

# Trend analysis of modern high-rise construction

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**Abstract.** The article reviews the main trends of modern high-rise construction considered a number of architectural, engineering and technological, economic and image factors that have influenced the intensification of construction of high-rise buildings in the 21st century. The key factors of modern high-rise construction are identified, which are associated with an attractive image component for businessmen and politicians, with the ability to translate current views on architecture and innovations in construction technologies and the lobbying of relevant structures, as well as the opportunity to serve as an effective driver in the development of a complex of national economy sectors with the achievement of a multiplicative effect. The estimation of the priority nature of participation of foreign architectural bureaus in the design of super-high buildings in Russia at the present stage is given. The issue of economic expediency of construction of high-rise buildings, including those with only a residential function, has been investigated. The connection between the construction of skyscrapers as an important component of the image of cities in the marketing of places and territories, the connection of the availability of a high-rise center, the City, with the possibilities of attracting a "creative class" and the features of creating a large working space for specialists on the basis of territorial proximity and density of high-rise buildings.

## 1 Introduction

Over the past 17 years of the XX century, the number of super-high skyscrapers in the world has quadrupled. "Superhigh buildings" or "super-high skyscrapers" are commercial or multi-functional (having both business and residential zones and sometimes other function zones) structures with a height of more than 300 m. Their number in the world in 2017 increased to 126 compared to 111 in 2016 . [1].

First of all, high rates of construction of super-high buildings are currently characteristic of the dynamically developing economies of the APR and the "monarchies of the Gulf" (oil-rich Persian Gulf Arab countries), which demonstrate their growing economic power in high-rise buildings and, in many cases, attract local and foreign investors. The most active in the construction of super-high buildings in the last two decades are China, the United Arab

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Emirates, the United States, Hong Kong, Saudi Arabia, Russia, Great Britain, Taiwan, South Korea, France, Singapore, Australia and Indonesia [2-5].

In Russia, the first super-high commercial buildings (over 300 m) appeared in the 2010-s during the construction of the complex "Moscow City", in 2018-2020 will complete the construction of two extra-high buildings in St. Petersburg and Grozny. In addition to Moscow, St. Petersburg, Grozny and, probably, Ekaterinburg, construction of buildings of this height in other cities of Russia is not yet planned [6]. Therefore, despite the fact that for other cities in the country in 2000-2010-s in general, the tendency of growth of the height of the erected buildings is also typical, for the absolute majority of cases of high-altitude construction in Russia, the previously formed concept of a "high-rise building" remains relevant. In Russia and the countries of the USSR, "high-rise" are conventionally considered to be buildings taller than 75 meters or more than 25 floors [7].

In other countries of the world, high-rise buildings are considered, ranging from 35 to 100 meters. In many cities of Europe, Asia and Africa today, one of the tallest buildings remains bell towers and cathedrals / pagodas / other religious buildings built in the 19th century and earlier, for example, the Cologne Cathedral (height 157 m), the Peter and Paul Cathedral in St. Petersburg (height 122 m) and others.

According to CTBUH (Council on Tall Buildings and Urban Habitat), the world leader in skyscrapers continues to be New York, where now in the process of erecting 30 skyscrapers, and the skyscraper "Empire State Building" 443 m high remained the tallest building in the world for more than 40 years. However, the status of New York already in the 2020s. will be ready to challenge China's cities. In the last five years, 38 skyscrapers above 300 m have appeared in the People's Republic of China. In 2018, 18 super-skyscrapers will be added to them, and China's share will exceed half of the world's super-skyscrapers. Now it is 46 out of 100. Particularly impressive megaregion of the Pearl River Delta (PRD) area of approx. 40 thousand km<sup>2</sup>. This is the place where the Pearl River flows into the South China Sea and where the most densely populated and industrially developed urban area of the planet develops. In PRD there are such cities as Hong Kong, Guangzhou and Shenzhen and 20 of the hundred highest buildings. In addition to New York and PRD, the third most important region, actively developing high-rise construction, are the oil-rich Arab countries. In Dubai (UAE) is the highest skyscraper "Burj Khalifa" (828 m) and in the process of construction - 13 buildings with a height of at least 300 meters. In Mecca (Saudi Arabia), the third highest altitude at the end of 2017 from the completed skyscrapers in the world is the hotel for pilgrims "Clock Tower" (601 m).

Until the end of the 20th century, most European cities did not build tall buildings in order not to violate the historical architectural appearance (sky line). When high-rise blocks appeared in a number of capitals (the "D fense" in Paris in the 1990s, the "City" quarter in London in 2010), they were located on the outskirts of cities. The height of buildings in Europe for the first time exceeded 100 m only in the 1950s. unlike the United States, where it happened in 1913. The tallest buildings in Europe (except Russia) are in London (310 m), Paris (built 323 m), Madrid (296 m), Frankfurt (257 m), buildings higher 200 m are also available in Milan, Turin, Warsaw, Kiev, Istanbul. In addition to the Moscow skyscrapers, the highest skyscraper in Europe is the Shard London Bridge (2010), whose height is 310 m.

## **2 Methodological approaches and analysis**

The work deals with buildings used for offices, housing, hotels in various combinations, whose height exceeds 250-300 m, TV towers, radio masts and similar technical facilities were not considered. To analyze the driving factors of building super-high buildings at the present time and the interrelationships of the image of the city, the development of occupations attributed to the creative class with the presence of high-rise buildings,

qualitative methods of analytical research have been applied. In assessing the economic feasibility of building high-rise buildings, an empirical approach is applied based on information available to authors on the payback period of a number of high-rise buildings in St. Petersburg, which in most cases is classified as a trade secret.

It should be noted that some topical works of Russian authors are devoted to high-rise construction in general [8, 9], there is also a new work published in Voronezh devoted to risk assessment, including financial risks, in the implementation of high-rise construction projects [10]. In addition to these, the main provisions and conclusions of this article are based on a number of works by foreign authors [11-15] devoted to the architectural and technological, as well as the financial and image aspects of the construction of high-rise buildings, the CTBUH database was taken into account [16], the materials of urban planning meetings councils, hearings of professional public.

## **2.1 Architectural and technological plus image "imperatives" of high-rise construction, the possibility of achieving a multiplicative economic effect.**

It is often said that the main reason for high-rise construction in large cities, where it first appeared naturally, was the high cost of land in the center of the city, in the specific areas where concentrations of high-rise buildings began to arise. Because of the high cost of land, they tried to place the maximum possible number of useful areas (office, retail, residential), based only on existing technological and economic constraints. However, in addition to the deficit of specific land plots and areas in the city center (City), other factors play a role for modern high-rise construction:

A) The image component is the desire of the management of large corporations, the authorities to give a grandiose look to the period of their rule in the historical perspective, to form positive associations, and in the medium term to demonstrate the effectiveness and significance of their activities for both the local administrative and business community and the population, and for visitors of large national and international events, foreign tourists, representatives of the "creative class".

B) The ability to translate modern views on architecture by designers and innovative building technologies created by manufacturing companies. Well-known architectural bureaus together with the companies-producers are often lobbyists of high-rise construction. At the same time, the opponents of high-rise construction - especially in the territories of historic neighborhoods - are usually the local communities of conservative cultural workers and architects - "soil people". The latter seek to limit the height of all newly constructed buildings so that they do not conflict with existing architectural dominants, especially if they themselves do not belong to a company promoting a high-rise architectural project.

B) In the conditions of the "underheated" national economy - with signs of recession, slow growth - high-rise construction of such infrastructure can serve as an effective tool - a driver for the development of construction and a number of adjacent to the construction sectors of the national economy, which in turn, according to the views of Keynesians, institutionalists and a number of other schools of economic policy, is able to have a positive multiplier effect on the entire economic system.

Most high-rise buildings today are designed as multi-functional (with various classes of functional fire danger) and include office premises, residential premises (apartments, hotels), trade and even universities and hospitals.

Designers of most of the skyscrapers around the world are international companies, most of which are based in Great Britain and the United States. Could be mentioned the architectural bureau Skidmore, Owings & Merrill, Ilies and Morrison, Foster & Partners, Adrian Smith in partnership with the design bureau Thornton Tomasetti, Thom Mayne from Morphosis, which have implemented many projects around the world. To date, the "Anglo-

Saxon leadership in the architectural design of superheavy buildings" is recognized [17]. Russia is no exception, where foreign architectural bureaus are the designers of skyscrapers, while foreign companies also develop most constructive elements and parts of engineering systems of high-rise buildings, serve as contractors.

## **2.2 Construction features of high-rise buildings**

The structural system of a high-rise building is a combination of its vertical and horizontal bearing structures that together provide strength, rigidity and stability of the structure. The main priority in the design and construction of high-rise buildings is to ensure their strength and stability, as well as rigidity, taking into account the impact of significant wind forces, overcoming the uneven shortening of vertical structures from reinforced concrete (walls and columns) under the influence of load.

In high-rise construction, materials such as steel and concrete are mainly used. It is the use of strong steel frames, which was first used in the construction of the famous New York building "Fuller Flatiron" in 1902, dramatically increased the number of storeys compared to the stone. The rigidity of the "skeleton" of construction helps to withstand the wind loads, and flexibility - to resist seismic fluctuations. In the facades of skyscrapers today, mainly steel profiles and light curtain panels of transparent and darkened glass, aluminum, and polymers are used. Popular ventilated systems, which are finished with natural or artificial stone, metal sheets, fiber concrete, i.e. concrete with fibers of metal and polymers. Innovative facade constructions are designed to increase the strength and durability, the level of protection from fire and excessive heat in the premises (in addition to the air conditioning system with high insolation), the ability to compensate for changes in loads in the internal premises, even associated with the movement of furniture. Among the newest types of cladding - ceramics with borosilicate glass (which has in its composition alkali instead of boron oxide, which makes the glass resistant to fire), panels of metal foam, nanocomposites, glass panels with a water repellent self-cleaning layer and so on.

In the construction of high-rise buildings, special requirements are advanced to the supplied elevators, air conditioning and fire extinguishing systems, to other engineering systems. In some cases, special construction technologies are used, such as the "Top-Down" technology. In Russia, the technology "Top-Down" has found wide application (in St. Petersburg - Lakhta Center, as well as some facilities in the Moscow City complex). This is explained by the fact that this method allows almost simultaneously to work on the construction of the underground and ground parts of the building, which, accordingly, accelerates the construction period and the subsequent return on investment. It is also important to note that this method allows minimizing the deformations of the enclosing structures and, accordingly, the drafts of neighboring buildings. The method of construction "Top-Down" involves a device from the ground or from intermediate marks in the excavation of temporary or permanent supports inside the structure's contour, supporting the floors of the underground part of the building, which are concreted on the ground and perceive the action of the spacer from the excavation fence. The excavation work in the foundation pit is made from under the floors through the arranged technological openings. Concreting of underlying floors is carried out in sequence as the ground is removed. In the construction of the "Top-Down" technology to protect the excavation in modern conditions, the "wall in the ground" is often used, as the most versatile structure capable of absorbing vertical loads from the weight of underground floors and protection from groundwater [18, 19].

"Modular" (block) construction of high-rise buildings is also developing. Known examples are: a 30-story hotel "T30 Hotel" in Changsha, China, built in 15 days by the forces of 200 workers by technology of Broad Sustainable Building; "SOHO Apartments Darwin", 29 floors, Australia, 2014 (apartments); «Victoria Hall, Wolverhampton» 25 floors, United

Kingdom, 2009 (student hostel). Broad Sustainable Building in Changsha, China, implements a project of the construction of a super skyscraper Sky City with a height of 838 m in block technology, in early 2018 construction site preparation continues [20].

### **2.3 Economic feasibility of high-rise buildings**

The most attractive sites for the construction of residential and office areas in many European cities, including in the cities of Russia, are in the historical center, in which buildings, as a rule, developed in the XVII-XIX. On the contrary, in cities such as New York and Chicago, in the actively built cities of China and other Southeast Asian countries, in the actively expanding cities of the "oil monarchies" (UAE, Saudi Arabia, Qatar, Kuwait), which are currently being built and planned the construction of the largest number of skyscrapers, on the contrary, it is often the new high-rise buildings that form or form the business and cultural center of the city. The problems of destroying monuments of historical architecture or nature for building on-site skyscrapers in their cases did not arise or became public domain.

A complex dilemma of combining a possible high-rise center (City) with a historical one arises in front of cities with numerous preserved architectural monuments, forming a historical center, primarily in front of European cities. As part of the solution to this problem in Paris, the high-rise quarter of Defance (the height of buildings from 180 to 323 m) is moved to the east of the city. In Moscow and Yekaterinburg, the City managed to locate in relative proximity to the historical center, which significantly increases the attractiveness of new skyscrapers for investors. [21]

In London, a different approach is applied: in the historical center, separate high-rise buildings are being constructed (for example, Shard 310 m high at London Bridge, One-Canada 235 m and others). However, the attempt to go this way with St. Petersburg was unsuccessful: it was decided to move the construction site of the tallest building in Europe and Russia to Okhta under pressure from the public to the northwest of the city to the shoreline of the village of Lakhta ..

Lahta Center is being built since 2012 in an area with exceptionally modern buildings, which greatly simplified the problem of combining architectural solutions with existing facilities, gave greater freedom of creativity to architects and designers and an opportunity to improve the transport infrastructure in the skyscraper construction area.

At the same time, high-rise buildings on the outskirts of cities are much less attractive for tenants and tenants, which makes it necessary to solve the problem of economic feasibility of such buildings. It is likely that if the Lakhta Center project were implemented not by the largest national corporation of Russia but by a local developer, then the transfer of the location of the structure from the center to the outskirts in terms of project payback could be of critical importance. The cost of renting and selling a square meter of commercial real estate is 1.5-2 times lower in new districts of the city than in the historical center.

The construction of a high-rise building in terms of payback is always a risky project. Dozens of projects for the construction of super-high and high-rise buildings in Russia in the 2010s. were delayed or postponed (see section "Undelivered and unimplemented buildings" of the resource at wikipedia.org "List\_of\_most\_high\_Buildings\_in\_Russia"). In particular, in St. Petersburg, the local developer Adamant in 2007-2008 planned for the construction series of office and retail buildings with a height of more than 100 m including: Warsaw Prospect (Warsaw Railway Station), Pulkovskiy (Pulkovskoye Shosse), Ladozhsky (near the Ladozhskaya metro station), Balkansky (near the station metro station "Kupchino"). Sketches of these projects, developed by the architectural workshop "Freifeld-Sedakov", were presented in the investment memorandums of the company 2005-2008. However, the high payback period for high-rise office buildings (based on 12 to 20 years or more), as well as

the deterioration in the economic situation since 2008, forced Adamant to abandon these plans or implement significant less ambitious projects in existing areas.

In all cases, the most important problem remains with the transport accessibility of the area near high-rise buildings. If the transport and communal infrastructure needs to be created anew or radically reconstructed, the cost of the project may increase from 1.5 to 2.5 times. In this case, the payback period becomes the limit (50 years and more) and unattractive for investors. The current format of the multifunctional designation of super-high buildings (common everywhere except the United States and Hong Kong, where they continue to build only office skyscrapers) [22], allows the developer to sell part of the space as permanent housing, part of the office space, another part for the hotel, and in the lower floors to create an attractive shopping and entertainment center for the mass visitor.

High-rise housing construction should be considered separately. Implemented in Russia, high-rise residential projects in height do not reach office and multifunctional buildings, however, they are often huger by total area. High-rise residential construction has received a new development in St. Petersburg in 2000-2010-s with the appearance of 30-40 storey residential complexes in comparison with the record of a Soviet period 22 floors (residential buildings on Victory Square and on the Novosmolenskaya embankment). It should be noted that many experts do not see any sense in the mass erection of high-rise buildings, arguing that this has already formed the construction of cities and the availability of the opportunity to significantly expand suburban agglomeration areas due to low-rise construction [23, 24].

Most real estate developers are ready to deal with high-rise construction only with an eye to the long-term image effect. More expensive for high-rise residential buildings are both design and construction (due to complex foundation works, tougher fire regulations, increased requirements for the reliability of engineering systems), and home maintenance. "If you take two houses that are similar in terms of flatography and architecture, but different in height, the cost of a square meter for a building that is more than 75 meters tall will be 10-15% more than for a regular 25-storey building, argues director of RosStroyInvest Igor Kreslavsky. "The cost of a square meter for ultrahigh houses, from 100 meters, can increase by 50% or more because we have to use more expensive structural materials that can withstand wind loads, rent special construction equipment, etc.," the company's UNISTO Petrostal CEO Arseniy Vasilyev argues.

For high-rise construction, architects solve the problems of developing planning solutions that meet both fire and engineering standards, and are able to optimize the useful - subsequently sold or leased - area. This task is not easy, because in a skyscraper the specific area of stairs, elevators, corridors and technical rooms is higher than in typical structures. As a result, the profitability of high-rise residential projects, as a rule, is lower than "conventional" ones.

Such projects are realized for two reasons. Firstly, high-margin sales of apartments on the upper 5-7 floors (sales of "penthouses") are typical. If there are even symbolic differences from the lower floors of the building, apartments on the last floors can be sold with a coefficient of 1.2-1.5 or more from the standard price in the area for this type of housing. However, this rule works primarily for specific objects (water, historical center) and is of little use for buildings near industrial zones and within the sleeping areas. Secondly, the iconic skyscrapers are not only the "calling card" of the construction company, but also often of the district, the city, sometimes the country. In the market conditions - the construction of a unique high-rise building - a successful approach to "detuning" and differentiation among competitors.

## **2.4 Skyscrapers and image of cities**

It should be noted that according to the existing ideas about branding of cities ("marketing of places and territories"), the success of a city in a competitive environment depends on the ability to attract investment and professional staff ("creative class" - specialists creating technological and image leadership) to its territory, flows of tourists. The creative class is the decisive factor that determines the status and functional purpose of the territory. In such global financial and business, as well as tourist centers like New York, Hong Kong, Beijing, Shanghai, London, Paris, Frankfurt, Moscow, Delhi, Dubai, Mecca, Kuala Lumpur, Chicago, Melbourne, Guangzhou and Shenzhen and others in high-rise quarters are concentrated offices of banks and insurance companies, major construction contractors and architectural bureaus, leading media, designers, trade and manufacturing companies [25-27]. It can not be said that office skyscrapers are the only place for "placing" the creative class. In low-story Silicon Valley (USA), Dublin (Ireland), Mont-Pellier (France), Ideon (Sweden) or Skolkovo (Russia) and in other world innovation clusters characterized by low-rise buildings, there are enough specialists who are referred to as the "creative class". However, it can be argued that skyscrapers today provide a convenient way and environment for the concentration of highly skilled workers and the management of significant labor resources in a territorially confined space, as well as a comfortable living environment for wealthy people with interests within the city. The unique skyscrapers on the territory of the UAE and Saudi Arabia at the same time are more focused specifically on the residence function.

### 3 Results

The work states three main reasons for sufficient increase of super-skyscraper erection and high-rise construction in the beginning of XXI century. The image imperatives for authorities plus the possibility of achieving a multiplicative economic effect, the lobbyism by architectural and technological companies as well as huge contractors. The new format of super-skyscraper include not only offices but multiple functions. The predominance of Anglo-Saxon specialists in the design of super-high skyscrapers and high-rise structure continues, however, there appear more and more qualified specialists and architectural bureaus from Arab countries, Asia-Pacific countries, Russia and other countries.

In the most countries in XXI the functional purpose of the super high buildings being built began to differ from the traditional office one - the world's highest hotel for pilgrims in Mecca appeared, the apartments occupy the upper part of the highest skyscraper "Burj Khalifa". In the projected skyscrapers there are hospitals, educational institutions, the public area of the lower floors becomes larger and more significant. The architecture of the projected superhigh buildings is moving farther from the usual parallipeds and cylinders, becoming like a spiral, taking on other complex shapes.

### 4 Conclusion

In the paper, the following are considered consistently:

- architectural and technological and image "imperatives" of high-rise construction, the possibility of achieving a multiplicative economic effect by investing in high-rise construction;
- constructive features of construction of high-rise buildings that determine their modern appearance and provide opportunities to increase the altitude and reduce the scope of works at the facility;
- issues of economic feasibility of construction of high-rise buildings;
- the interrelation of the construction of skyscrapers with the provision of the growth of a positive image of cities within the framework of marketing of territories and attraction of representatives of the "creative class" to the cities.

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