Research of Socially Affordable Housing Development Factors in Yerevan City

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Abstract

*Introduction***.** Housing construction is the most important sector in urban planning, since the urban space is formed to provide a comfortable environment for the population, therefore, the priority is to build the required number of residential buildings. *Purpose of the study.* The study aimed to define the main directions, methods of development of socially affordable housing in the conditions of the city of Yerevan. *Methods.* The work is based on the methods of historic research, including comparative analysis, identifying the principles of socially affordable housing design. *Results.* The factors of socially affordable housing formation are highlighted. These factors include methods of integration and development of residential buildings, optimal urban planning, volumetric-spatial, architectural planning solutions, which include some measures to reduce the cost of construction. Housing management decisions based on various factors / prerequisites include design, legal and economic methods. Planning solutions need to be developed in accordance with the existing housing shortage for households with different numbers of family members. The percentage of different types of households leads to the implementation of the required number of suitable planning solutions that meet the population needs. All stages of the implementation of socially affordable housing include an economic factor that affects the final cost of housing, so at each stage it is necessary to adhere to the principles leading to the lowest construction cost.

Introduction

In order to develop socially affordable housing, a study is needed to identify the factors affecting the construction of housing. The first priority is the step-by-step analysis of theoretical data and practical experience, which helps to introduce methods of designing socially affordable housing. Analysis of the prerequisites for the development of socially accessible housing, historical information, legislative, economic, urban planning, in particular, methods of integrating new buildings into the existing city development, spatial, architectural and planning solutions, taking into account the economic and aesthetic aspects of socially affordable housing, allows us to develop optimal design solutions for structures.

Purpose of the study

The study of socially affordable housing development factors includes development of the main provisions, recommendations and the most rational solutions for the design of socially affordable housing, taking into account the specifics of local conditions and trends in the development of modern comfortable housing, individualization of architecture, including urban planning, volumetric-spatial, architectural and planning solutions, for use in the city of Yerevan.

Methodology

Research is based on an integrated approach, including the study of scientific articles, literature on relevant topics, regulatory documentation and design work of socially accessible housing, an analysis

of the existing situation in the field of housing construction and the need to create socially accessible housing to improve the living conditions of the population in need, providing methods of structured construction and provision of housing. The work is based on the methods of scientific research, including comparative analysis, identifying the principles of solving the tasks.

Results

Analysis of the main factors, including theoretical and practical aspects, makes it possible to identify the best methods for the development of socially affordable housing. Socially affordable housing development factors include the study of prerequisites, historical information, legislative, economic, urban planning, volumetric-spatial and architectural planning solutions, etc.

The factors influencing the formation of socially affordable housing are as follows:

- socio-demographic factors / preconditions influencing the development of socially affordable housing,
- methods of development and provision of socially accessible housing,
- integration of structures into the existing settlement of the city or the development of residential areas in free areas,
- economically affordable volumetric-spatial, planning, constructive solutions for socially accessible housing,
- planning solutions corresponding to the existing housing shortage for households with different numbers of members.

To identify the existing housing shortage, it is necessary to study the prerequisites / socio-demographic factors, including population change, as well as the presence of people in particular need of housing, military or post-war situations, natural disasters, mass disasters, dilapidated housing stock, urban expansion. The listed prerequisites are present to one degree or another in the RA, in particular in the city of Yerevan. In the RA, the population decreases by 0.3-0.4% annually, while in the city of Yerevan it increases by 0.2% [1]. There is a pronounced centralized distribution of the population in the RA, since 1/3 of the people live in the capital. A large percentage of the population needs to improve housing conditions, and the condition of the housing stock must be carefully analyzed to identify physical and moral deterioration, since most of the residential buildings were built mainly in the 1950-1990s.

About half of the existing apartments are located in the city of Yerevan. Approximately 8.7% of the population in the RA, 9.2% in the city of Yerevan needs to improve housing conditions [1]. The largest percentage of residential buildings was built in 1950-1990, subsequently the percentage of residential buildings construction decreased. According to the Ministry of Emergency Situations, a large number of buildings built of stone walls, prefabricated panel, structures built by raising floors method, were recognized as not earthquake resistant [2]. The United Nations Economic Commission for Europe concludes that the 2011 census results show that 30,000 families have no housing and about 30,000 need better housing [3].

Based on data on housing shortages in various countries of the world, measures are being developed to regulate housing conditions, in particular socially affordable housing. Government agencies introduce legislative measures to stabilize the housing stock. In the RA there are laws aimed at providing housing to those in need, but according to the law, only families without a place of residence, victims of technogenic disasters, families of military personnel can hope to receive housing. International and local charities are developing programs for the development and provision of housing with the support of the state. There are mortgage schemes that allow families to purchase housing, but in the RA the poor population make up 23.5%, of which 1.0% are extremely poor, in the city of Yerevan 22.4% are poor, 1.0% are extremely poor; labor resources in the RA make up 67.7%, in the city of Yerevan - 59.6%; economically active population in the RA - 56.9%, in the city of Yerevan - 58.6%; the employment rate in the RA is 45.2%, the informal employment rate is approximately 41.3%, the employment rate in the city of Yerevan is 42.5%; unemployment rate in the RA - 20.5%, in the city of Yerevan - 27.4% (data based on a statistical study of 2018-2019) [1]. Average salaries are approximately $400-500. Consequently, the payment of arrears can be delayed

for decades, the existing measures for the provision of housing are not sufficient to meet the needs of the majority of the population.

For the development of socially affordable housing, it is necessary to introduce legislative projects regulating the percentage of socially affordable housing from the total number of residential buildings erected annually and create state organizations, programs for financing, construction and provision of socially affordable housing. Within the framework of housing provision schemes, the percentage of housing purchased by citizens at their own expense, by using mortgages system, housing provided by state and municipal, charitable organizations, etc. should be regulated with the aim of creating a variety of housing for different segments of the population. The methods of financing socially accessible housing that can be used in the RA, in particular in the city of Yerevan, are as follows: own funds of citizens; investors attraction; attraction of credit institutions; public fundraising; funding from municipal and state organizations; funding from charitable organizations. The methods of acquiring and providing housing that can be used in the RA, in particular in the city of Yerevan, are as follows: own funds of the citizens; loans; mortgage credit; subsidies, special programs for the purchase of housing with certain benefits; special co-financing programs; purchase of housing at the stage of shared construction; rent payment with subsequent redemption; funding from municipal and state organizations; funding from charitable organizations.

When distributing new structures in urban development or in free areas, it is necessary to take into account compliance with regulatory requirements, covering the following factors: optimal population density, natural and climatic conditions, zoning of urban space, infrastructure of residential areas, etc.

The distribution of the population on the territory of the country is possible according to two schemes: even or centralized distribution of the population. Most countries are faced with the problem of overpopulation and the neglect of certain regions. One of the clearest examples of centralization is the resettlement of the population from rural to industrialized areas during the industrial revolution. Therefore, when designing new residential areas, it is necessary to take into account the following parameters: population size and population density of individual areas. These indicators must be taken into account on the scale of all countries and individual regions. 1/3 of the RA population lives in the city of Yerevan, of which: Ajapnyak, Arabkir, Center, Erebuni, Nor-Nork, Malatia-Sebastia, Shengavit districts accommodate from 10.1 to 13% of the population; Kanaker-Zeytun places 6.9%; Davtashen, Avan - 3.9-1.9%, Nork-Marash, Nubarashen - 1.1-0.9% [1] (Fig.1). The population density is as follows: Arabkir, Nor-Nork, Center, Kanaker-Zeytun districts have from 8638 to 9599 people/km^2; Davtashen, Avan - 6569-7287 people/km^2; Ajapnyak, Malatia-Sebastia - 4249-5509 people/km^2; Nork-Marash, Erebuni, Shengavit - 2458-3466 people/km^2; Nubarashen - 569 people/km^2 [1] (Fig.2). It is necessary to choose areas with the lowest population density: Ajapnyak, Malatia-Sebastia, Nork-Marash, Erebuni, Shengavit, Nubarashen districts. If there is a shortage of areas for construction, it is possible to attract the territories of the Yerevan city agglomeration: Aragatsotn, Armavir, Ararat, Kotayk, Gegharkunik provinces. The territories of the city of Yerevan are divided according to functional zones, of which territories for low-rise, multi-floor buildings, mixed, free development, industrial structures (if the industrial zones do not function as intended, observing sanitary and hygienic conditions) can be used for the construction of residential buildings.

The first priority is the selection of zones intended for the placement of residential buildings, then the allocation of areas free from structures within them. It is necessary to select land areas in accordance with the relevant technical data of the soil for construction. The most important aspect is the allocation of sites with satisfactory geological conditions, since the cost of improving soil conditions significantly increases the cost of construction. Together with the geological conditions, it is necessary to take into account the engineering and communication and road networks, the construction of which also increases the cost of construction. The cost of strengthening the ground is approximately 10% of the construction of the building, depending on the type of ground strengthening, the market value of materials and labor, etc. the percentage may vary. For example, the total cost of soil strengthening and protection of the foundation from groundwater is calculated individually and depends on the volume of work and the consumption of building materials. For a guideline, we will give the minimum figures - work on strengthening the soil foundation of the

foundation will take from 10 days, the minimum order is from 100 square meters, the price of 1 square meter is from 4 thousand rubles [4]. A summary of the estimated cost of soil improvement according to MBIE (2015) guidance is $ 176-522 per m^2 depending on type [5]. The average price per square meter is $ 250. With an increase in the number of building floors, the percentage of the cost of improving soil (geological) conditions per square meter of housing decreases. The average cost of building 1 km of road in China is $ 2.2 million, in the EU - $ 6.9 million, in the United States - $ 5.9 million. In Russia, according to the federal target program, the average cost per kilometer in 2010–2015 is $ 17.6 million [6]. The price varies depending on the quality and type of road, which includes major highways, district roads, narrow lanes, etc. Thus, the cost of road works is approximately 5-7% of the construction of a building, depending on the quality, type of road and building, market value of materials and labor, etc. the percentage may vary. With an increase in the area from 150 to 300 m^2, the length of the driveways increases by only 4-5% [7]. With an increase in the number of building floors, the percentage of the cost of roadways per each square meter of housing decreases. Therefore, it is necessary to choose the optimal area of the plot surrounded by the road and the height of the buildings, taking into account the acceptable building density. It should be noted that in parallel with the construction of roadways, it is necessary to develop communication systems, which accordingly increases the cost of residential buildings.

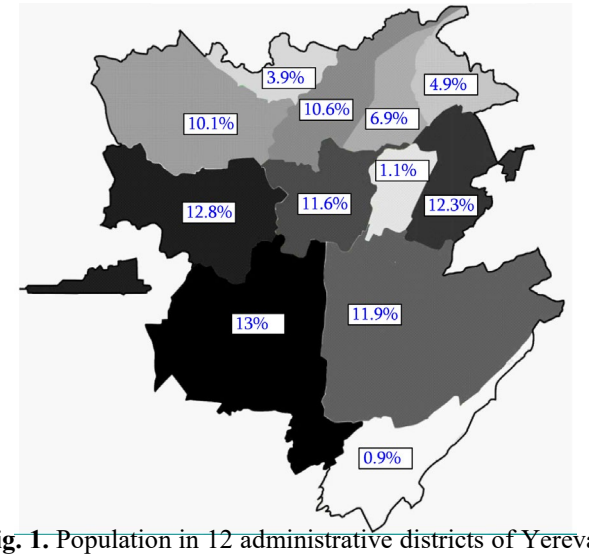

Fig. 1. Population in 12 administrative districts of Yerevan as a percentage of the total (according to the data of the National Statistical Service of the Republic of Armenia)

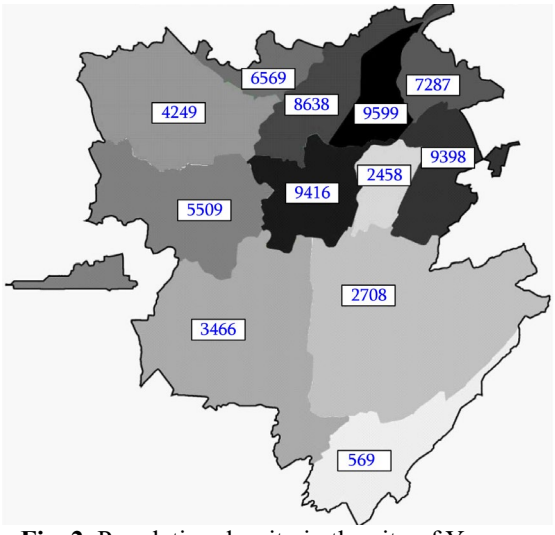

Fig. 2. Population density in the city of Yerevan (persons / km^2)

The next aspect is the choice of territories based on its cost, since the city of Yerevan is divided into five price categories. Consequently, it is possible to grade the areas for development according to the priority of use, initially using areas with satisfactory geological conditions, engineering, communication and road networks in the territories of the fifth cheapest land, gradually using less satisfactory areas. It should be borne in mind that the cost of the Yerevan city territories divided into five price zones is given according to the cadastral data; when calculating the cost of construction, market prices should be used.

The design of residential buildings also includes: architectural and planning solutions, technical and environmental indicators, sanitary and hygienic indicators, fuel and energy, water, territorial solutions, the state of the environment, taking into account the forecast of changes in the future natural and other conditions, etc.

Development areas are divided into areas with existing buildings and free areas. The first type includes the presence of a developed infrastructure, but limits the possibilities of volumetric-spatial, architectural planning solutions in connection with the existing structures. The second type is the opposite: there is no established infrastructure, but free urban planning, volumetric-spatial, architectural planning solutions are possible. When designing residential areas, it is necessary to take into account the natural and climatic conditions, urban planning, architectural solutions of the existing

development, constructive solutions, the choice of building materials, the preference of the population.

In the case when buildings are integrated with the existing development of the city, the following stages of residential areas development can be applied:

- integration of an urgently needed number of residential buildings,
- integration or use of existing engineering and communication networks, infrastructure for buildings under construction,
- a gradual increase in the number of residential buildings with appropriate engineering and communication networks, infrastructure, gradually populating the territory allocated in the existing development.

In the case when buildings are located at a certain distance from other urban buildings, the following stages of residential areas development can be applied:

- construction of a necessary number of residential buildings,
- development of engineering and communication networks, infrastructure for buildings under construction,
- a gradual increase in the number of residential buildings with appropriate engineering and communication networks, infrastructure, gradually settling in the allotted territories.

Depending on the development of new buildings on the territory with existing buildings and on free territories, it is necessary to take into account the corresponding compositional solutions, number of storeys, design solutions, the choice of materials, architectural elements that can distinguish and merge new structures with existing buildings.

Building parameters depend on: dimensions, configuration; availability of infrastructure elements; building configuration; building density; compactness; insolation. Building density depends on: distance between buildings; configuration of buildings; number of storeys of the building.

The choice of volumetric-spatial and architectural planning solutions for socially affordable housing depends on: natural and climatic conditions; existing urban planning conditions; architectural solutions of the surrounding buildings; the preferences of the population; optimal design solutions; materials used for construction.

The calculation of the cost of residential buildings consists of a variety of parameters, which are calculated according to the existing market value. Volumetric-spatial, architectural planning, constructive solutions of socially affordable housing should lead to a decrease in the cost of construction.

Factors affecting the cost of socially affordable housing:

- natural and climatic conditions (providing insolation, protection from cold and overheating, accounting for wind conditions, energy saving, protection against overheating, terrain, seismically active zones, etc.),
- urban planning conditions, infrastructure development (the cost of land areas, the construction of various elements of the residential area, the area of the territory depending on the number of floors, etc.),
- volumetric-spatial, architectural planning, constructive solutions.

The compact distribution of residential buildings for the largest number of the population in the periphery of cities is the most economical for socially accessible housing construction.

It is necessary to optimally choose the building density, close to the minimum regulatory requirements. The spreading density can be adjusted using the height and configuration of the structures, taking into account the rules of insolation and fire requirements.

Determination of the distance between buildings in accordance with fire safety recommendations is made depending on the degree of fire resistance of the building. The construction of 9-storey buildings with a floor height of 3 *m* meets the regulatory requirements for most fire resistance classes of a building, except for the III degree of fire resistance of a building with constructive fire safety class C1 (maximum height 15 *m*, which corresponds to a 5-storey building with a floor height of 3 *m*), and hall-type buildings should not be higher than 17 *m*. The maximum allowable area of the fire compartment on a floor varies from 500-2500 m^2 [8].

The specified data must be compared with the insolation requirements. Within the framework of the study, a graph is considered, which was drawn up for a area of 2 hectares (200 *m* wide and 100 *m* long), on which buildings with different widths and heights are alternately located, the angle of inclination of the shadow is $\alpha = 30^0$ (the value of this parameter meets insolation requirements for the distance between buildings, depending on their height, the optimal ratio in this case is 1:2 (building height / width between buildings)) (Fig. 3). Based on such graphs, it is possible to choose the optimal height of the building depending on its width. It should be noted that the graphic can be drawn up for any width of the building, but in practice, the depth of the living room should not exceed 6 *m*, therefore, with two-sided placement of rooms and taking into account the presence of a corridor between them, the width of the building can be 11-16 *m*.

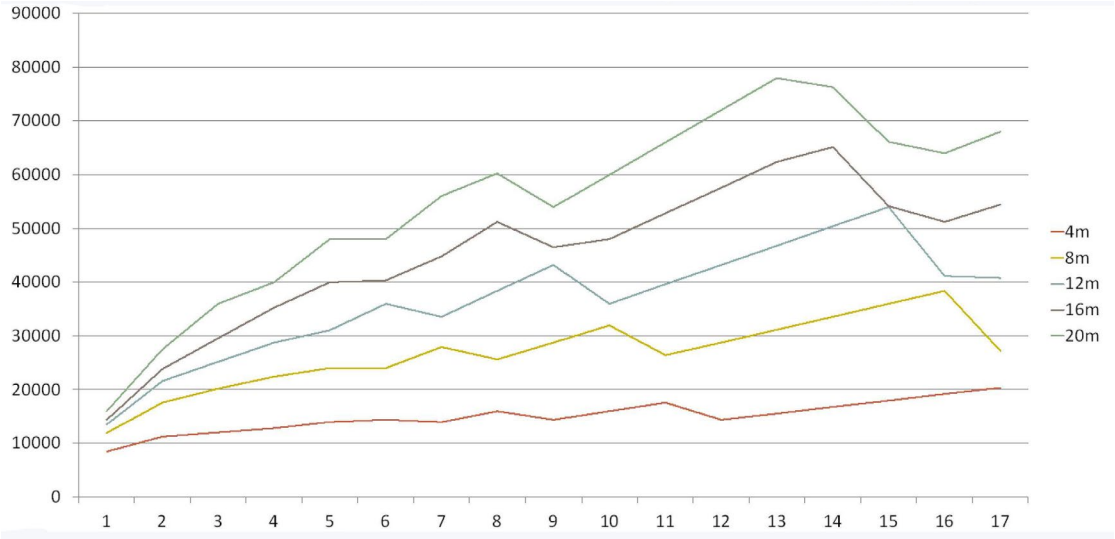

Fig. 3. The graph of the dependence of the total area of buildings on an area of 2 hectares with different heights and widths of the building (angle of inclination $\alpha = 30^0$)

In order to identify the impact of building configuration on productivity in the use of the building area, it is necessary to analyse a number of different planning solutions that can be applied. After analyzing many planning solutions, it is revealed that the simplest rectangular shapes located next to each other are more profitable. It should be noted that with an increase in the width of buildings, the losses in the area of the site, which are necessary to ensure fire and insolation requirements, decrease. Since the population density increases significantly due to changes in the number of floors of buildings, it is necessary to take into account the requirements for population density in accordance with the fact that the territory of the Republic of Armenia is located in a seismically active zone with a temperate climate (climatic zone - IIB), therefore, in zones with a high and medium degree of urban planning value the maximum population density is 300 people / ha, and with a low degree - 180 people / ha [9], from this it follows that other planning solutions of residential buildings can be used to prevent overpopulation of the territory.

30-35% of a separate building in residential and public buildings of low and medium floors is the cost of wall structures, 11-18% of floors and 3-6% of the roof. In high-rise buildings, the cost of walls does not exceed 20%, frame structures with ceilings account for up to 35% of the estimated cost and roofing - 1-3% [10].

The most important aspect affecting the cost of an apartment is the number of floors in buildings. With an increase in the number of floors, the construction costs percentage of common building elements (roof, foundation, etc.) per square meter of living space decreases, for example, in 9-storey buildings by 4-4.5%, in 16-storey - by 5.5-6% [10]. The installation of elevators, which is mandatory in buildings above four floors, increases construction costs due to the installation of equipment, loss of total area for the placement of the elevator unit and strengthening of the structure. The technical component of the construction and arrangement of the necessary equipment of buildings becomes more complicated with an increase in the number of floors, and, accordingly, the cost of structure

operation increases. In the structure of operating costs, the largest share falls on the operation of elevators, accounting for 20% in 9-storey buildings, 24% in 16-storey buildings, and up to 30% in 22-24-storey buildings [10].

The choice of a building plan configuration is related to the consumption of materials for the construction of external walls and heat losses, which occur mainly through the external walls. External walls in the cost of a residential building take about 15% [10]. Therefore, it is necessary to reduce the ratio of the area of the outer walls to the volume of the building. The ratio of the building area enveloping the building volume (the so-called exposure coefficient S / V) affects the energy efficiency of a building [10]. The most favorable configurations from the point of view of energy saving are round or square plans. The desire of the architect to increase the width of the building in order to increase its efficiency is limited by the requirements of insolation. In multi-section houses, the width of the building in the middle lane, which meets these conditions, is usually 11-12 *m* [10]. The length of the structure also affects the economy of the construction of residential buildings. The length factor with an increase in the length of the building more than 6 sections (130-150 *m*) usually ceases to work. The estimated increase in the cost of the total area in relation to a 6-section building is about 7% [10] in a one-section building. From the planning solutions point of view, the maximum possible number of apartments should be placed on one staircase, since the cost of staircase and elevators, common corridors is divided into a larger number of dwellings. Thus, in 9-storey buildings with 8-apartment sections, the living space costs 3-4% less than in houses with 4-apartment sections [10].

Estimated construction cost depends on: volumetric-spatial solutions; constructive solutions depending on natural conditions and volumetric-spatial solutions; building materials depending on natural and climatic conditions; number of floors. Operating costs depends on: energy efficiency of structures; maintenance work of the elevator; the cost of providing utilities and the operation of engineering systems.

Approximate percentage of the price of different parts of the building: frame - 22-30%; plumbing, ventilation, heating, air conditioning, electricity - 24-28%; external walls - 7-10%; partitions- 7-9%; elevators - 3-6%; market fluctuations - 20-25% [11]. From other source: foundation - 15%; walls - 30%; ceilings and stairs - 12%; roof - 18%; facades and openings - 25%; heating - 9%; water supply, sewerage - 7%; electrical - 6%; finishing works - 38 % [12]. Percentages fluctuate depending on the source, but an approximate representation of the cost of residential elements can be count.

These percentages allow to orient during the design of socially affordable housing. To select possible options for the distribution of socially affordable housing in the territory of the city of Yerevan, Table 1 and 2 are given, which shows the percentage ratios of costs per 1 square meter of housing, depending on the height of the structure. The calculation of maintenance works is difficult to compare with the estimated costs of the construction of the building, but nevertheless, this price should be taken into account in the calculations. Thus, the costs of maintenance work, including heating, capital and current repairs, administrative and management costs, the maintenance of public places (stairs, elevators), the total cost of maintaining the house, can be taken into account by adding approximately 0.1% when calculating for 10 years.

With a total area of apartments on the floor of more than 500 m^2, evacuation must be carried out in at least two stairwells (normal or smoke-free) [13]. Elevators should be provided in residential buildings where the floor elevation of the upper residential floor is 12 *m* higher than the elevation of the first floor [13].

Therefore, comparing the costs of correcting the geological imperfections of the plots, the development of the communication and road system of residential areas, the cost of land areas for construction in territories located in different price zones of the city of Yerevan, as well as taking into account the estimated and operating costs, depending on the increase in the number of storeys of the building, it is possible to obtain the optimal option for building socially affordable housing. It should be borne in mind that when constructing 10-storey buildings, the used area of buildings is 1.7 times more, and for 16-storey buildings - 2.1 times more.

Table 1.

	m^2	G1	G2	R1	R2	Z1	Z2	Z3	Z4	Z5
4-floor	S	0%	14%	0%	25%	0,38%	0,29%	0,21%	0,13%	0,5%
10- floor	1,7S	0%	7%	0%	10%	0,15%	0,12%	0,09%	0,05%	0,02%
16- floor	2.1S	0%	5%	0%	6%	0,09%	0,07%	0,05%	0,03%	0,01%

G1 - territories with satisfactory geological conditions
G2 - territories with unsatisfactory geological conditions
R1 - territories with satisfactory roads and communication systems
R2 - territories with unsatisfactory roads and communication systems
Z1 - territories in first price zone of Yerevan city
Z2 - territories in second price zone of Yerevan city
Z3 - territories in third price zone of Yerevan city
Z4 - territories in forth price zone of Yerevan city
Z5 - territories in fifth price zone of Yerevan city
Percentages are given for one square meter

Table 2.

	Estimated price	Exploitation. (for 10 years)
4-floor	P1	P2
10- floor	P1+10%	P2+0.1%
16- floor	P1+17%	P2+0.1%

Percentages are given for one square meter

With an increase in the number of floors, the price per square meter of a territory is divided by the number of floors. It should be noted that when calculating the territory used for construction, it is necessary to take into account the area between the structures, which is allocated to ensure insolation and losses due to the configuration of the building. The above calculations take into account the cadastral prices of land plots, but it is necessary to take into account the market value, which can be several times higher.

From the above data, it follows that the construction of some elements of buildings with 10 and 16 floors is more expensive than the construction of 4-storey buildings, and it is also necessary to take into account that with an excessive building density, the number of floors of the building should be reduced. But the table shows the percentage ratios of the cost of land plots, depending on the data provided by the cadaster, therefore, with an excessively high market value of the construction area, which may exceed the cost of building buildings above 4 floors (in which an elevator must be installed), buildings should be constructed up to 9-10 floors, in which one elevator is installed, in order to save land. The priority is to use local building materials to avoid material transport costs, which increases costs by about 30%.

It should be noted that natural and climatic conditions affect the volumetric-spatial, architectural planning, constructive solutions, the choice of building materials and, consequently, the cost of structures. Factors such as protection from cold and overheating, wind, taking into account relief conditions, in particular in seismically active zones, ensuring the necessary insolation, ventilation of premises, etc. must be taken into account at the initial design stages. Ensuring each of the listed factors affects the cost of buildings, therefore, the optimal design solution will reduce the cost of building in general.

Research shows that the most necessary is the construction of two-, three-, four-room apartments. For households with a large number of members, several apartments should be provided rather than developing non-standard layouts to meet their needs.

Conclusion

Thus, the study of all the above indicators allows us to determine the optimal options for building socially affordable housing in the city of Yerevan. It should be noted that these percentages are arbitrary, since during the construction of buildings, one of the most important aspects affecting the cost of construction is the design decisions and the choice of building materials, the value of which is variable. Nevertheless, these recommendations make it possible to significantly influence the cost of building socially affordable housing by applying optimal design solutions.

Construction savings depend on many factors. Building density is one of the most important factors influenced by height, building configuration, etc. It is necessary to choose three-dimensional, architectural and planning solutions, decorative solutions, available building materials (possibly local production), etc. The most optimal is the construction of 9-10 floor buildings with one elevator, initially using sites with satisfactory geological conditions, engineering communications and road networks in the territories of the fifth price zone, gradually using less satisfactory sites.

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