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Housing in a Smart City

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Abstract. The main requirements for housing in a smart city are systematized. These requirements are the basis for building a system of notions necessary for the development of a “smart city” complete concept.

1. Introduction

The search for the ideal home has always excited people. Back in the IV century BC, Plato laid the foundations of the ancient concept of an ideal city in the dialogue “State”. This concept was based on the ideas about the most advanced models of human settlement. Later, Plato's ideas were developed in the works of architects, as well as theorists creating social utopias.

Today, this problem is becoming particularly important in connection with the development of the “smart city” concept.

Housing in a smart city can be viewed from different perspectives [1–24]. These works focus on various aspects of the smart city: creating a theory of the building as a unified energy system [1], developing carbon-free cities by constructing buildings with zero or close to zero energy consumption [2], digitalizing of the city [3–5], developing a new socio-technological paradigm of the city [6, 7], looking at the smart city in terms of architectural and urban planning qualities [8, 9], increasing the stability of the urban environment by improving human habitat's comfort [10–15], expanding the role of education in urban planning [16]. Renovation of residential buildings of the first mass series plays an important role in current conditions [17–19] with the use of energy-efficient, resource-saving, bio-positive structures, construction systems and technologies. A global challenge worldwide is to improve indoor air and environmental quality due to the rapid spread of new corona virus infection COVID-19 [20].

However, the system requirements for residential buildings in a smart city are currently not clearly stated. This makes it difficult to build a system of concepts necessary for the development of a holistic “smart city” concept.

The purpose of this research is to systematize housing requirements in a smart city.

2. Methods

The research uses science based methods of architectural design of buildings and structures on the basis of integrated approaches that cover social, functional and economic aspects of implemented design solutions. The study of the urban environment is based on the methodological foundations of urban



forecasting, planning and design. When evaluating the shape and design of buildings, climate aspects are taken into account, including various climate impacts, as well as climatological support of buildings. Assessment of buildings' thermal characteristics is based on the theory of heat and mass transfer in fences and modern methods for calculating energy savings in buildings. In developing requirements for housing, science-based methods have been widely used to create environmentally friendly, energy-efficient, resource-saving, and biopositive structures, construction systems and technologies, including urban life support systems.

3. Results and discussion

3.1. Polycentric city as an effective settlement model

Special attention should be paid to improving the settlement system. The structure of a monocentric city formed around a single urban center is not always stable. In such a megalopolis, there are risks of urban environment degradation due to the high cost of land, transport collapse, poor ecology, and regular virus epidemics.

A more effective settlement model is a polycentric city based on the existence of several interconnected urban centers. They can be located away from the historical center, including in the suburbs, complementing the old city center and competing with it. A specific feature of a polycentric city is the presence of several centers of attraction on its territory. This fundamentally distinguishes it from a monocentric city, within the borders of which a single center of attraction stands out. The spatial structure of a polycentric metropolis or agglomeration is determined by the mutually located attraction centers of different levels. This structure of centers complicates the configuration of flows of different nature (energy, substance, information), but provides a multi-functional and variable urban space consumption by residents (figures 1, 2).

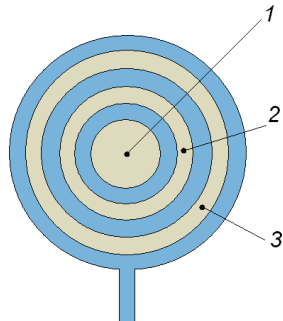


Figure 1. Plato's model of a city-state: 1 – philosophers; 2 – warriors; 3 – artisans and peasants.

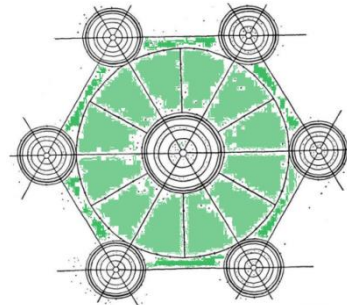


Figure 2. An ideal diagram of Howard's garden cities.

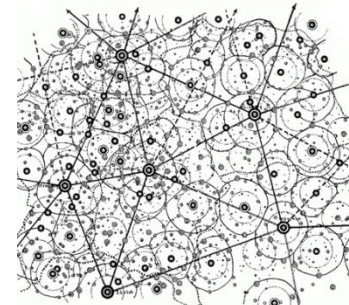


Figure 3. The Crystalline model.

Geographers have built a model that determines the optimal spatial distribution of economic activity centers – the Crystalline model (figure 3).

According to this model, large urban centers are located at the nodes of a hexagonal lattice. Each of the centers is surrounded by a ring of smaller cities; these, in turn, are surrounded by even smaller settlements gravitating towards them. It is clear that in reality such a correct hierarchical distribution is very rare: many historical, political, and geographical factors violate the spatial symmetry. The described static optimization model is a possible, but unlikely, outcome of evolution.

In a more advanced dynamic optimization model [2] the polycentric city model [2] the authors proceed from the hypothesis that the city has a number of interconnected social and business zones that can be located at a distance from the urban core. The new zones are functionally linked and evolve over time. The model allows one to determine the possible “history of urbanization” and trace the emergence of hierarchically ordered activity. The model shows that even if the initial state of the system is completely

homogeneous, the game of random factors alone is enough to break the symmetry – the appearance of zones with a high concentration of activity and a simultaneous decline in economic activity in other areas and the outflow of population from them. The system itself chooses scenarios for the development of events.

The development of a polycentric city aims at creating compact planning structures, which is very important for solving the global task of the green economy – energy conservation and energy efficiency.

3.2. Regulation of climate impacts is an important aspect of creating a comfortable energy-efficient environment

Vitruvius wrote in Ten Books on Architecture that “... when building houses, it is necessary ... to take into account the properties of certain countries and the differences in their climatic conditions”. In a properly designed building, climate control should always be ensured. This means that in such a building, the positive effects of the external climate on the energy balance of the building should be used in the best way and the negative effects should be neutralized. Being exposed to various climatic influences, the building envelope must provide the required thermal protection of premises, moisture protection, and have the necessary air-insulating properties.

The climate of most of the territory of our country is more severe and diverse than in other countries. This requires increased attention to the thermal protection of buildings in the cold season. But in hot areas, it is necessary to protect buildings from overheating due to solar radiation and provide artificial cooling of the premises during the warm season.

The building should have a compact shape and a high level of thermal protection. Area reduction of the building envelope can significantly decrease climate load on the building, reduce heat loss; cut material and technical resources (figure 4). In an ideal building there are no “bridges of cold”, which results in reduction of heat losses through the envelope by about 40%. To minimize infiltration heat loss, the building envelope must be airtight. At the same time, the required air exchange in the premises can be provided both by natural ventilation and by applying mechanical ventilation with heat recovery.

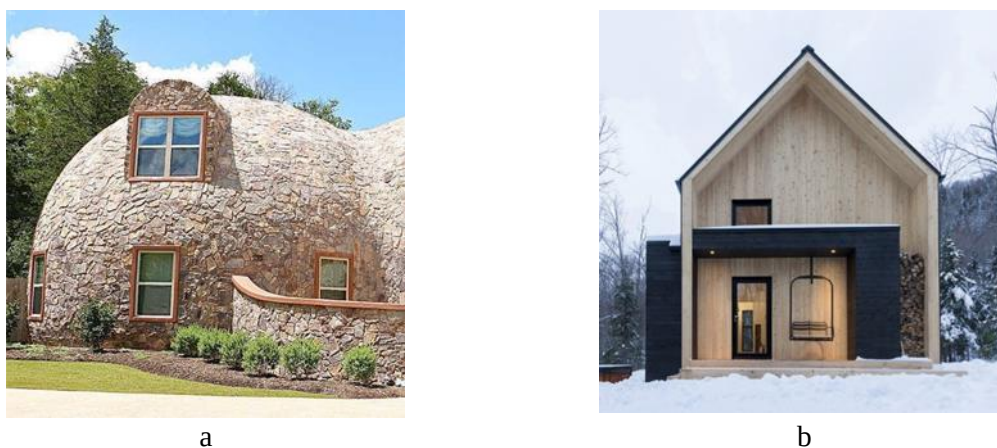


Figure 4. Energy-efficient buildings: a – domed house; b – Scandinavian house.

It is important to note that the regulation of climate impacts by urban planning, architectural planning and engineering methods opens up wide opportunities for creating a comfortable energy-efficient environment, ensuring the best human health and reducing energy loads on the building climate system.

3.3. Green construction has high energy saving potential

It should be noted that green building technologies should be widely used in an ideal home. A striking advantage of green technologies is the creation of conditions for a healthy lifestyle, primarily by absorbing dust, reducing noise and protecting building enclosing structures from atmospheric influences.

Thanks to application of green building technologies, a high effect is being achieved by reducing

heat losses through the outer building envelope, which allows cutting the amount of heat consumed. Comfort in the premises increases due to a decrease in the intensity of radiant and convective heat exchange on the inner surface of the enclosing structures. Environmental pollution decreases due to reduced emissions of harmful substances into the atmosphere. Green roofs are an effective way to increase the area of the green zone in the urban environment and improve the microclimate of buildings.

Green roof structures are widely used for energy saving in many countries with different climatic conditions. The scope of their application in heated and cooled buildings depends on the design features and outdoor climate. A striking advantage of green roofs is their high thermal stability due to the device of plant soil (figure 5). Thickness of the outer layer of sharp temperature fluctuations is insignificant, so most of the structure is located in the zone of constant temperature. This significantly increases the performance properties of the structure in summer. The useful thermal effect of using green roofs in winter depends on the type of climate, the location of the building, the roof structure, and the type of vegetation.

The color of the coating also has a great influence on the thermal regime of roofs. It is convenient to use the difference between the temperature of the external surface and the outside air (ΔT) as a parameter that characterizes the thermal impact of the structure on the environment. This parameter is a kind of indicator of thermal pollution of the environment. In [17], a comparative assessment of the thermal impact of various types of roofs on the environment was performed, the results of which are shown in figure 5.

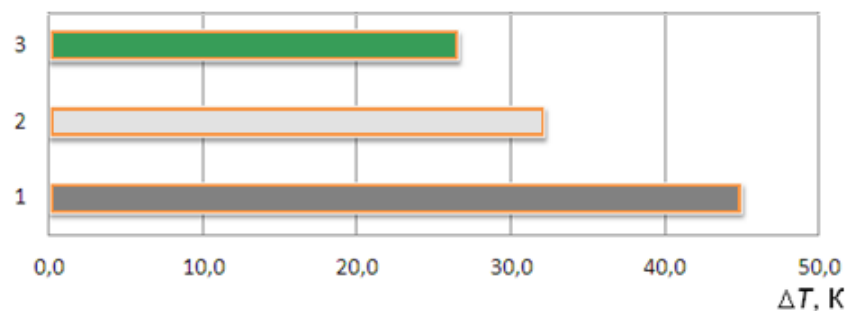


Figure 5. Thermal impact of various types of roofs on the environment:

1 – traditional roof with a dark roof; 2 – the same, with a light roof; 3 – green roof.

The analysis of the results shows that the greatest thermal impact on the external environment has a traditional roof with dark roofing. The use of light roofing significantly reduces the heat load, decreasing the external surface temperature of the structure due to high reflection of solar radiation. The maximum effect of equalizing temperature gives the green roof, mainly due to the thermal accumulation of the surface massive layer.

The greening of facades and roofs helps to mitigate the heat regime of the urban environment through shading, evaporative cooling and thermal insulation. The use of green roofs smoothes the effect of “heat islands” by equalizing the surface temperature and can significantly lower the average temperature of an whole city.

3.4. Solar architecture is a significant factor in improving the sustainability of the urban environment

The origin of solar architecture seems to date back to the V century BC, when Socrates proposed the concept of a solar house. This concept is based on the passive use of solar energy by direct capturing solar radiation through large south-facing windows. In modern architecture, more complex systems have also been used: a solar greenhouse attached to the building, and a Trombe wall. The efficiency of modern passive solar heating systems for buildings can reach 60-75%. Passive systems do not require the use of special expensive equipment, and therefore they are often used in energy-efficient buildings.

Active use of solar energy is based on the use of solar installations that convert solar energy into heat. For heating and air conditioning of buildings, heat pump systems are widely applied, using the heat of the upper layers of the earth and ground water.

In the nearest perspective, conversion based on semiconductor solar cells may become an effective method of converting solar energy into electrical energy. Experts say that in 20-30 years this type of solar energy will be economically comparable with other types of energy.

The use of solar energy in a smart city will completely solve the issue of preserving natural resources for future generations.

3.5. Digitalization

Digitalization is the process of creating a new digital environment through the widespread use of science-based innovative systems and mechanisms of artificial intelligence. The main goal of implementing digital technologies in a smart city is to increase security, create an optimal level of comfort, and ensure maximum efficiency of energy and resource consumption.

The facility's engineering systems should be integrated into a single control and management system by:

- comfort of the object's environment (heat and humidity, air, light and acoustic modes);
- collection and disposal of waste with a closed cycle of waste management;
- water supply and waste disposal;
- heat energy consumption for heating and ventilation, hot water supply, electric energy consumption;
- consumption of renewable and secondary energy resources;
- the impact of the object on the environment.

The result is achieved by a significant improvement in the performance quality of life support systems of the object environment.

The use of breakthrough IT-technologies for self-learning allows implementing an optimal management strategy based on a mathematical model of the thermal and physical characteristics of a building as a holistic energy system [1]. At the same time, the optimal control algorithm is aimed at optimizing thermal comfort while minimizing energy consumption.

4. Conclusion

The principles outlined above are the theoretical basis for creating a system of notions necessary for the development of a holistic concept of a “smart city”, which allows achieving a new level of comfort, energy efficiency and environmental protection in the interests of the present and future generations.

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