Organizing vertical layout environments: a forward-looking development strategy for high-rise building projects

A.A. Magay[1], *E.A.* Bulgakova[2,3*], *S.A.* Zabelina[2,3]

[1]Institute for complex design of residential and public buildings
Dmitrov highway,house 9, building 3, Moscow,127434

[2]Moscow Information and Technological University
32 Volgogradsky Prospekt, building 11 , Moscow, Russian Federation, 109316

[3] Moscow Architecture and Construction Institute
32 Volgogradsky Prospekt, building 11 , Moscow, Russian Federation, 109316

Abstract. The article highlights issues surrounding development of high rise buildings. With the rapid increase of the global population there has been a trend for people to migrate into megacities and has caused the expansion of big city territories. This trend, coupled with the desire for a comfortable living environment, has resulted in numerous problems plaguing the megacity. This article proposes that a viable solution to the problems facing megacities is to create vertical layout environments. Potential options for creating vertical layout environments are set out below including the construction of buildings with atriums. Further, the article puts forth suggested spatial organization of the environment as well as optimal landscaping of high-rise buildings and constructions for the creation of vertical layout environments. Finally, the persuasive reasons for the adoption of vertical layout environments is that it will decrease the amount of developed urban areas, decrease traffic and increase environmental sustainability.

1 Introduction

Despite the variety of works devoted to residential high-rise buildings, there are no complex researches on the specifics of the formation of a vertical habitat with the development of terminology on this topic. For centuries, construction of buildings had a horizontal layout. First, there were caves altered for habitation. Then simple structures, that were constructed using the landscape features, such as leaning tree. Following this, building

* Corresponding author: traumeels@mail.ru

materials came into place and the first single-story buildings started to appear. With the invention of bricks (an artificial material), it became possible to construct building of three to five levels. If single-story buildings called for only a simple roof covering, multi-story buildings required floor slabs. To reach the second floor and higher, the stairway was invented - and that was the first step to introducing a vertical layout environment.

Increasing the height of buildings came with new issues, mainly involving construction. The issues included; defining the bearing, constructing protective structures, pumping water to the higher floors and developing water management, heating and lighting systems. These same problems were encountered with the appearance of taller buildings with between nine and sixteen floors. With buildings that had many levels, new challenges were encountered such as; ensuring water supply and transportation to the top floors, that required more advanced technology. Despite the increase in multi-level buildings, the general direction of urban and rural development was to remain following the horizontal layout. Following this trajectory, there would be an expansion in the occupation of more and more of the planet's territory [1].

2 Materials and Methods

Further expansion of vertical layout environments required special conditions, which arose at the end of 19th century in Chicago, USA, when massive fire destroyed most of the important strategic infrastructure of the city. After the fire, land speculators and various business owners started to rebuild the city, the price of land increased, which in turn caused the height of the buildings to increase too. Building developers began to favor multi-story houses that simultaneously used less land and achieved the required number of houses for residents.

In 1891, the tallest load-bearing brick building called "The Monadnock" was constructed, but it remains a sole example of this record-breaking height [2]. Without steel reinforcement, the walls of the first floor were 1.8 m thick, which naturally caused problems with lighting and inhibited the use of wide glazing. The problem was solved by specialists from the famous "Chicago School" of architecture, who implemented steel frames for high-rise buildings. This marked a revolutionary transition from load-bearing walls to steal frame construction of skyscrapers.

One of the pioneering ideologists of high-rise buildings was Louis Sullivan, who set out the architectural principle that "form follows function". Later, he divided the vertical space of skyscrapers into functional zones, stating that: "At first, a skyscraper needs an underground floor, where boiler rooms, power engines and other systems that supply resources for the building will be placed. Second, banks, shops and other institutions that require wide space, a lot of lighting, bright display cases and easy access from the street should be placed on the first floor. Third, the second floor should not have any less lighting or space than first floor, because it is easily accessible by stairway. Fourth, in between the second and the last floor, there should be numerous offices that may not differ in layout. Lastly, the top floor, just as the underground, should be technical and contain ventilation systems" [3]. Until recently, his division was applied by all architects. Modern architects implemented functions of the urban habitat such as: living place, work, trade, study, vacation and amusement. Yet with the change in the desired functions of the urban habitat, it became necessary to modify the concept of vertical zoning layouts with a new wider and forward-looking approach.

According to projections made by the United Nations Department of Social and Economic Affairs (UN DESA) and UN-HABITAT, 80% of people will be living in cities and the world's total population will reach nine billion by 2050, up from the current estimated population figure of 7.1 billion. This will result in the expansion of urban territories and an increase in population density, especially for existing large cities. Therefore, issues of vertical environment development for existing megacities becomes especially topical [4].

One of the major techniques used in creating vertically-oriented environmental layouts was the implementation of atriums that ensured the organization of multi-storey internal space with natural lighting and natural ventilation. A primary example of this technique is clearly seen in the construction of the Guggenheim Museum in New York City, USA. Implementation of an atrium into construction, besides creating a distinctive layout and composition (see Fig. 1a), works to organize traffic of visitors inside the space on the ramp, from top to bottom (see Fig. 1b).

a) b)

Fig. 1. The organization of vertical environment space in the Guggenheim Museum, New York City, USA.

Another noteworthy example is the experimental 16-story residential building with vertically composed public spaces was built in Tashkent, Uzbekistan. In this monolith construction, two buildings are connected at certain floors (2, 5, 8, 11 and 14) by traditional Uzbek open galleries [5]. Multi-story spaces were aimed to establish public zones for rest and residential interaction (see Fig. 2).

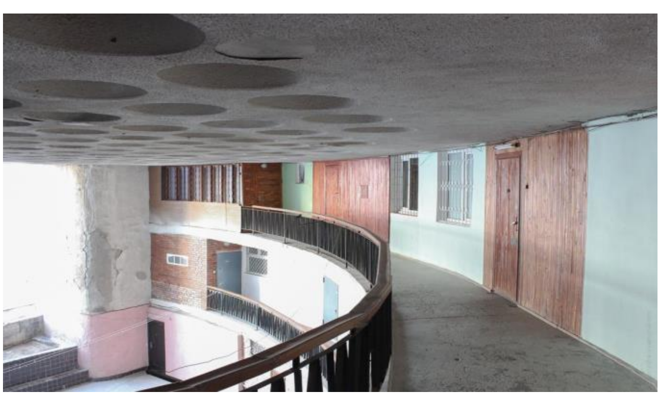

Fig. 2. Organization of public vertical space in the residential house. Tashkent, Uzbekistan.

The next step in the evolution of vertical environment layouts was the construction of Commerzbank in Frankfurt, Germany. Architect N. Foster designed an atrium that spread through the entire 260-meter building, and created additional open space with a 4-story winter garden, where light shines through internal windows into the building. Moreover, all of these spaces have natural ventilation because of the atrium construction.

At present, various designs and layouts are being developed and built, in which all kinds of human living activities could be efficiently carried out without leaving the building or complex. One common thread of all these current projects is that they implement vertical spaces. An example of this would be two residential towers "Bosco Verticale" (Vertical forest) in Milan, Italy, that represent possibilities of vertical environment layout for everyday living [6]. Specialists from "Boeri Studio" created a concept of space where high rise building are integrated with the greenery and landscape. This takes the shape of "Bosco Verticale" not only becoming a concrete building with potted plants on its sides, but a real forest with different species of bushes and trees intertwined. There are more than 800 trees, up to 5000 bushes and more than 10000 perennial plants and flowers in "Bosco Verticale" (see Fig. 3).

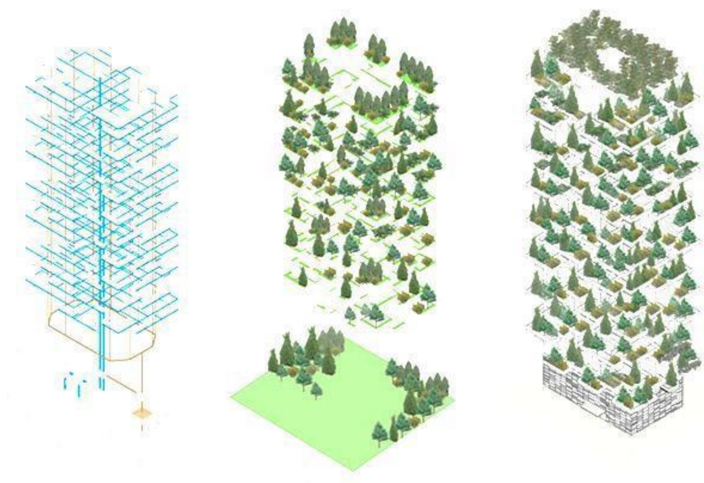

Fig. 3. Sustainable spatial landscaping of high rise residential building "Bosco Verticale", Milan, Italy.

There are also examples of modern high-rise office buildings with vertical environments. An example is the 330-meter tall "Chinese World Trade Tower III" skyscraper in Beijing, China [7]. In this multifunctional building there are hotels, offices, apartments, restaurants and different commercial spaces. The lower four floors are connected to the underground trade center, which expands the vertical environment for living activities. On the roof of the stylobate, there are pines growing with water cascades fitted into the green landscape. This building is a clear example of uniting the internal vertical space with the external urban environment.

A future project to construct a sustainable skyscraper with greenery and 26-stories of vertical space was recently proposed by Malaysian architect K. Young. The "EDITT Tower" skyscraper aims to bring living nature to the area of development that is currently lacking plants and vegetation. Architects are attracted to the visual effect of transitioning from a horizontally-oriented surrounding landscape to a vertical one, thus creating an organized vertical environment. A diverse vertical living environment can be attained by using wide open ramps that will connect higher floors with the first level.

A concept for a residential pyramid was designed for the Parisian exhibition complex of Porte de Versailles. It is suggested that a pyramid skyscraper will incorporate whole town districts with a full range of services for its inhabitants. There will be residential blocks, offices, restaurants and recreational areas [8].

A different take on the vertical layout is in the 196-floor skyscraper-city «Tokyo's Sky City 1000» project, developed by Japanese company "Mori". The skyscraper is divided into 14 platform sectors, each the size of a stadium, which can accommodate 35,000 people for living and further 100,000 for working. This city-skyscraper is designed to incorporate full-circle urban infrastructure and to satisfy all human needs including; accommodation, work and recreation. Being a full-fledged city, this skyscraper will help its inhabitants save a great amount of time. This is an especially pertinent factor considering that nowadays, most of Tokyo's citizens spend anywhere from two to four hours commuting [9]. Combining the hours spend commuting each day, in an average lifetime, commuting takes up six years.

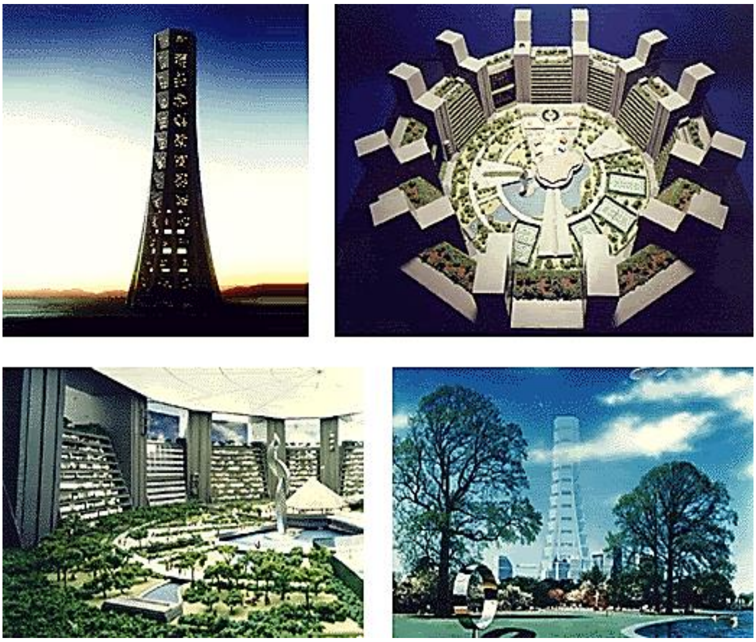

Fig. 4. Project for organizing an autonomous vertical city space in skyscraper. Tokyo, Japan.

Creators of the futuristic project "Endless City", went even further and developed an idea of turning a skyscraper into a true vertical sustainable system (see Fig. 4) [10]. It is designed as a multifunctional ramp tower that is surrounded by a gigantic atrium. Ramps represent streets and connect various horizontal spaces into one vertical body of green landscapes, shops, restaurants and promenades - all together forming a comprehensive vertical-horizontal system. The design of the building responds to the needs for natural ventilation and natural lighting, that are aimed at decreasing the tower's energy consumption. It is important to highlight that numerous floors of this construction will have the ability to transform according to needs. Further details stipulate ramp platforms serving as open parking lots and public spaces. Projects like this futuristic skyscraper actually shifts urban life from horizontal living space that is close to the ground into a vertical habitat that provide all necessary functions for human living [11,12]

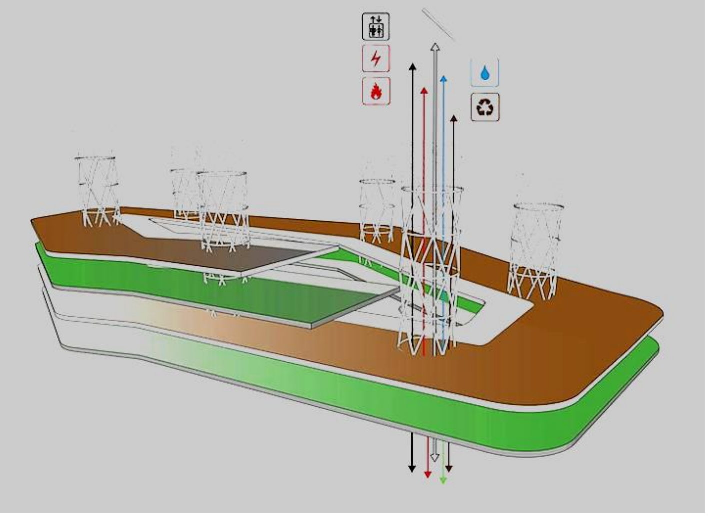

Fig. 5. Organization of vertical-horizontal living environment. Futuristic project.

World design experience shows that the main focus of high-rise building in the future is the creation of vertical cities [13, 15]. The projects are still in the nature of offers, but the main trend is aimed at providing everything necessary for a large number of people, which may live and work there; and at the same time envisage the use of solar and wind energy.

The mandatory consideration of environmental standards has revealed an actual perspective for creating intellectual self-sufficient and self-regulating houses [14]. The projects envisage the maximum use of natural daylight, reducing of energy consumption and reducing of solar overheating [16].

The best environmental direction is manifested in the (so-called) "green skyscrapers". The main feature of such constructions is that one-third of the total area of the high-rise building is allocated to gardens with live plants and a natural irrigation system, which forms a general view of the building [17,18]. The main idea is the effect, when the surrounding landscape turns from the horizontal plane into the vertical one.

Analysis of the submitted material makes possible to single out several trends of long-term development of the vertical habitat`s creation, including: the possibility of transformation in function and structure, the formation of multifunctional complexes, essentially "vertical cities" and an environmental component, that combines several functions in a vertical structure [19].

3 Results

As aforementioned, it could be argued that one of the most progressive directions for architecture and high-rise construction development is the organization of vertical layout environments. Different projects reviewed in this article let us define trends of development.

From buildings already existing, such as Guggenheim Museum and the 16-floor residential house, “Bosco Verticale”, to projects that are ready to be implemented, such as the “Chinese world trade tower III”, and the “EDITT Tower”. Additionally, conceptual projects such as a pyramid construction in Paris, and futuristic projects such “Tokyo’s Sky City 1000” and “Endless City” let us envisage what is to come [20].

4 Discussion

The theoretical basis for the study were the work of Y. Bocharov, A. Bokov and others. In the work on this topic were used the design materials of the Central Research and Design Institute for Residential Construction, where the questions of typology and social aspects of construction of high-rise buildings were analyzed in the works of A. Magay [5,6], T. Maklakova, A. Rubanenko, H. Saprykina, and others. Foreign researches of high-rise buildings, with the linkage of bioclimatic design, are associated with the works: K. Yang, Alexander, Masetti and others.

5 Conclusions

Design and engineering of buildings and constructions with vertical environment layouts will help to accomplish several tasks at once such as: improvement of ecology through introduction of greenery and vegetation in buildings, reduce the spread of megacities into wider territories, diminish traffic and commuting time and conserve energy consumed by shortening time spent travelling to services. Beyond the positives of implementing vertical layout environments, distinctive architecture of high-rise buildings and constructions may make the urban landscape more diverse and create new urban visual accents.

References

1. A. A. Magay, Architectural design of high rise building and complexes: Learning material, 248 (Moscow, ASV Publishing, 2015)
2. A. A. Magay, Modelling of functional structures in high rise buildings, *Housing construction*, **12**, 17-21 (2016)
3. A. A. Magay, Normative basis for high rise building in Russia, ed. Nikolaev S.V. *Housing construction*, **1(2)**, 3-6 (2016)
4. Skyscraper, Wikipedia — the free encyclopedia-2007. [Electronic resource]
5. A. A. Magay, High rise buildings as vertical integrated residential environment, *BST: bulletin for building technic,* **6**, 64-65 (2016)
6. A. A. Magay, Specificities of architectural typology of high rise buildings, *Architecture and construction in Russia*, **4**, 22-29 (2009)
7. B. Gaiboullaev, I. I. Tojiyev, Principles for projecting energy-active buildings, *Young Scientist,* **7**, 55-58 (2016)
8. http://www.membrana.ru/ particles/tag/151 (last accessed 2017.08.22)
9. E. A. Boulgakova, A. A. Savicheva, Modern trends in engineering of transport hubs in megapolis infrastructure, *Eurasian scientists union*, **4**, 155 (2015)

10. Y. G. Repin, Spatial city: theory and practise, Yuri Gavrilovich Repin, 267 (2009)
11. http://skyscrapernews.com (last accessed 2017.08.22)
12. S. V. Nikolaev, V. I. Travush, Y. A. Tabunshikov, Regulatory Framework of High-Rise Construction in Russia, *Housing construction*, **1-2**, 3-6 (2016)
13. A. A. Magay, V. S. Zyrianov, E. Y. Shalygina, Importance of Special Technical Conditions for Design of High-Rise Buildings *Housing construction,* **11**, 17-20 (2015)
14. A. A. Magay, Architectural and compositional features high-rise buildings, *Akademicheskij vestnik uralniiproekt RAASN*, **4**, 25-30 (2015)
15. G. P. Vasilyev, V. A. Leskov, N. V. Mitrofanova, V. F. Gornov, Technical solution for protection of heat pump evaporators against freezing the moisture condensedmatec web of conferences Cep, *"2015 International Conference on Mechanical Engineering and Electrical Systems, ICMES 2015"* (2016)
16. K. Yeang, Eco Skycrapers, 160 (Hong Kong, Images Pudlishing, 2007)
17. A. A. Magay, Prospects of development of the regulatory framework of high-rise construction in Russia, *Housing construction*, **12**, 3-6 (2016)
18. A. A. Magay, The peculiarities of architectural typology of high-rise buildings, *Architecture and construction of Russia*, **4**, 22-29 (2009)
19. N. A. Saprykina, Architecture on the edge integrated technologies, *Housing construction*, **7**, 14-16 (2003)
20. http://www.jbdesign.it/ (last accessed 2017.08.22)