Constant)	5.259	0.012	440.534	0.000
Urbanization rate *TIME (1960-70)	-0.001	0.000	-1.319	0.187
Urbanization rate *TIME (1970-80)	0.000	0.000	-1.138	0.255
Urbanization rate *TIME (1980-90)	3.765E-06	0.000	0.013	0.990
Urbanization rate *TIME (1990-00)	4.157E-05	0.000	0.142	0.887
Urbanization rate *TIME (2000-10)	**-0.001**	0.000	-3.366	**0.001**
Urbanization rate *TIME (2010-20)	**0.001**	0.000	3.208	**0.001**
a. Dependent Variable: LN Arch Height				

Model 4.6	Unstandardized Coefficients			
	B	Std. Error	t	Sig.
(Constant)	5.210	0.029	182.604	0.000
Urbanization rate*REGION (Central America)	0.003	0.002	1.577	0.115
Urbanization rate*REGION (North America)	0.001	0.001	1.119	0.263
Urbanization rate*REGION (South America)	-0.003	0.002	-1.928	0.054
Urbanization rate*REGION (Africa)	-0.002	0.003	-0.512	0.609
Urbanization rate*REGION (Europe)	0.001	0.001	0.372	0.710
Urbanization rate*REGION (Middle East)	**0.005**	0.001	3.804	**0.000**
Urbanization rate*REGION (Oceania)	0.001	0.002	0.949	0.343
Urbanization rate*REGION (China only)	**0.004**	0.001	3.086	**0.002**
Urbanization rate*REGION (Rest of Asia)	0.002	0.001	1.182	0.237
a. Dependent Variable: LN Arch Height				

Figure 4.20 Models 4.5 and 4.6 including the interaction of urbanization rate with time(decade) and space(regions), respectively.

Regarding the combined effect of urbanization rate at country level with time, findings support their linkage with height for the two latest decades, 2000-09 and 2010-19. The urbanization rates of the first decade of 21st century impacted negatively the height of tall buildings, while the following decade this impact is reversed. Stronger impact appears in terms of regional effect for the locations of Middle East and China alone, both influencing height positively. Again, the findings for Asia are not on the same page as the rest of Asia.

4.3.6 Assessment of performance and remarks for independent variables

Variables of Population size and urbanization rate (country)

The variable of national population size turned out to be statistically insignificant for the majority of the regression models. As a result, its influence on the dependent variable of architectural height is deemed negligible. The models for which it occurred to be significant were characterized by the absence of space and time fixed effects, and its coefficient was negative, but low in value. Even when the supplementary analysis with interactions was performed, no impact was detected.

The case of urbanization rate variable is slightly better than population size. No solid influence on architectural height is proven, as it proved to be insignificant for most of the models examined as well. Moderate statistical significance appears in models excluding fixed effects, for which the coefficient was negative, yet low in value. Better results occurred from the supplementary analysis with the interactions. Small influence is proven when urbanization was interacted with residential and office use, for the locations of China and Middle East and in terms of time, for the last two decades.

Variable of GDP and FDI (country)

The variable of country GDP turned out to be statistically significant for the majority of the examined models. Negative coefficient, yet low impact was observed. The cases for which this variable was rendered redundant included the application of space fixed effects. It makes sense to have high correlation between these two variables, as they both characterize the location of the construction of a tall building.

The variable of FDI turned out to be statistically insignificant for most of the models. Therefore, no influence on architectural height is detected. The supplementary analysis with the interactions showed moderate impact on height for FDI, when combined with the regions of Middle East and China, and in terms of time effect, solely for the last decade.

Variable of Real interest rate (country)

The variable of country real interest rate proved significant in almost all the models, similar to GDP. It showed negative coefficient, with low impact though. Compared to GDP, its impact was double on the dependent variable, still bearing in mind that this impact is low. Similar to GDP, an overlap with the space fixed effect was marked.

Variable of Amount of completions of the year

The variable of the amount of completions per year was statistically significant for most of the models, but with quite low impact and fluctuations in its coefficient sign. It was detected to be overlapping with the time fixed effect, signaling that only one of them is required to illustrate the impact of mostly increasing completions through time.

Variable of Building use and structural material

The variable of building use showed strong increase in the explanatory value of all models and substantial impact on height. This is the case for the following subcategories; residential, office and mixed type. The impact of these three were also enhanced with the interaction of them with the urbanization rate at country level. Urbanization with mixed and office type impacts positively height, while the interaction with residential type affects negatively. Compared to office purposes, height was linked negatively with residential type and positively with the mixed-use type.

The variable of selected structural material for tall buildings proved to have solid impact on the dependent variable of height. The use of composite materials showed high and positive impact on height, as well as steel and mixed material but these two to lesser extent, almost half the size.

Variable of Space and Time fixed effect

The space fixed effect was investigated in two dimensions; one at regional scale and one at country scale. It turned out that the country scale effect resulted in slightly higher explanatory power, but reduced the significance of all models substantially. Zooming into specific geographic regions, the location of Middle East has the strongest impact on height increase, followed by Asia, with less than half the impact. Regarding locations that impact the height negatively, Europe and South America are the ones. Between the two fixed effects examined, it is concluded that the impact of space is stronger on height compared to time.

The time fixed effect turned out to be significant and increasing the explanatory power of all models. It was basically observed that the periods of 2010-14 and 2014-19 impact the architectural height significantly.

Variable of Vanity Height

The variable of vanity height turned out to have the most significant impact on architectural height, both in explanatory power and statistically. However, this is a result of a smaller sample of observations, as already stated. Twice as strong impact resulted for buildings taller than 300 meters, in contrast to lower ones. Additionally, the regression models provided evidence that vanity height impacts more the buildings located in Middle East.

4.4 Comparison of findings with similar studies

A comparison of the findings of this research with findings of similar studies is discussed as follows. Attention should be pointed out on the fact that each study has its specific scope, and any deviating elements are mentioned to preserve clarity and completeness.

As far as height determination is concerned, no strong relationship between height and population size of a country is found based on the findings of this thesis. Certain previous studies have proved linkage between height and population size and others have not, yet with population being examined at country scale in all them. More specifically, height is associated positively with city population size for cities of North America (Barr, 2010, 2012, 2013), while for the cities of China no significant connection is detected in another study (Barr & Luo, 2016). The combination of these findings indicate that the size of a country's populations is not a consistent factor from a global viewpoint. Similarly, no correlation between height and urbanization rate at country level is found in this research, except for the region of Middle East and the country of China. In a study of global scope, Honorée et al. (2018) have included urbanization rate as a factor and suggest a positive relationship with height. However, their research included only the tallest building per country, fact that makes the data sample really small.

This research also proved no solid correlation between height and GDP at global level, while using variables at country level. However, there are studies that include GDP as an influential factor for height, but as far as GDP is concerned for a city indicator. Higher city level GDP has been suggested to drive height to an increase for cities of North America (Barr, 2012), for cities of China (Barr & Luo, 2016; Li & Wang, 2018), cities of South America (Garza & Lizieri, 2016), for office spaces in across regions (Barkham et al., 2017; Honorée et al., 2018; Rovelli, 2017). In a recent study for China, city GDP is suggested not to be significant for all examined cities, thus there are no solid grounds to extend the findings to country level (Chiang, 2019). It is evident that city GDP is connected with height, but this regards certain regions and cannot be generalized at global scale. The inconsistency most probably derives from the regions of Middle East and Europe, where country level GDP acts in an opposite way, negatively, compared to the rest of the regions. The impact of Foreign Investments (FDI) for a region is found to be rather low in this thesis, from a global perspective, with just limited influence for China and Middle East. Rovelli (2017) also suggests that FDI is a significant global factor for completions, but not for height. Closing with the economic factors, throughout this specific study, real interest rate at country level proves to be the strongest determinant for height. Low real interest rates are associated with an increase in height. This fact is supported by other relevant studies that suggest taller buildings when the levels of real interest rates are lower, with results regarding either globally or North America (Barr, 2012; Honorée et al., 2018).

The use of a tall buildings is proven to be highly contributing to its height. Positive relationship is found for mixed and office type, while negative is found for residential spaces. In similar findings, it is suggested that office buildings are linked with larger heights, especially when the economic situation is solid for the case of North America (Barr, 2012), and likewise for mixed type and offices globally (Rovelli, 2017). Regarding height competition, there are signs in the findings of this thesis to support the existence of this phenomenon throughout the years. However, due to the nature of the phenomenon, conclusions should be treated carefully. Findings relate to the presence of height competition in the region of Middle East with more confidence and in general terms it is associated with buildings of the height category above 300 meters. The latter finding is supported by similar results with the use of the variable height/floor, instead of vanity height (Rovelli, 2017). In other studies, evidence is found for interurban competition between New York and Chicago (Barr, 2012, 2013), while no signs are found for the region of China (Chiang, 2019). Regarding the amount of tall buildings across the world, the findings of the present research infer that completions are influenced by global economic indicators. This is also supported by another recent study with global scope for buildings taller than 200 meters, in which world level GDP and world level FDI affect positively the completions globally, and in particular the uses of office and mixed buildings (Rovelli, 2017). Additional studies focusing on individual cities have also connected the amount of tall buildings with local economic indicators. City GDP and employment levels have also been linked with impacting positively completions, but at city scale, regarding cities of North America (Barr, 2010) and China (Barr & Luo, 2016). Findings also indicate that increasing populations drive the development of tall buildings as well. This is also corroborated by relevant studies on the amount of tall buildings across different locations. For instance, this regards cities in North America (Barr, 2010) and China (Barr & Luo, 2016; Li & Wang, 2018) more specifically.

Taking the above comparative discussion into consideration, no striking irregularities are observed, based on the results of the analysis in this study. The effect of space is concluded to be dominant when considering tall buildings' height from a global point of view, and economic variables to be less significant. No strong correlations between height and economic indicators is also supported by the study of Rovelli, which is the most relevant one to this research based on its scope, which is global (Rovelli, 2017). The main inconsistencies between present findings and related literature derive from the nature of data, as the examined figures are at national level, while the majority of the rest of the studies have focused on individual locations, thus using variables for city level.

4.5 Summary of Chapter 4

In this chapter, the global distribution of tall buildings is elaborated with the use of informative graphs, tables and illustrations. The evolution through time of the amount and height of tall buildings are among the main findings. The duration of important phases of the buildings as projects is investigated as well. Correlations among the examined variables and relevant discussion are developed. The chapter closes with the presentation of the models produced throughout the regression analysis, accompanied by the relevant observations and comparison of findings against similar studies. The collective conclusions deriving from the phase of analysis are presented in Chapter 5 below.

5 Conclusions

The focus of the specific research is to provide an understanding of the drivers that determine the global development and height of tall buildings. Apart from its scientific relevance into expanding the current pool of research on tall buildings' development, this thesis has societal relevance. This is illustrated by the fact that tall buildings can be an efficient space provider for a constantly urbanized world. The main methodology employed concerns descriptive statistics, correlation and regression analysis, in order for the suggested drivers to be examined in terms of impact. The presentation of conclusions takes place in reverse order of the stated research questions. To begin with, the distribution of tall buildings is addressed per region.

The amount of tall buildings has increased drastically throughout the last 20 years. For every global geographic region, without exceptions, the number is rising especially for the decade of 2010 to 2019. The region of North America introduced the phenomenon of tall buildings, but since 1990 the trend has shifted to the region of Asia, and specifically China. Tall buildings are observed to be located in highly urbanized locations, and not to be spread out in uniformity across each country or region. In alignment with the amount, the average height of tall buildings globally is detected to have been increasing steadily, particularly for the regions of Middle East and Asia. Since 2010, five times more buildings over 300 meters have been completed, compared to the previous decade.

Since 2000, a shift towards residential and mixed-type function is identified, although tall buildings began as a building typology for business purposes, providing office spaces. This takes place in parallel with the increasing urbanization phase the world is experiencing. It is attributed to the excessive need for accommodating more people in limited space. Residential buildings are identified to being built for the practical reason of accommodating rising populations and linked with heights lower than 300 meters, whereas as heights grow the rest of types are dominant. In terms of building materials, concrete is most commonly used and composite materials are preferred for taller structures. These conclusions for both building use and material show consistency among regions.

From the construction management point of view, an important factor is the duration of construction works required for the completion of such a complex structure. In average terms, the reasonable duration for works is found to be 3.5 years. No significant deviations are observed depending on different geographic regions. Buildings with extreme heights require in average 1-2 years of additional works. A complementary size to construction duration is the time-period required between the project proposal and start of construction works. In this period, the final design phase, alterations and obtaining necessary permits is mainly included. The average duration for this period was identified to be 2 years. Unlikely to the duration of construction works, deviations are observed based on geographic regions. Building proposed in Europe required over 3 years for this preliminary stage before the start of construction, while Asia and Middle East appear to have expedited procedures, requiring 1 to 1.5 years in contrast. This is attributed to the more elaborate and demanding bureaucracy and regulations of European union.

Following, the conclusive remarks addressing the identification and impact of driving factors are elaborated, starting with the amount of completions and concluding with the height.

From a global perspective, the amount of tall buildings is driven positively by the global urbanization rate and world GDP level. Increasing world population size and Foreign Direct Investments also result in rising amount of completions, but to lesser extent compared to urbanization and GDP. Therefore, it is concluded that world level economic and demographic indicators determine the aspect of demand for tall buildings across the world.

The situation regarding the determination of height is not as straightforward as for the amount of them, which is directly linked positively with the world's economic growth. The height of tall buildings is heavily affected by the location in which they are based. The countries of Middle East show the tendency to build taller, compared to European and South American countries that have the lowest tall buildings. In numbers, the height of buildings located in Middle East are larger by 15% compared to Europe. As far as certain countries that stand out are concerned, UAE, Saudi Arabia and Malaysia host buildings approximately 10% taller compared to USA, while Brazil and United Kingdom construct 10% shorter buildings, again compared to USA.

Impact of similar size on height occurs depending on the function a building is designed to accommodate. Buildings that are characterized as mixed, in terms of functionality, impact the height of a building positively by 10%, while residential buildings affect by the same impact, yet negatively. Combined findings additionally suggest that national demographic factors, such as population size and urbanization rate, are interlinked with the need for residential type of buildings, as well as mixed, since half of them employ residential functions. The choice of building material is also highly associated with the height. Using composite materials, height can be increased by 16%. The effect of time progression is also significant for height. Heights of buildings completed the last two decades are by 10% taller.

In connection with the significance of location, the height of tall buildings is influenced by national economic indicators. The national GDP level and national real interest rate proved to affect height, but to lesser extent compared to location, use and material. Real interest rate has double the impact in contrast with GDP, but again it should be highlighted that the level of their impact is small. Both factors affect height increase negatively. Regarding GDP level, this is interpreted that extreme heights are not necessarily associated with regions and countries with high GDP levels. For instance, the region of Middle East has the 5^{th} lowest GDP among the examined regions, yet it hosts the most extreme heights. The negative impact of real interest rate is expected. It is reasonable for height to be larger when the real interest rate of a region or country is low. Low interest rates are linked with low cost of capital, boosting the activity in the construction sector, since borrowing money is cheaper.

No proof is found to connect height determination with national population size, while weak signs for the impact of urbanization rate and FDI are detected. In particular, the economic indicator of FDI showed to have a recent impact, only during the last 10 years, while previously its influence is irrelevant. In addition to this, its influence is not regarded as uniform at global scale, yet only limited to the individual locations of Middle East and China. Likewise, national urbanization rate is proved to be a recent driving factor, with significant impact on height after the year 2000 and particularly pertinent to the demographic situation of Middle East and China.

Less confident conclusions infer strong impact of vanity height on architectural height. The lower certainty derives from a smaller -by 3 times- data sample, compared to the previous conclusive arguments. Vanity height is used in this research to depict the presence of the phenomenon of height competition. It is indicated that vanity height impacts the determination of height stronger than any of the examined driving factors. The presence of height competition is additionally supported by the fact that the vanity height of buildings taller than 300 meters impacts height twice as much as lower buildings. In terms of regions, the impact of vanity height for buildings in Middle East is stronger compared to other regions, which coincides with the region hosting extreme heights. In terms of time effect, there is evidence that height competition is not a recent phenomenon, but always in existence, having a peak between 1980 and 1990, and a small decrease between 2000 and 2010.

Summing up the conclusions, the decision to develop a tall building is primarily location-based. Therefore, it is concluded that developers should take foremost into account the economic situation of a location, when considering a new construction. A solid prior consideration of the factors investigated in this thesis will lead to a more efficient design and capital allocation for all actors involved.

Limitations

A basic limitation encountered in this study regards the availability of data. It is evident that the factors of population, urbanization, amount of completions, GDP, FDI and real interest rate at national level are not sufficient to explain the determination of architectural height. This is supported by the empirical analysis resulted in low correlation coefficients R^2 of 20 to 40%. This means that approximately half of the variance of the dependent variable could be explained with the used independent variables. Certain variables that were intended to be researched, such as construction costs, land values, existence of land-use regulations and size of land area per city and country could not be collected or are not available. In addition to this, data for around 1000 out of 4800 buildings of the dataset could not be acquired concerning the structural material. Another point worthy of commentation is the approach of the factors depicting the characteristics and economic situation of the locations included. According to literature, the population size of a specific city is more indicative to the development of tall buildings, than the population size of the specific country. The same is suggested for economic indicators such as GDP. However, these economic indicators are rarely documented at a city scale and even if, only for large countries. Demographic data are most common at city scale, yet the documentation of them regards the recent years. This generalization of using country data instead of city data bears adequate fit, but not the optimal, that could be generated using the most accurate ones. Lastly, local cultural preferences can have an impact on height , but again there were no available data to illustrate this in order to be analysed.

Recommendation for further research

A suggestion for further research is to conduct a similar research including more variables, such as construction costs, city-related indicators or the number of local firms capable of undertaking such large-scale projects. More targeted studies on specific locations could be also encouraged, in order for more data to be acquired. Another suggestion could involve a focused research for the buildings of the last 20 years, when the boom took place. An alternative recommendation would be a study to examine cases, in which the construction was delayed or eventually aborted. Identifying the reasons for delay can at the same time generate drivers for development, possibly neglected. Complementary to this study, an investigation of whether local expert contractors are present in countries with abundance of tall buildings could generate interesting results. Limiting a study solely to the buildings with extreme heights, such as over 400 or 500 meters can potentially identify better the drivers pushing building higher. In general terms, studies focused on more narrow scopes could benefit the quality and collection of more precise data.

6 Reflection

In this reflection section of the report, the learnings achieved throughout this research process are briefly described and discussed.

Admittedly, I was quite indecisive regarding which specific area of research I would like to do my thesis on. I began with an unorthodox approach and instead of focusing on my areas of greater interest, I decided that I would enjoy better a topic of quantitative nature. The majority of my fellow students are involved in studies requiring analysis of interviews, questionnaires and case studies in a qualitative manner. After reading many past theses, I thought I would not enjoy a qualitative approach, and started the journey on the current topic. The main initial idea was to investigate the drivers that influence the development of tall buildings across the world. Starting with the stage of research proposal, the end-result of the thesis has not deviated. It is always good to set alternative directions in case obstacles occur in the process. Looking back, I conclude that the more settled and well-designed the kick-off report is, the sooner you can dive into the analysis part.

The phase of literature review was quite challenging for me. At first, it was easy to read and understand the conclusions and objectives of various papers and studies, but I could not comprehend much from the analysis and the results. My approach was to return for another reading or more, when the phase of my analysis starts. In retrospect, I could have devoted more time to understand the methodology of each study, before the prescribed stage of my analysis part. However, time constraints were present and reading multiple publications with empirical findings is already an arduous process. In retrospect, I realize that if had existing knowledge of how a regression analysis operates, my literature review could have been more precise. I feel it ended up being more discussive, than intended.

Next in order was the phase of data analysis. For the purposes of the thesis, certain data needed to be mined and collected from online databases. I really enjoyed this phase and I even remember looking for efficient ways for data mining during the Christmas holidays. The analysis phase was one of the most interesting parts of the whole process, especially once you fully grasp all the required elements. Interpreting the results was the most beneficial phase of the research for myself. Trying to link theory with results, and provide quality writing and solid conclusions is what challenged me more and improved my scientific approach. Perhaps coinciding the collection phase with some initial, preliminary analysis could have saved some time, for the sake of additional analyses.

An interesting flaw I detected in my thinking process concerned the handling of the data. Since I had several variables collected, I found myself trying to think of ways to include as many of them as possible, although they might not serve any purpose to the stated research questions. I realised that this was not the right direction, as following the set research path gives validity to the research. Regarding the overall analysis, I am happy to have worked with statistics, graphs and numbers.

To sum up, I will try to highlight my main learnings in this last paragraph. First of all, patience is a virtue. Quality writing is also important, as it is your way to present your research to others. An author should never take things for granted and should be as explanatory as possible. Listening to advice and having different perspectives is highly beneficial. Although the support from my supervisors was more than enough, it was quite stressful for me to work so much on my own and critically make decisions on the process of the research. An informative graph is not sufficient, it should be accompanied by quality verbiage. This phrase marks the most important lesson learnt of this thesis. Associating causes and effects and interpreting findings with relevant studies is a highly intensive process, yet tremendously beneficial. Never underestimate the time needed in the process, a thesis includes large workloads. I am an improved version of myself after the completion of this thesis and this involvement with statistics has set my appetite to dig deeper and perhaps take some programming courses. Be patient and be proactive is a moto I can use after completing this research.

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Appendices

Appendix I – Supportive material for Literature Study

In the following Table, the key elements of the publications of quantitative nature that are included in Section 2.3 are presented. The Table is in fact the full version of Table 2.3.

Author	Study area	Study period	Heights examined	Observa tions	Dependent variable	Independent/ Examined variables	Model	R^2 and information regarding lagging of variables
(Clark & Kingston, 1930)	Manhattan	1929-1930	-	-	-	-Construction costs -Land values -Rent prices	Cost-Benefit Analysis	
(Frenkel, 2007)	Tel Aviv, Israel	Until 2001	>27m	1506	-Amount of buildings	-Building use -District located within city -Income	Multinomial Logit Model/ Regression	
(Helsley & Strange, 2008)	-	-	-	-	-	-Height competition -Strategic interaction between developers	Game-theoretic model	
(Moon et al., 2010)	Seoul, South Korea	-	>100m	30	-Rent price	-Height -Gross building space -Number of households -Avg. surrounding heights -Years to completion -Uniqueness of appearance	Multiple Regression	
(Barr, 2010)	Manhattan	1895-2004	>100m	87-115	-Number of completions -Average height	**Building-related:** -Avg. (skyline) height -Avg. plot size	Regression /OLS	R2 = 0.44-0.99 for avg height R2 = 0.77-0.86 for completions *Variables lagged by 5 years from completion

						Economic-related: -Real construction costs index (national) -Inflation, GDP deflator % (national) -Value of real estate loans (national) -F.I.RE/total employment (national) -Real interest rate (national) -Avg. daily traded stock volume -Population (city) -Dow Jones industrial index -City's economic volatility **Topical:** -Zoning regulations		
(Barr, 2012)	New York	1895-2004	>100m	86-458	-Height	**Building-related:** -Plot size & shape -Depth to bedrock -Distance to Central business core -Building use (residential, office, etc.) **Economic-related:** -Real interest rate -Real construction cost index -City population -National F.I.RE/ Employment -Equalized land assessed value **Topical:** -Zoning regulations -Floor Area Ration -Purchased air rights	Decision theory game/(Spatial) regressions	R2 = 0.38-0.42 for height *Variables lagged by 1 or 2 years from completion

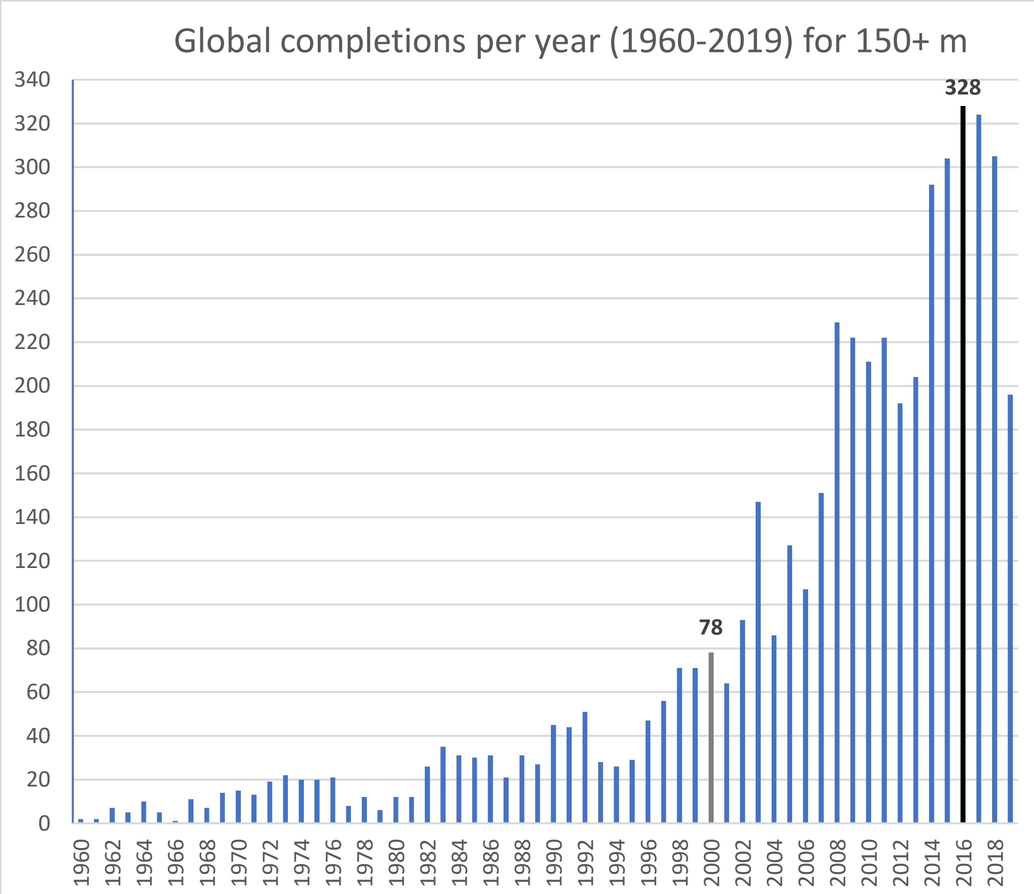
(Barr, 2013)	Chicago & New York	1885-2007	>80m (for Chicago buildings) >90m (for New York buildings)	113+113 for both cities	-Number of completions per city -Maximum height	**Building-related:** -Avg. Height -Avg. & max. plot size **Economic-related:** -GDP (national) -F.I.RE/ Employment rate (National) -Real material cost index (national) -Real estate loans (national) -Real interest rate (national) -Population size (city) -NYSE/CSE stock volume **Topical:** -Zoning regulations	Regressions	R2 = 0.67-0.71 for Max. height R2 = 0.86-0.89 for completions *Variables lagged by 1-3 years from completion
(Barr et al., 2015)	USA, Canada, China, Hong Kong	1885-2009 (USA), 1922-2008 (Canada), 1972-2008 (China), 1950-2008 (Hong Kong)	Tallest completed per year			-Height -GDP	Vector AutoRegressions	
(Barr & Luo, 2016)	China	1970-2014	>183m	74 cities	-Annual completions -Max. height	-Height -Population -GCP (city GDP) -Government revenues -Government expenditures -Relative distance	(Spatial Autocorrelation) Regression	R2 = 0.51-0.56 for Max. height R2 = 0.57-0.62 for completions
(Garza & Lizieri, 2016)	Latin America (29 cities from 10 countries)	2000-2012	>65m	377	-Height	-Building use -District within city -completion date -GDP (national)	Regression / OLS	R2 = 0.37-0.63 for Height *Variables lagged by 2 years from completion

						-Area size (city) -UNESCO Global Heritage Site -Population -Urbanization -Business cycle -City Ranking (GaWC)		
(Barkham et al., 2017)	Global	2000-2015	>200m	(Office use only)	-Number of floors	-GDP -Income -Land area -CBD distance -Global connectivity	Regression	R2 = 0.67 for number of floors
(Rovelli, 2017)	Global	1909-2016 (building-related), 1960-2015 (GDP),1970-2015 (FDI), 2009-2017 (construction costs)	>200m	1694	-	**Building-related:** -Height -Number of floors -Building use -Material -Date of proposal -Date of completion **Economic-related:** -GDP growth -Real interest rate -FDI -Construction costs (residential or office) -City Ranking **Topical:** -Location (city, country)	Correlations	
(Ahlfeldt & McMillen, 2018)	Chicago	1870-2010	>17m	1737	-Land prices/values	-Height -Land use (commercial or residential) -Distance to CBD -Floor space/area (limited data) -Construction costs (limited data)	Spatial/ Micro-geographic analysis and correlations	R2 = 0.79-0.80 for land prices R2 = 0.32-0.49 for height

(Honorée et al., 2018)	Global/ 90 countries	Until 2008	Tallest building per country	90	-Height	**Cultural (Hoftstede's dimensions):** -Power Distance -Individualism -Uncertainty Avoidance -Masculinity **Building-related:** -Height -Building use **Economic-related:** -GDP growth -Real interest rate **Topical:** -Urbanization rate -Located in capital city	Regression	R^2 = 0.35 for Height *The average value of the economic variables was used in the models, for the timeframe between: [proposal year minus 1 year; completion year]
(Li & Wang, 2018)	China	2003-2015	>200m	722	-Cumulative Height per city	-Height -Population -Urbanization rate -GDP -FDI -Employment rate	Regression	R^2 = 0.18-0.56 for annual Cum. height
(Chiang, 2019)	China	1980-2018	>200m	620-807	-Height (Architectural, Occupied, Vanity)	**Building-related:** -Number of floors -Building use -Material -Type of finishing (roof) -Date of proposal -Date of start -Date of completion **Economic-related:** -GDP (city) -Industrial size **Topical:** -City size -Population -Population density -Government control -Completions	Regression	R^2 = 0.22-0.36 for Height R^2 = 0.86-0.89 for completions

Appendix II – Supportive material for Global distribution of tall buildings

- **Global completions per year:**



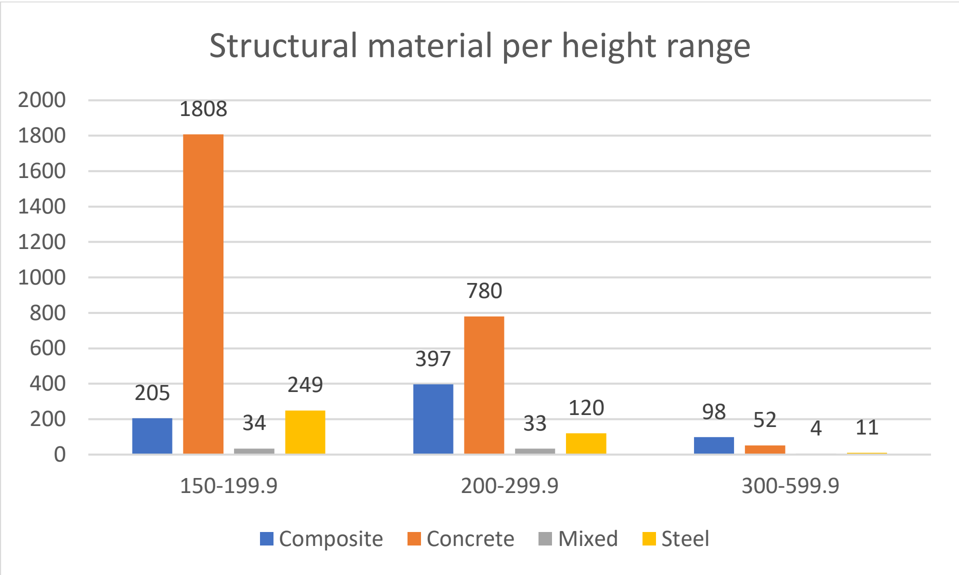
- **Completions per 5 years, divided in geographic region:**

	1960-64	**1965-69**	**1970-74**	**1975-79**	**1980-84**	**1985-89**	**1990-94**	**1995-99**	**2000-04**	**2005-09**	**2010-14**	**2015-19**	Sub-total
Africa	0	0	2	2	0	0	0	0	0	0	3	5	**12**
Asia	0	1	8	9	16	37	95	237	362	526	788	1056	**3135**
Central America	0	0	0	0	0	0	0	4	1	18	24	7	**54**
Europe	0	0	4	4	3	3	9	9	23	24	62	57	**198**
Middle East	0	0	0	0	0	0	1	4	21	130	131	86	**373**
North America	26	33	71	41	88	93	74	13	50	105	83	189	**866**
Oceania	0	1	1	7	3	7	15	5	8	20	15	30	**112**
South America	0	3	3	4	6	0	0	2	3	13	15	27	**76**
Subtotal	**26**	**38**	**89**	**67**	**116**	**140**	**194**	**274**	**468**	**836**	**1121**	**1457**	4826

- **Detailed distribution of building use per region**:

	Hotel	Mixed	Office	Other	Residential	Subtotal
Africa	**0**	**2**	**8**	**0**	**2**	12
Asia	**171**	**531**	**1212**	**22**	**1199**	3135
Central America	**1**	**5**	**7**	**0**	**41**	54
Europe	**6**	**42**	**86**	**0**	**64**	198
Middle East	**29**	**77**	**112**	**0**	**155**	373
North America	**28**	**123**	**447**	**4**	**264**	866
Oceania	**1**	**13**	**56**	**0**	**42**	112
South America	**3**	**10**	**25**	**1**	**37**	76
Subtotal	239	803	1953	27	1804	

- **Detailed distribution of structural material per height category and per region**:



	Africa	Asia	Central America	Europe	Middle East	North America	Oceania	South America
Composite	1	542	0	30	16	92	18	2
Concrete	11	1557	54	145	326	406	83	58
Mixed	0	31	0	1	16	23	1	1
Steel	0	149	0	8	0	221	2	0
Precast	0	14	0	0	1	0	0	0

- **Average construction duration per region and per decade:**

	1960-69	1970-79	1980-89	1990-99	2000-09	2010-19
Africa	-	6.00	-	-	-	4.28
Asia	3.00	3.60	3.13	3.13	3.36	3.90
Central America	-	-	-	2.00	2.67	4.21
Europe	-	3.83	5.20	3.01	3.59	4.16
Middle East	-	-	-	3.00	2.84	5.22
North America	2.75	3.92	2.56	2.35	2.62	3.43
Oceania	2.00	4.00	4.50	2.96	2.40	2.99
South America	7.67	3.88	6.25	3.50	2.17	4.14

- **Average duration from proposal to starting works, per region and per decade:**

	1960-69	1970-79	1980-89	1990-99	2000-09	2010-19
Africa	-	-	-	-	-	2.80
Asia	-	-	5.00	1.75	1.48	1.65
Central America	-	-	-	-	-	2.00
Europe	-	-	7.00	-	2.75	3.40
Middle East	-	-	-	1.00	1.18	1.55
North America	1.67	9.00	2.00	1.33	1.86	2.47
Oceania	-	3.00	-	-	4.00	2.51
South America	-	-	-	7.00	-	1.53

- **Average duration from proposal to completion, per region and per decade:**

	1960-69	1970-79	1980-89	1990-99	2000-09	2010-19
Africa	-	-	-	-	-	7.60
Asia	-	-	9.00	5.57	5.71	5.74
Central America	-	-	-	-	-	5.89
Europe	-	-	16.00	-	5.75	7.27
Middle East	-	-	-	6.00	4.45	6.41
North America	5.67	13.00	5.00	4.33	4.77	5.91
Oceania	-	8.00	-	-	7.50	5.49
South America	-	-	-	10.00	-	6.10

Appendix III- Supportive material for Regression Models

- **Models excluding the variable of Population size, with Architectural height as dependent variable:**

	Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height		
Variables	**Model P1**			**Model P2**			**Model P3**			**Model P4**			**Model P5**			**Model P6**		
	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF
Constant	5.4474	90.390	-	5.7516	85.295	-	4.4494	23.516	-	5.2323	67.430	-	5.5545	64.389	-	5.5029	49.401	
Amount of year's completions	0.0002	4.572	1.309	-0.0005	-6.209	6.221	-0.0001	-1.444	3.597	0.0001	2.599	1.635	-0.0005	-6.191	6.292	-	-	-
Population size (country)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Urbanization rate (country)	0.0001	0.542	1.075	0.0001	0.355	1.131	0.0002	0.261	22.593	0.00003	0.122	2.125	-0.0001	-0.461	2.232	0.00001	0.037	3.173
GDP (country)	-0.0101	-4.079	1.630	-0.0121	-4.878	1.691	0.0286	3.798	15.947	-0.0020	-0.663	2.555	-0.0054	-1.747	2.628	-0.0093	-2.391	4.178
FDI Net Inflows (country)	0.0021	1.721	1.497	0.0014	1.151	1.541	-0.0006	-0.455	1.897	0.0023	1.896	1.526	0.0018	1.469	1.598	0.0016	1.270	1.666
Real interest rate (country)	-0.0019	-2.628	1.011	-0.0027	-3.690	1.098	-0.0004	-0.482	1.678	-0.0006	-0.715	1.249	-0.0016	-1.946	1.374	-0.0010	-1.242	1.387
Residential	-0.062	-7.308	1.703	-0.062	-7.271	1.773	-0.061	-6.984	1.918	-0.063	-7.433	1.747	-0.061	-7.118	1.817	-0.060	-6.925	1.835
Hotel	-0.025	-1.483	1.102	-0.030	-1.766	1.107	-0.036	-2.120	1.140	-0.033	-1.969	1.108	-0.036	-2.181	1.112	-0.035	-2.118	1.112
Other	-0.120	-1.721	1.006	-0.111	-1.603	1.010	-0.088	-1.289	1.019	-0.120	-1.738	1.009	-0.104	-1.512	1.012	-0.104	-1.508	1.012
Mixed	0.069	7.015	1.323	0.064	6.543	1.344	0.067	6.892	1.383	0.066	6.791	1.327	0.063	6.498	1.347	0.064	6.591	1.347
Office	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Steel	0.031	2.258	1.348	0.040	2.836	1.425	0.065	4.489	1.555	0.032	2.323	1.397	0.037	2.586	1.485	0.042	2.918	1.507
Composite	0.164	16.985	1.366	0.162	16.964	1.372	0.166	17.036	1.457	0.162	16.618	1.413	0.160	16.593	1.429	0.159	16.346	1.436
Mixed	0.115	4.864	1.031	0.114	4.868	1.033	0.119	5.015	1.095	0.106	4.537	1.035	0.104	4.511	1.038	0.108	4.619	1.038
Precast	-0.034	-0.658	1.021	-0.021	-0.405	1.025	0.058	1.115	1.102	-0.038	-0.739	1.034	-0.019	-0.371	1.039	-0.019	-0.382	1.043
Concrete	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Observations	3703			3703			3703			3703			3703			3703		
Fixed effect	No			Time (5-year)			Space (Countries)			Space (Regions)			Time+Space (Regions)			Time+Space (Regions)		
R^2/Adjusted R^2	0.180/0.177			0.203/0.200			0.232/0.218			0.198/0.193			0.220/0.213			0.212/0.205		
F-value	62.226			42.745			15.949			45.325			35.646			34.013		

- **Models excluding the variable of GDP, with Architectural height as dependent variable:**

	Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height		
Variables	**Model G1**			**Model G2**			**Model G3**			**Model G4**			**Model G5**			**Model G6**			**Model G7**		
	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF
Constant	5.477	96.798	-	5.743	91.123		5.512	72.270	-	4.778	28.592		5.241	53.215		5.159	147.012		5.564	52.699	
Amount of year's completions	0.0002	4.125	1.242	-0.001	-6.353	6.200	-	-	-	0.00002	0.343	2.288	0.000	2.669	1.464	0.00010	2.547	1.412	-0.001	-6.330	6.257
Population size (country)	-0.0137	-5.030	2.748	-0.014	-5.252	2.867	-0.013	-5.474	2.228	0.01511	1.887	24.868	-0.004	-0.888	7.900	-	-	-	-0.008	-1.701	8.018
Urbanization rate (country)	-0.0008	-3.144	2.242	-0.001	-3.410	2.365	-0.001	-3.252	2.230	0.00203	3.132	15.915	-0.0002	-0.562	3.534	-0.00004	-0.161	2.741	-0.0004	-1.313	3.690
GDP (country)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FDI Net Inflows (country)	0.0024	2.027	1.446	0.001	1.218	1.506	-	-	-	-0.00034	-0.266	1.722	0.002	1.967	1.544	0.002	1.858	1.512	0.002	1.206	1.659
Real interest rate (country)	-0.0016	-2.319	1.016	-0.002	-3.338	1.099	-0.002	-2.874	1.094	-0.00018	-0.207	1.598	-0.001	-0.695	1.271	-0.001	-0.769	1.263	-0.001	-1.802	1.401
Residential	-0.062	-7.285	1.704	-0.062	-7.215	1.774	-0.062	-7.251	1.793	-0.062	-7.148	1.887	-0.063	-7.375	1.771	-0.064	-7.448	1.764	-0.060	-6.976	1.838
Hotel	-0.026	-1.507	1.102	-0.030	-1.766	1.107	-0.030	-1.825	1.104	-0.035	-2.107	1.121	-0.033	-1.972	1.108	-0.033	-1.975	1.108	-0.036	-2.169	1.112
Other	-0.118	-1.684	1.006	-0.108	-1.560	1.010	-0.112	-1.719	1.012	-0.088	-1.283	1.018	-0.120	-1.732	1.009	-0.121	-1.745	1.009	-0.102	-1.493	1.012
Mixed	0.069	7.050	1.322	0.064	6.573	1.344	0.064	6.574	1.339	0.069	7.106	1.359	0.066	6.805	1.327	0.066	6.768	1.324	0.063	6.508	1.348
Office	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Steel	0.034	2.495	1.347	0.040	2.865	1.417	0.040	2.963	1.636	0.060	4.192	1.536	0.033	2.382	1.410	0.031	2.258	1.363	0.037	2.599	1.494
Composite	0.166	17.214	1.369	0.163	17.057	1.375	0.162	16.988	1.381	0.166	17.135	1.446	0.162	16.638	1.417	0.162	16.622	1.408	0.159	16.454	1.429
Mixed	0.114	4.853	1.030	0.113	4.827	1.033	0.115	4.918	1.032	0.117	5.000	1.073	0.106	4.542	1.035	0.106	4.519	1.034	0.104	4.509	1.038
Precast	-0.028	-0.553	1.022	-0.017	-0.336	1.026	-0.030	-0.602	1.012	0.051	0.981	1.096	-0.036	-0.708	1.037	-0.040	-0.785	1.030	-0.017	-0.340	1.043
Concrete	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Observations	3703			3703			3789			3703			3703			3703			3703		
Fixed effect	No			Time (5-year)			Time (5-year)			Space (Countries)			Space (Regions)			Space (Regions)			Time+Space (Regions)		
R^2/Adjusted R^2	0.182/0.179			0.204/0.200			0.195/0.190			0.226/0.226			0.198/0.193			0.197/0.193			0.220/0.213		
F-value	63.035			42.960			41.385			25.436			43.194			45.137			34.447		

- **Models excluding the variable of Urbanization rate, with Architectural height as dependent variable:**

	Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height		
Variables	Model U1			Model U2			Model U3			Model U4			Model U5			Model U6		
	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF
Constant	5.430	90.263	-	5.740	84.830	-	5.618	86.285	-	4.610	26.152	-	5.211	51.056	-	5.599	49.825	-
Amount of year's completions	0.0002	4.115	1.374	-0.0005	-6.232	6.225	-	-	-	-0.0001	-1.418	3.417	0.000	2.235	1.865	-0.0005	-6.163	6.328
Population size (country)	-0.0042	-1.650	2.411	-0.0025	-0.976	2.522	-0.002	-0.818	2.521	-0.014	-1.455	35.128	-0.003	-0.555	8.919	-0.0004	-0.085	9.171
Urbanization rate (country)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GDP (country)	-0.0064	-1.919	2.985	-0.010	-2.946	3.112	-0.011	-3.370	3.097	0.031	4.292	14.746	-0.0002	-0.053	5.154	-0.0071	-1.593	5.590
FDI Net Inflows (country)	0.0023	1.855	1.492	0.0015	1.230	1.541	0.002	1.303	1.541	-0.001	-0.761	1.773	0.002	1.905	1.569	0.0016	1.259	1.665
Real interest rate (country)	-0.0018	-2.609	1.007	-0.0027	-3.686	1.091	-0.002	-3.265	1.086	0.000	-0.438	1.608	-0.001	-0.720	1.271	-0.0015	-1.808	1.399
Residential	-0.062	-7.298	1.704	-0.062	-7.259	1.773	-0.062	-7.207	1.773	-0.062	-7.114	1.886	-0.064	-7.397	1.772	-0.060	-6.990	1.837
Hotel	-0.025	-1.485	1.102	-0.030	-1.764	1.107	-0.029	-1.716	1.107	-0.036	-2.146	1.120	-0.033	-1.976	1.108	-0.036	-2.174	1.112
Other	-0.120	-1.720	1.006	-0.110	-1.598	1.010	-0.112	-1.609	1.010	-0.088	-1.279	1.018	-0.121	-1.749	1.008	-0.103	-1.501	1.012
Mixed	0.068	6.989	1.323	0.064	6.538	1.344	0.065	6.611	1.343	0.069	7.098	1.359	0.066	6.773	1.329	0.063	6.512	1.347
Office	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Steel	0.029	2.147	1.340	0.039	2.767	1.422	0.042	2.981	1.420	0.063	4.425	1.535	0.031	2.265	1.398	0.038	2.684	1.505
Composite	0.165	17.028	1.367	0.162	16.983	1.373	0.161	16.798	1.373	0.165	17.095	1.440	0.161	16.529	1.418	0.160	16.492	1.435
Mixed	0.113	4.788	1.032	0.113	4.824	1.034	0.115	4.923	1.034	0.116	4.953	1.073	0.106	4.518	1.036	0.105	4.530	1.038
Precast	-0.036	-0.693	1.019	-0.022	-0.424	1.023	-0.026	-0.512	1.023	0.057	1.096	1.098	-0.040	-0.774	1.034	-0.016	-0.315	1.040
Concrete	-	-	-	-	-	-				-	-	-	-	-	-	-	-	-
Observations	3703			3703			3703			3703			3703			3703		
Fixed effect	No			Time (5-year)			Time (5-year)			Space (Countries)			Space (Regions)			Time+Space (Regions)		
R^2/Adjusted R^2	0.180/0.177			0.204/0.199			0.195/0.191			0.228/0.219			0.198/0.193			0.220/0.213		
F-value	62.454			42.792			42.544			25.700			43.176			34.482		

- **Additional models, with Architectural height as dependent variable:**

	Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height			Dependent Variable: Ln Architectural Height		
Variables	Model a			Model b			Model c			Model d			Model e			Model f			Model g		
	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF	Coeff.	t-value	VIF
Constant	5.512	72.270	-	5.4911	73.425	-	5.2323	67.430	-	4.610	26.152	-	5.5029	49.401	-	5.3848	51.046	-	5.427	51.298	-
Amount of year's completions	-	-	-	-0.0005	-6.252	6.792	0.0001	2.599	1.635	-0.0001	-1.418	3.417	-	-	-	-0.0005	-6.196	6.868	-	-	-
Population size (country)	-0.013	-5.474	2.228	-	-	-	-	-	-	-0.014	-1.455	35.128	-	-	-	-	-	-	-	-	-
Urbanization rate (country)	-0.001	-3.252	2.230	-	-	-	0.00003	0.122	2.125	-	-	-	0.00001	0.037	3.173	-	-	-	-	-	-
GDP (country)	-	-	-	-0.0104	-4.871	1.289	-0.0020	-0.663	2.555	0.031	4.292	14.746	-0.0093	-2.391	4.178	-0.0064	-1.803	3.690	-0.008	-2.319	3.665
FDI Net Inflows (country)	-	-	-	-	-	-	0.0023	1.896	1.526	-0.001	-0.761	1.773	0.0016	1.270	1.666	-	-	-	-	-	-
Real interest rate (country)	-0.002	-2.874	1.094	-0.0026	-3.621	1.090	-0.0006	-0.715	1.249	0.000	-0.438	1.608	-0.0010	-1.242	1.387	-0.0014	-1.738	1.377	-0.001	-1.178	1.366
Residential	-0.062	-7.251	1.793	-0.0625	-7.3553	1.79161	-0.063	-7.433	1.747	-0.062	-7.114	1.886	-0.060	-6.925	1.835	-0.0606	-7.0828	1.8531	-0.0604	-7.015	1.8531
Hotel	-0.030	-1.825	1.104	-0.0312	-1.8815	1.10439	-0.033	-1.969	1.108	-0.036	-2.146	1.120	-0.035	-2.118	1.112	-0.0377	-2.2937	1.1093	-0.0369	-2.2359	1.1092
Other	-0.112	-1.719	1.012	-0.1134	-1.7472	1.0116	-0.120	-1.738	1.009	-0.088	-1.279	1.018	-0.104	-1.508	1.012	-0.1064	-1.6543	1.0132	-0.1071	-1.6568	1.0132
Mixed	0.064	6.574	1.339	0.06253	6.4908	1.33878	0.066	6.791	1.327	0.069	7.098	1.359	0.064	6.591	1.347	0.06185	6.471	1.3428	0.06293	6.5525	1.3424
Office	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Steel	0.040	2.963	1.636	0.038	2.841	1.612	0.032	2.323	1.397	0.063	4.425	1.535	0.042	2.918	1.507	0.036	2.598	1.728	0.039	2.823	1.725
Composite	0.162	16.988	1.381	0.162	17.103	1.378	0.162	16.618	1.413	0.165	17.095	1.440	0.159	16.346	1.436	0.160	16.810	1.414	0.160	16.661	1.414
Mixed	0.115	4.918	1.032	0.114	4.901	1.029	0.106	4.537	1.035	0.116	4.953	1.073	0.108	4.619	1.038	0.104	4.525	1.038	0.107	4.613	1.038
Precast	-0.030	-0.602	1.012	-0.027	-0.531	1.007	-0.038	-0.739	1.034	0.057	1.096	1.098	-0.019	-0.382	1.043	-0.021	-0.423	1.030	-0.025	-0.494	1.030
Concrete	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Observations	3789			3789			3703			3703			3703			3789			3789		
Fixed effect	Time (5-year)			Time (5-year)			Space (Regions)			Space (Countries)			Time+Space (Regions)			Time+Space (Regions)			Time+Space (Regions)		
R^2/Adjusted R^2	0.195/0.190			0.202/0.198			0.198/0.193			0.228/0.219			0.212/0.205			0.219/0.213			0.211/0.205		
F-value	41.385			43.447			45.325			25.700			34.013			35.097			34.639		

- **Full statistical Model 1.6:**

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.441[a]	.194	.190	.19429	.194	43.218	21	3768	.000

a. Predictors: (Constant), TIME DUMMY 2015-19, Material_Dummy_Precast, Use_Dummy_Other, Use_Dummy_Hotel, Material_Dummy_Mixed, TIME DUMMY 1975-79, TIME DUMMY 1965-69, TIME DUMMY 1970-74, TIME DUMMY 1980-84, TIME DUMMY 1985-89, TIME DUMMY 1990-94, Use_Dummy_Mixed, TIME DUMMY 1995-99, Material_Dummy_Composite, Real interest rate Lag-3, TIME DUMMY 2000-04, LN_GDP_COUNTRY, TIME DUMMY 2005-09, Material_Dummy_Steel, Use_Dummy_Residential, TIME DUMMY 2010-14

b. Dependent Variable: LN Arch Height

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	34.260	21	1.631	43.218	.000[b]
	Residual	142.238	3768	.038		
	Total	176.498	3789			

a. Dependent Variable: LN Arch Height

b. Predictors: (Constant), TIME DUMMY 2015-19, Material_Dummy_Precast, Use_Dummy_Other, Use_Dummy_Hotel, Material_Dummy_Mixed, TIME DUMMY 1975-79, TIME DUMMY 1965-69, TIME DUMMY 1970-74, TIME DUMMY 1980-84, TIME DUMMY 1985-89, TIME DUMMY 1990-94, Use_Dummy_Mixed, TIME DUMMY 1995-99, Material_Dummy_Composite, Real interest rate Lag-3, TIME DUMMY 2000-04, LN_GDP_COUNTRY, TIME DUMMY 2005-09, Material_Dummy_Steel, Use_Dummy_Residential, TIME DUMMY 2010-14

Coefficients[a]

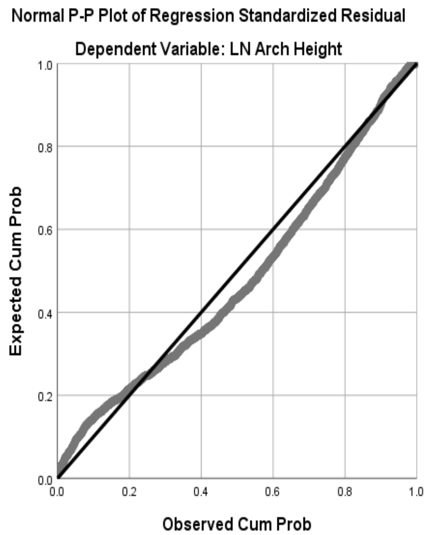
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	5.510	.075		73.375	.000					
	LN_GDP_COUNTRY	-.011	.002	-.088	-5.317	.000	.072	-.086	-.078	.780	1.283
	Real interest rate Lag-3	-.002	.001	-.049	-3.197	.001	-.054	-.052	-.047	.922	1.085
	Use_Dummy_Residential	-.062	.009	-.143	-7.301	.000	-.285	-.118	-.107	.558	1.792
	Use_Dummy_Hotel	-.030	.017	-.028	-1.831	.067	-.006	-.030	-.027	.906	1.104
	Use_Dummy_Other	-.114	.065	-.026	-1.752	.080	-.020	-.029	-.026	.989	1.012
	Use_Dummy_Mixed	.063	.010	.111	6.559	.000	.211	.106	.096	.747	1.338
	Material_Dummy_Steel	.041	.013	.056	3.031	.002	-.023	.049	.044	.621	1.611
	Material_Dummy_Composite	.161	.010	.291	16.923	.000	.342	.266	.247	.726	1.378
	Material_Dummy_Mixed	.116	.023	.074	4.989	.000	.064	.081	.073	.972	1.029
	Material_Dummy_Precast	-.032	.050	-.009	-.637	.524	-.024	-.010	-.009	.994	1.006
	TIME DUMMY 1965-69	-.035	.060	-.015	-.575	.565	-.027	-.009	-.008	.302	3.312
	TIME DUMMY 1970-74	-.008	.055	-.005	-.152	.879	-.023	-.002	-.002	.174	5.758
	TIME DUMMY 1975-79	-.039	.058	-.020	-.676	.499	-.024	-.011	-.010	.250	3.998
	TIME DUMMY 1980-84	-.002	.055	-.001	-.034	.973	-.026	-.001	.000	.171	5.862
	TIME DUMMY 1985-89	.032	.055	.021	.575	.566	-.002	.009	.008	.156	6.425
	TIME DUMMY 1990-94	.052	.054	.043	.968	.333	.002	.016	.014	.111	9.027
	TIME DUMMY 1995-99	.016	.053	.014	.304	.761	-.044	.005	.004	.100	9.991
	TIME DUMMY 2000-04	.041	.052	.054	.789	.430	-.069	.013	.012	.046	21.558
	TIME DUMMY 2005-09	.034	.052	.059	.653	.514	-.116	.011	.010	.026	38.197
	TIME DUMMY 2010-14	.076	.052	.153	1.477	.140	.022	.024	.022	.020	50.134
	TIME DUMMY 2015-19	.106	.052	.232	2.051	.040	.158	.033	.030	.017	59.817

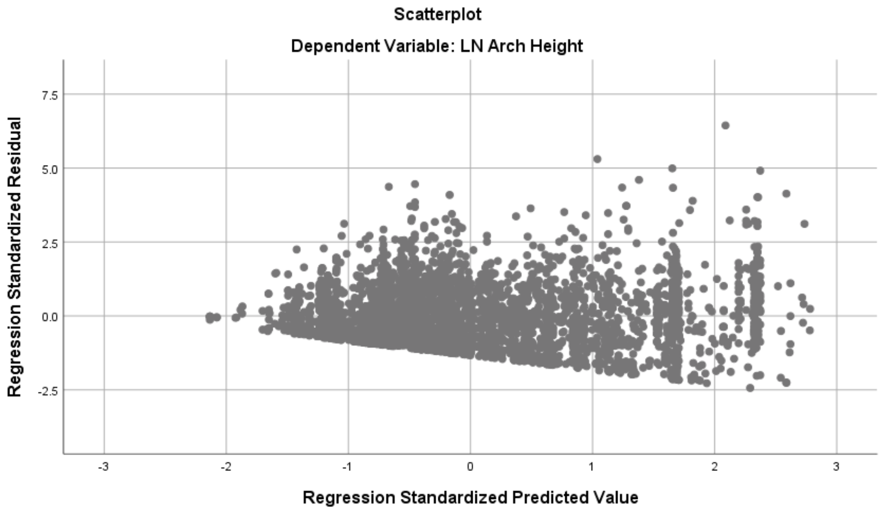
a. Dependent Variable: LN Arch Height

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	5.0659	5.5334	5.2689	.09509	3790
Residual	-.47346	1.25146	.00000	.19375	3790
Std. Predicted Value	-2.135	2.782	.000	1.000	3790
Std. Residual	-2.437	6.441	.000	.997	3790

a. Dependent Variable: LN Arch Height





- **Full statistical Model 1.7:**

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.443[a]	.197	.193	.19381	.197	54.464	17	3784	.000

a. Predictors: (Constant), Withoug China Asia Dummy, Material_Dummy_Mixed, Use_Dummy_Hotel, Africa_Dummy, Use_Dummy_Other, Year's completions, CentrAmerica_Dummy, SouthAmerica_Dummy, Material_Dummy_Precast, Oceania_Dummy, Europe_Dummy, Use_Dummy_Mixed, Material_Dummy_Composite, MiddleEast_Dummy, Material_Dummy_Steel, Use_Dummy_Residential, CHINA REGION DUMMY

b. Dependent Variable: LN Arch Height

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	34.779	17	2.046	54.464	.000[b]
	Residual	142.137	3784	.038		
	Total	176.916	3801			

a. Dependent Variable: LN Arch Height

b. Predictors: (Constant), Withoug China Asia Dummy, Material_Dummy_Mixed, Use_Dummy_Hotel, Africa_Dummy, Use_Dummy_Other, Year's completions, CentrAmerica_Dummy, SouthAmerica_Dummy, Material_Dummy_Precast, Oceania_Dummy, Europe_Dummy, Use_Dummy_Mixed, Material_Dummy_Composite, MiddleEast_Dummy, Material_Dummy_Steel, Use_Dummy_Residential, CHINA REGION DUMMY

Coefficients[a]

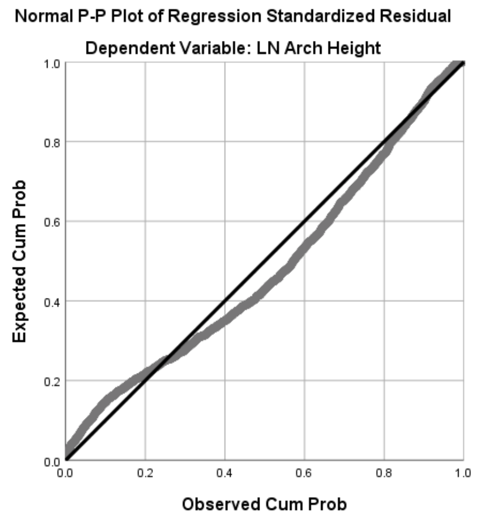
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	5.204	.011		461.000	.000					
	Use_Dummy_Residential	-.062	.008	-.143	-7.371	.000	-.283	-.119	-.107	.563	1.775
	Use_Dummy_Hotel	-.034	.017	-.032	-2.068	.039	-.007	-.034	-.030	.905	1.105
	Use_Dummy_Other	-.122	.065	-.027	-1.880	.060	-.020	-.031	-.027	.993	1.007
	Use_Dummy_Mixed	.066	.010	.116	6.917	.000	.212	.112	.101	.759	1.317
	Material_Dummy_Steel	.024	.013	.033	1.871	.061	-.027	.030	.027	.684	1.461
	Material_Dummy_Composite	.162	.009	.291	17.094	.000	.343	.268	.249	.732	1.366
	Material_Dummy_Mixed	.106	.023	.067	4.552	.000	.064	.074	.066	.969	1.033
	Material_Dummy_Precast	-.047	.050	-.014	-.940	.347	-.024	-.015	-.014	.987	1.014
	Year's completions	.000	.000	.059	3.578	.000	.107	.058	.052	.786	1.273
	CentrAmerica_Dummy	.084	.028	.046	3.051	.002	.002	.050	.044	.924	1.082
	SouthAmerica_Dummy	-.076	.026	-.044	-2.886	.004	-.077	-.047	-.042	.914	1.094
	Africa_Dummy	-.067	.057	-.017	-1.187	.235	-.024	-.019	-.017	.980	1.021
	Europe_Dummy	-.033	.016	-.032	-2.000	.046	-.053	-.032	-.029	.805	1.241
	MiddleEast_Dummy	.101	.013	.137	7.737	.000	.091	.125	.113	.675	1.482
	Oceania_Dummy	.005	.021	.004	.253	.800	-.020	.004	.004	.877	1.141
	CHINA REGION DUMMY	.024	.010	.053	2.480	.013	.104	.040	.036	.464	2.156
	Withoug China Asia Dummy	.021	.010	.041	2.078	.038	-.062	.034	.030	.544	1.837

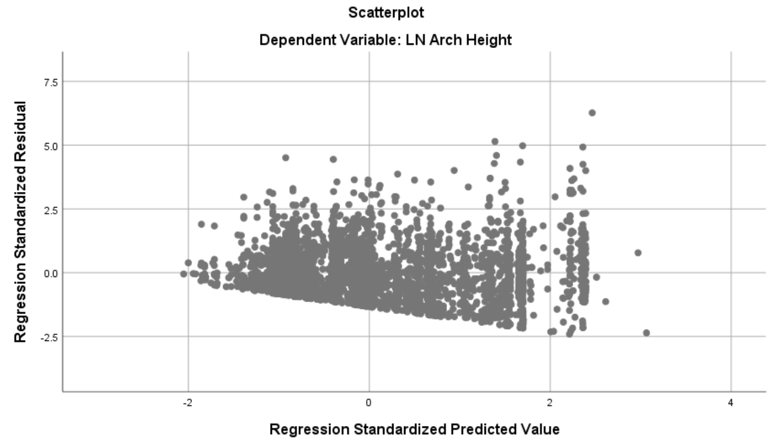
a. Dependent Variable: LN Arch Height

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	5.0723	5.5617	5.2685	.09566	3802
Residual	-.46693	1.21476	.00000	.19338	3802
Std. Predicted Value	-2.052	3.064	.000	1.000	3802
Std. Residual	-2.409	6.268	.000	.998	3802

a. Dependent Variable: LN Arch Height





- **Full statistical Model 1.7, altered with country fixed effect:**

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.472[a]	.223	.215	.19118	.223	28.351	38	3763	.000

a. Predictors: (Constant), KAZAKHSTAN, AZERBAIJAN, Use_Dummy_Residential, COUNTRY Singapore, UKRAINE, GEORGIA, South America WITHOUT Brazil, COUNTRY RUSSIA, COUNTRY Vietnam+Cambodia, ISRAEL, COUNTRIES OF AFRICA, Material_Dummy_Precast, COUNTRY Saudi Arabia, Use_Dummy_Other, COUNTRY TURKEY, UK, SWE, NL, ITALY AND SPAIN, COUNTRY Indonesia, COUNTRY CANADA, COUNTRY BRAZIL, KUWAIT, BAHRAIN, LEBANON, JORDAN, IRAN, IRAQ, COUNTRY Malaysia, COUNTRY QATAR, COUNTRY MEXICO, COUNTRY Australia and New Zealand, COUNTRY Philippines, PANAMA AND DOMINICAN REPUBLIC, DACH & POL & FRA & MONACO, COUNTRY THAILAND, COUNTRIES OF India, Sri Lanka, Bangladesh, COUNTRY UAE, Material_Dummy_Mixed, Year's completions, Use_Dummy_Hotel, COUNTRY SOUTH KOREA, COUNTRY JAPAN, Material_Dummy_Composite, Use_Dummy_Mixed, Material_Dummy_Steel, COUNTRY CHINA

b. Dependent Variable: LN Arch Height

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	39.377	38	1.036	28.351	.000[b]
	Residual	137.539	3763	.037		
	Total	176.916	3801			

a. Dependent Variable: LN Arch Height

b. Predictors: (Constant), KAZAKHSTAN, AZERBAIJAN, Use_Dummy_Residential, COUNTRY Singapore, UKRAINE, GEORGIA, South America WITHOUT Brazil, COUNTRY RUSSIA, COUNTRY Vietnam+Cambodia, ISRAEL, COUNTRIES OF AFRICA, Material_Dummy_Precast, COUNTRY Saudi Arabia, Use_Dummy_Other, COUNTRY TURKEY, UK, SWE, NL, ITALY AND SPAIN, COUNTRY Indonesia, COUNTRY CANADA, COUNTRY BRAZIL, KUWAIT, BAHRAIN, LEBANON, JORDAN, IRAN, IRAQ, COUNTRY Malaysia, COUNTRY QATAR, COUNTRY MEXICO, COUNTRY Australia and New Zealand, COUNTRY Philippines, PANAMA AND DOMINICAN REPUBLIC, DACH & POL & FRA & MONACO, COUNTRY THAILAND, COUNTRIES OF India, Sri Lanka, Bangladesh, COUNTRY UAE, Material_Dummy_Mixed, Year's completions, Use_Dummy_Hotel, COUNTRY SOUTH KOREA, COUNTRY JAPAN, Material_Dummy_Composite, Use_Dummy_Mixed, Material_Dummy_Steel, COUNTRY CHINA

Coefficients[a]

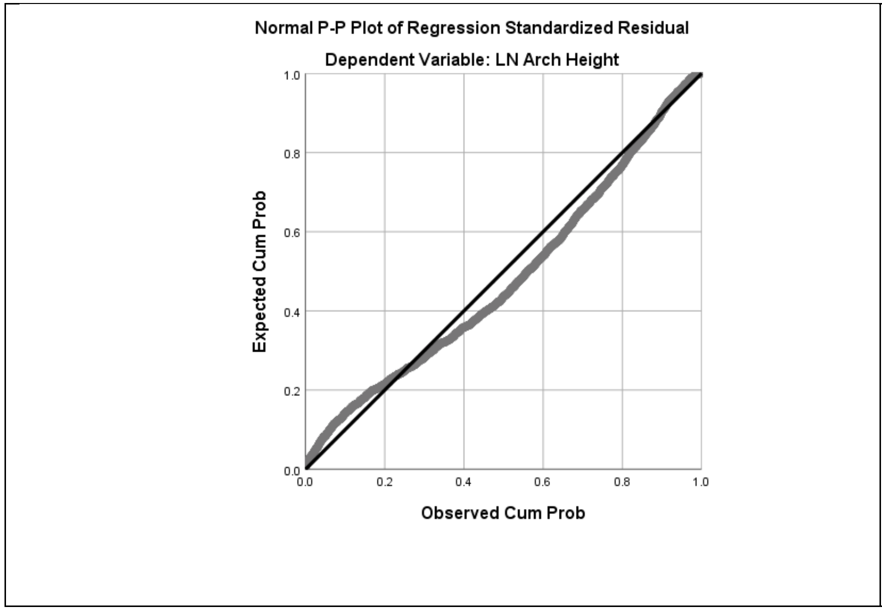
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	5.200	.012		439.667	.000					
	Use_Dummy_Residential	-.063	.009	-.145	-7.347	.000	-.283	-.119	-.106	.528	1.895
	Use_Dummy_Hotel	-.037	.016	-.034	-2.271	.023	-.007	-.037	-.033	.896	1.116
	Use_Dummy_Other	-.097	.064	-.022	-1.512	.131	-.020	-.025	-.022	.984	1.016
	Use_Dummy_Mixed	.070	.010	.122	7.285	.000	.212	.118	.105	.739	1.353
	Material_Dummy_Steel	.050	.013	.070	3.735	.000	-.027	.061	.054	.594	1.683
	Material_Dummy_Composite	.170	.010	.306	17.870	.000	.343	.280	.257	.703	1.423
	Material_Dummy_Mixed	.119	.023	.076	5.107	.000	.064	.083	.073	.933	1.071
	Material_Dummy_Precast	.039	.052	.011	.760	.447	-.024	.012	.011	.918	1.089
	Year's completions	.000	.000	.061	3.691	.000	.107	.060	.053	.758	1.320
	COUNTRY CANADA	-.008	.021	-.006	-.391	.696	-.030	-.006	-.006	.857	1.167
	COUNTRY MEXICO	-.086	.034	-.038	-2.532	.011	-.032	-.041	-.036	.936	1.068
	PANAMA AND DOMINICAN REPUBLIC	.090	.028	.050	3.285	.001	.002	.053	.047	.906	1.104
	COUNTRY BRAZIL	-.106	.036	-.043	-2.927	.003	-.072	-.048	-.042	.939	1.065
	South America WITHOUT Brazil	-.051	.034	-.022	-1.472	.141	-.041	-.024	-.021	.941	1.063
	COUNTRY TURKEY	-.035	.028	-.019	-1.265	.206	-.045	-.021	-.018	.892	1.121
	COUNTRY RUSSIA	.095	.032	.044	2.951	.003	.025	.048	.042	.930	1.075
	DACH & POL & FRA & MONACO	-.077	.028	-.041	-2.735	.006	-.048	-.045	-.039	.900	1.111
	UK, SWE, NL	-.137	.041	-.049	-3.353	.001	-.030	-.055	-.048	.962	1.040
	ITALY AND SPAIN	-.024	.050	-.007	-.484	.628	-.007	-.008	-.007	.970	1.031
	UKRAINE, GEORGIA	-.050	.111	-.006	-.447	.655	-.014	-.007	-.006	.993	1.007
	COUNTRY UAE	.126	.015	.144	8.289	.000	.085	.134	.119	.687	1.456
	COUNTRY QATAR	.038	.034	.017	1.113	.266	.015	.018	.016	.924	1.083
	COUNTRY Saudi Arabia	.123	.037	.050	3.341	.001	.045	.054	.048	.930	1.075
	ISRAEL	-.062	.047	-.019	-1.319	.187	-.029	-.021	-.019	.962	1.039
	KUWAIT, BAHRAIN, LEBANON, JORDAN, IRAN, IRAQ	.074	.035	.031	2.091	.037	.024	.034	.030	.932	1.072
	COUNTRIES OF AFRICA	-.065	.056	-.017	-1.152	.250	-.024	-.019	-.017	.974	1.027
	COUNTRY Australia and New Zealand	.007	.021	.005	.340	.734	-.020	.006	.005	.844	1.185
	COUNTRY CHINA	.023	.010	.052	2.257	.024	.104	.037	.032	.387	2.582
	COUNTRY JAPAN	-.080	.018	-.075	-4.510	.000	-.071	-.073	-.065	.743	1.346
	COUNTRY SOUTH KOREA	.042	.017	.042	2.484	.013	-.015	.040	.036	.735	1.361
	COUNTRY THAILAND	.045	.022	.032	2.032	.042	-.021	.033	.029	.850	1.176
	COUNTRY Indonesia	.032	.022	.023	1.436	.151	-.013	.023	.021	.839	1.193
	COUNTRY Malaysia	.113	.025	.070	4.561	.000	.043	.074	.066	.878	1.140
	COUNTRY Philippines	.047	.023	.031	2.024	.043	-.018	.033	.029	.863	1.158
	COUNTRY Singapore	.074	.027	.041	2.722	.007	.026	.044	.039	.908	1.101
	COUNTRIES OF India, Sri Lanka, Bangladesh	.009	.024	.006	.364	.716	-.050	.006	.005	.849	1.178
	COUNTRY Vietnam+Cambodia	-.004	.036	-.002	-.113	.910	-.009	-.002	-.002	.930	1.075
	KAZAKHSTAN, AZERBAIJAN	-.154	.073	-.031	-2.102	.036	-.025	-.034	-.030	.972	1.029

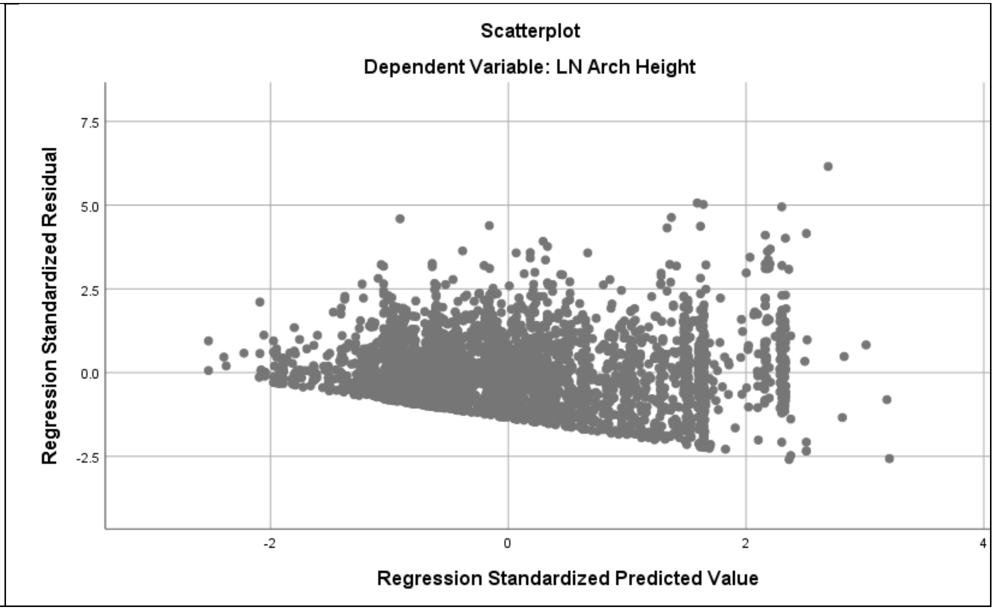
a. Dependent Variable: LN Arch Height

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	5.0119	5.5948	5.2685	.10178	3802
Residual	-.49567	1.17664	.00000	.19022	3802
Std. Predicted Value	-2.522	3.206	.000	1.000	3802
Std. Residual	-2.593	6.155	.000	.995	3802

a. Dependent Variable: LN Arch Height





- **Full statistical Model 2.4:**

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.642[a]	.412	.402	.20961	.412	43.892	18	1129	.000

a. Predictors: (Constant), Withoug China Asia Dummy, Use_Dummy_Other, Africa_Dummy, CentrAmerica_Dummy, Use_Dummy_Hotel, SouthAmerica_Dummy, Material_Dummy_Precast, Material_Dummy_Steel, Oceania_Dummy, Material_Dummy_Mixed, Europe_Dummy, Use_Dummy_Mixed, LN Vanity, MiddleEast_Dummy, Material_Dummy_Composite, Real interest rate Lag-3, Use_Dummy_Residential, CHINA REGION DUMMY

b. Dependent Variable: LN Arch Height

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	34.713	18	1.929	43.892	.000[b]
	Residual	49.606	1129	.044		
	Total	84.319	1147			

a. Dependent Variable: LN Arch Height

b. Predictors: (Constant), Withoug China Asia Dummy, Use_Dummy_Other, Africa_Dummy, CentrAmerica_Dummy, Use_Dummy_Hotel, SouthAmerica_Dummy, Material_Dummy_Precast, Material_Dummy_Steel, Oceania_Dummy, Material_Dummy_Mixed, Europe_Dummy, Use_Dummy_Mixed, LN Vanity, MiddleEast_Dummy, Material_Dummy_Composite, Real interest rate Lag-3, Use_Dummy_Residential, CHINA REGION DUMMY

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	4.749	.035		134.096	.000					
	LN Vanity	.176	.010	.437	17.869	.000	.518	.470	.408	.872	1.146
	Real interest rate Lag-3	-.004	.002	-.081	-2.716	.007	-.141	-.081	-.062	.592	1.689
	Use_Dummy_Residential	.001	.017	.002	.063	.950	-.302	.002	.001	.561	1.781
	Use_Dummy_Hotel	-.063	.032	-.047	-1.966	.050	-.013	-.058	-.045	.906	1.104
	Use_Dummy_Other	-.042	.122	-.008	-.345	.730	-.017	-.010	-.008	.980	1.020
	Use_Dummy_Mixed	.121	.017	.189	7.207	.000	.262	.210	.165	.761	1.315
	Material_Dummy_Steel	.092	.031	.072	2.969	.003	.049	.088	.068	.878	1.139
	Material_Dummy_Composite	.156	.017	.248	9.258	.000	.323	.266	.211	.725	1.379
	Material_Dummy_Mixed	.036	.034	.025	1.069	.285	.059	.032	.024	.920	1.087
	Material_Dummy_Precast	-.104	.150	-.016	-.696	.486	-.018	-.021	-.016	.985	1.016
	CentrAmerica_Dummy	.068	.081	.020	.848	.397	.002	.025	.019	.969	1.032
	SouthAmerica_Dummy	.033	.063	.016	.532	.595	-.104	.016	.012	.598	1.671
	Africa_Dummy	-.084	.095	-.020	-.883	.377	-.002	-.026	-.020	.976	1.024
	Europe_Dummy	-.077	.028	-.072	-2.765	.006	-.081	-.082	-.063	.777	1.288
	MiddleEast_Dummy	.146	.024	.169	6.100	.000	.215	.179	.139	.675	1.481
	Oceania_Dummy	.028	.036	.019	.791	.429	-.037	.024	.018	.872	1.147
	CHINA REGION DUMMY	.011	.018	.019	.610	.542	.092	.018	.014	.532	1.878
	Withoug China Asia Dummy	.019	.019	.028	.970	.332	-.092	.029	.022	.612	1.633

a. Dependent Variable: LN Arch Height

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	4.7468	6.0197	5.3593	.17397	1148
Residual	-.56500	.89171	.00000	.20796	1148
Std. Predicted Value	-3.521	3.796	.000	1.000	1148
Std. Residual	-2.695	4.254	.000	.992	1148

a. Dependent Variable: LN Arch Height