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Cost Efficiency of Dwelling Construction with Account of Cities Factors

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ABSTRACT

The process of urbanization is widely spread. New city territories are being built-up with residential buildings. These territories are located in the city center as well as on its outskirts. Therefore, developers should think about cost efficiency of the residential building construction which depends on the kind of building site. The main goal is to analyze the cost efficiency of the residential building construction in central districts of Saint-Petersburg and on its outskirts. It is necessary to calculate a number of parameters characterizing the cost efficiency of the constructing such kinds of objects and take into account factors influencing on these parameters. These factors are location of construction objects in different parts of the city and, thus, different height restrictions, different average construction cost and different land acquisition cost]. After getting the results of the analysis [the conclusion will be made why the construction of residential building can be considered more appropriate in Krasnoselsky District (on the outskirts of the city) and less appropriate in Petrogradsky District (the center of the city) from the economic point of view. After all it will be possible to define economic feasibility of residential building construction in different parts of the city. This pattern will be also true for many other big cities.

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1. Introduction

Nowadays, the process of urbanization is very active. A large number of people move to big cities from small towns and villages [1]. Saint-Petersburg is one of those big cities where the process of urbanization is going on [2]. It causes an appearance of new building sites with dwellings constructed on them actively [3]. Building sites can be situated on the outskirts of the city (it usually means a territory development or massive construction) as well as in the central districts of it (construction of expensive business-class houses). It makes developers think about cost efficiency of constructing residential buildings in different parts of the city.

A number of factors must be taken into account when there is a construction in the big city because they influence on its cost efficiency [4]. First of all, it is about a *characteristic of a building site* (cadastral value of a land measured in rub/m² and depending on the location of it in some district of Saint-Petersburg). The second factor means a *structural type of a building* (site-cast concrete building, brick building, monolithic building with brick spandrel walls, frame-panel building), its height (a number of floors) and a floor area. Then there is such parameter as *estimated cost* which includes all construction costs (an average construction cost in Saint-Petersburg for 1 m² of living space is used). One of the most important things is an *amount of capital investment defined for each stage of construction* (that is cash distribution through the years of construction). And, finally, it is crucial to know about *expected price for released product* (speculated profitability of sales, %) [5]. We can find the same researches in other authors papers [6-32]. For example, the paper is based on such sources as [9-14]. Their general theme is also about urbanization of new city territories being built-up with residential buildings. And, on the one hand, the main goal is to conduct a cost efficiency analysis of residential building construction in different economic conditions of different countries considering macroeconomic problems. On the other hand, for example, the work [9] doesn't take into account urbanization problems of a single city but considers a number of cities in one country. The other work [10] talks about urban planning and building smart cities based on the Internet of Things using Big Data analytics. Nowadays, such an approach doesn't correspond to the current level of the urban development in Russian Federation. Such works as [11-14] conduct cost efficiency analysis without considering some social, cultural and historical factors which are crucial to many Russian big cities like Saint-Petersburg.

2. Methods of capital investment and cash flow calculation

There is a construction of residential building in two parts of Saint-Petersburg which are Petrogradsky District and Krasnoselsky District. The main difference between them is a parcel development planning approach caused by their different location (Petrogradsky District is the historic center of Saint-Petersburg and Krasnoselsky District is located in the south part of the city).

The both districts are planned to be sites for construction a monolithic building with brick spandrel walls. It has a rectangular shape in the plan view and its dimensions are 40×60 m. The dimensions of the build-up area are 50×70 m. Petrogradsky District is located in historic part of the city, because of that there is specific height restrictions which doesn't allow to construct high-rise buildings there and exceed the height of 33 m [5]. So that, the designed height is 8 floors (every storey has 4 meters of height that corresponds to business-class houses). The height restrictions for Krasnoselsky District is up to 75 meters and that's why the number of floors is 25 (the height of storey is 3 meters). The building construction period is going to be 3 years.

Cost efficiency analysis of residential building construction in the districts is connected with 3 parameters. These parameters are *net present value (NPV)*, *profitability index* and *payback period* [32]. The values depend on the referred factors. That's why, the main three tasks are to calculate these three parameters and compare them between two objects of construction. Finally, the main goal is to define a district (Krasnoselsky or Petrogradsky) where the construction of residential building can be considered more appropriate from the economic point of view.

The first thing is to calculate the amount of the capital investment. It consists of construction, design and survey work costs, noninvestment and building land acquisition expenses. Here we have got a budget for construction project or general estimated cost that is equal to the amount of the capital investment. Finally, there is a marketing value that means a summary of the general estimated cost and planned savings. The last one is some extra charges for the released product defined by an investor or developer.

The first stage is to calculate the parameters for the building construction in Petrogradsky District. The construction cost is calculated with the formula:

$$C_{\text{constr.}} = S_{\text{build.}} \times C_{\text{sq.m}} \quad (1)$$

as $S_{\text{build.}}$ is the whole area of the building, calculated as multiplication of the length, width and the number of floors of the building (length – $a = 60$ m, width – $b = 40$ m, number of floors – $n = 8$):

$$\begin{aligned} S_{\text{build.}} &= a \times b \times n, \\ S_{\text{build.}} &= 60 \times 40 \times 8 = 19200 \text{ m}^2; \end{aligned} \quad (2)$$

$C_{\text{sq.m}}$ – an average construction cost for 1 m^2 of living space in Saint-Petersburg (the figure for Petrogradsky District is equal to 84360 rub [32]).

Then:

$$C_{\text{constr.}} = 19200 \times 84360 = 1619712000 \text{ rub.}$$

The cost for acquisition of the building land is defined as:

$$C_{\text{land}} = S_{\text{build-up}} \times C_{\text{sq.m.land}} \quad (3)$$

as $S_{\text{build-up}}$ is a square of the build-up area, calculated as multiplication of length and width of the build-up area (length – $c = 70$ m, width – $d = 50$ m):

$$\begin{aligned} S_{\text{build-up}} &= c \times d \\ S_{\text{build-up}} &= 70 \times 50 = 3500 \text{ m}^2 \end{aligned} \quad (4)$$

$C_{\text{sq.m.land}}$ is the cadastral value for 1 m^2 of land in Saint-Petersburg (the figure for Petrogradsky District is equal to 37488 rub [32]).

Then:

$$C_{\text{land}} = 3500 \times 37488 = 131208000 \text{ rub}$$

The design and survey work cost takes, as usual, 3% from the construction costs:

$$\begin{aligned} C_{\text{DSW}} &= C_{\text{constr.}} \times 0.03 \\ C_{\text{DSW}} &= 1619712000 \times 0.03 = 48591360 \text{ rub} \end{aligned} \quad (5)$$

The noninvestment expense takes, as usual, 1% from the construction costs:

$$\begin{aligned} C_{\text{noninv.}} &= C_{\text{constr.}} \times 0.01 \\ C_{\text{noninv.}} &= 1619712000 \times 0.01 = 16197120 \text{ rub} \end{aligned} \quad (6)$$

The general estimated cost for the building construction is equal to the summary of the all calculated costs:

$$\begin{aligned} C_{\text{est.cost}} &= C_{\text{constr.}} + C_{\text{land}} + C_{\text{DSW}} + C_{\text{noninv.}} \\ C_{\text{est.cost}} &= 1619712000 + 131208000 + 48591360 + 16197120 = 1815708480 \text{ rub} \end{aligned} \quad (7)$$

Therefore, the amount of the capital investment for the building construction in Petrogradsky District is equal to 1815708480 rub.

An estimated cost for construction of 1 m² of living space is defined as an division of the general estimated cost to the square of the building:

$$C_{\text{est.cost1}} = \frac{C_{\text{est.cost}}}{S_{\text{build.}}} \quad (8)$$

$$C_{\text{est.cost1}} = \frac{1815708480}{19200} = 94568.15 \text{ rub}$$

All the results are presented in the (Tab. 1).

Table 1. Calculation of the capital investment amount (general estimated cost) for the residential building construction in Petrogradsky District

Average construction cost for 1 m ² of living space [rub]	84360.00
Building area [m ²]	19200.00
Construction costs [rub]	1619712000.00
Build-up area [m ²]	3500.00
Cadastral value of 1 m ² of land [rub]	37488.00
Building land acquisition costs [rub]	131208000.00
Design and survey work costs [rub]	48591360.00
Noninvestment costs [rub]	16197120.00
General estimated cost [rub]	1815708480.00
Estimated cost for 1 m ² of living space [rub]	94568.15

To calculate the marketing cost for 1 m² of living space, that will make an offer on the market, the estimated cost for 1 m² of living space should be summed with a certain planned savings. According to the information of Coordinating Center for pricing and budget normalization in big city construction developers are usually aimed to maximize their profit by increasing the planned savings up to 40-50% from the general estimated cost for the building construction. Therefore, the planned savings for construction of 1 m² of living space are about 50%. Thus, the marketing cost for 1 m² of living space is calculated with the formula:

$$C_{\text{mark.cost1}} = C_{\text{est.cost1}} + C_{\text{est.cost1}} \times 0.5 \quad (9)$$

$$C_{\text{mark.cost1}} = 94568.15 + 94568.15 \times 0.5 = 141852.23 \text{ rub}$$

Then a cash flow is going to be defined as a multiplication of marketing cost for 1 m² of living space and the building area:

$$R = C_{\text{mark.cost1}} \times S_{\text{build.}} \quad (10)$$

$$R = 141852.23 \times 19200 = 2723562816 \text{ rub .}$$

All the calculated results for the cash flow are presented in the (Tab. 2).

Table 2. Calculation of the cash flow from the residential building construction in Petrogradsky District

Marketing cost for 1 m ² of living space [rub]	141852.23
Cash flow [rub]	2723562816.00

As the building construction period continues 3 years, the distribution of the capital investment and cash flow through the years must be calculated. According to the experience of the residential building construction the amount of the capital investment may be distributed through the years in such percentage ratio as 35, 40 и 25% (without building land acquisition costs and design and survey work costs) for each 1, 2 и 3 years respectively. The other percentage ratio is for the cash flow which should be distributed as 10, 50 и 30% for each 1, 2 и 3 years respectively. The last 10% are determined for preventing various kinds of risks. The results of the distribution are presented in the (Tab. 3).

Table 3. Distribution of the capital investment amount and cash flow through the years for the residential building construction in Petrogradsky District

Distribution of the capital investment [rub]	
building land acquisition costs + design and survey work costs	179799360.00
1 year (35%)	572568192.00
2 year (40%)	654363648.00
3 year (25%)	408977280.00
Total volume of the capital investment	1815708480.00
Distribution of the cash flow [rub]	
1 year (10%)	272356281.60
2 year (50%)	1361781408.00
3 year (30%)	817068844.80
Total volume of cash flow	2451206534.40

The amount of the capital investment and cash flow is calculated for the building construction in Krasnoselsky District in the same way. The results are presented in the (Tab. 4). The difference between them is the number of building floors (25 floors instead of 8 ones in Petrogradsky District), cadastral value of 1 m² of land (9550 rub/m² for the district), average construction cost for 1 m² of living space (55680 rub/m² for the district), and also planned savings summed with the estimated cost of 1 m² of living space (40% instead of 50% that is caused by different values of sale profitability index of the districts (9% is for Krasnoselsky District and 19% is for Petrogradsky District).

Table 4. Calculation of the capital investment amount (general estimated cost) for the residential building construction in Krasnoselsky District

Average construction cost for 1 m ² of living space [rub]	84360.00
Building area [m ²]	19200.00
Construction costs [rub]	1619712000.00
Build-up area [m ²]	3500.00
Cadastral value of 1 m ² of land [rub]	37488.00
Building land acquisition costs [rub]	131208000.00
Design and survey work costs [rub]	48591360.00
Noninvestment costs [rub]	16197120.00
General estimated cost [rub]	1815708480.00
Estimated cost for 1 m ² of living space [rub]	94568.15

Table 5. Calculation of the cash flow from the residential building construction in Krasnoselsky District

Marketing cost for 1 m ² of living space [rub]	81850.08
Cash flow [rub]	4911004700.00

Table 6. Distribution of the capital investment amount and cash flow through the years for the residential building construction in Krasnoselsky District

Distribution of the capital investment [rub]	
building land acquisition costs + design and survey work costs	133652500.00
1 year (35%)	1180972800.00
2 year (40%)	1349683200.00
3 year (25%)	843552000.00
Total volume of the capital investment	3507860500.00
Distribution of the cash flow [rub]	
1 year (10%)	491100470.00
2 year (50%)	2455502350.00
3 year (30%)	1473301410.00
Total volume of cash flow	4419904230.00

3. Results and discussions of the cost efficiency parameters calculation

First of all, a discount coefficient must be calculated. The calculation is made for the first year of the building construction in Petrogradsky District. The discount coefficient is calculated with the formula:

$$\gamma = \frac{1}{(1 + E) \times t} \quad (11)$$

as E is a discount rate (taking into account the current inflation rate in Russia and also investment risks connected with the residential building construction E = 15%);

m – the current year of the construction (t = 1).

$$\gamma = \frac{1}{(1 + 0.15)} = 0.870.$$

The next stage is to calculate a discounted capital investment:

$$C_{1\gamma} = C_1 \times \gamma \quad (12)$$

as C₁ – capital investment amount determined for the first year of the building construction, rub.

$$C_{1\gamma} = 572568192 \times 0.870 = 497885380.00 \text{ rub.}$$

The discounted capital investments for the rest of the years are calculated in the same way and the results are presented in the (Tab. 7).

Table 7. Calculation of the discounted capital investment through the years (Petrogradsky District)

Year of investing (t)	Discount rate (E)	Discount coefficient (γ)	Capital investment through the years (C _t) [rub]	Discounted capital investment through the years (C _{tγ}) [rub]	Discounted capital investment C _{tγ} with progressive total [rub]
0	0.15	1.000	179799360.00	179799360.00	179799360.00
1	0.15	0.870	572568192.00	497885380.00	677684740.00
2	0.15	0.756	654363648.00	494792930.00	1172477670.00
3	0.15	0.658	408977280.00	268909200.00	1441386870.00
Total			1815708480.00	1441386870.00	

The figures in the last column of the (Tab. 7) are calculated as the sum of the discounted capital investment for a certain year and all the discounted capital investments for the previous years. For example, the discounted capital investment with progressive total for the first year is calculated with the formula:

$$C_{1\gamma \text{ total}} = C_{1\gamma} + C_{0\gamma} \quad (13)$$

as C_{0γ} is the discounted capital investment on the stage going before the first year of the construction (year 0).

$$C_{1\gamma \text{ total}} = 497885380 + 179799360 = 677684740 \text{ rub.}$$

The discounted cash flow through the years is calculated in the same way. The results are presented in the (Tab. 8).

Table 8. Calculation of the discounted cash flow through the years (Petrogradsky District)

Year of investing (t)	Discount rate (E)	Discount coefficient (γ)	Cash flow through the years (C _t) [rub]	Discounted cash flow through the years (C _{tγ}) [rub]	Discounted cash flow C _{tγ} with progressive total [rub]
0	0.15	1.000	0.00	0.00	0.00
1	0.15	0.870	272356281.60	236831550.00	236831550.00
2	0.15	0.756	1361781408.00	1029702390.00	1266533940.00
3	0.15	0.658	817068844.80	537236030.00	1803769960.00
Total			2451206534.40	1803769960.00	

Then using the results of the (Tab. 7) and (Tab. 8) an income distributed through the years is calculated. The first is to define the income through the years not discounted. It is equal to the difference between the cash flow and the capital investment for the first year:

$$I_1 = R_1 - C_1 \quad (14)$$

$$I_1 = 272356281.6 - 572568192 = -300211910.4 \text{ rub.}$$

Then the discounted income through the years is calculated:

$$I_{1\gamma} = I_1 \times \gamma \quad (15)$$

$$I_{1\gamma} = -300211910.4 \times 0.870 = -261053830 \text{ rub.}$$

After that the discounted income with progressive total is calculated in the same way as capital investment and cash flow are done. All the results of calculation are presented in the (Tab. 9).

Table 9. Calculation of the income through the years (Petrogradsky District)

Year of investing (t)	Discount rate (E)	Discount coefficient (γ)	Income through the years (C _t) [rub]	Discounted income through the years (C _{tγ}) [rub]	Discounted income C _{tγ} with progressive total [rub]
0	0.15	1.000	179799360.00	179799360.00	-179799360.00
1	0.15	0.870	300211910.40	261053830.00	-440853190.00
2	0.15	0.756	707417760.00	534909460.00	94056260.00
3	0.15	0.658	408091560.00	268326830.00	362383090.00
Total			635498050.00	362383090.00	

The value of the discounted income with progressive total in the third year of the construction is called net present value (NPV). NPV for the residential building construction in Petrogradsky District is equal to 36238390 rub.

The other parameter that is a profitability index is calculated as a ratio of the discounted cash flow total volume (fifth column of the (Tab. 8)) to the discounted capital investment total volume (fifth column of the (Tab. 7)):

$$I_p = \frac{R_{total \gamma}}{C_{total \gamma}} \quad (16)$$

$$I_p = \frac{1803769960}{1441386870} = 1.251$$

Table 10. Calculation of the discounted capital investment through the years (Krasnoselsky District)

Year of investing (t)	Discount rate (E)	Discount coefficient (γ)	Capital investment through the years (C _t) [rub]	Discounted capital investment through the years (C _{tγ}) [rub]	Discounted capital investment C _{tγ} with progressive total [rub]
0	0.15	1.000	133652500.00	133652500.00	133652500.00
1	0.15	0.870	1180972800.00	1026932870.00	1160585370.00
2	0.15	0.756	1349683200.00	1020554400.00	2181139770.00
3	0.15	0.658	843552000.00	554649130.00	2735788910.00
Total			3507860500.00	2735788910.00	

Table 11. Calculation of the discounted cash flow through the years (Krasnoselsky District)

Year of investing (t)	Discount rate (E)	Discount coefficient (y)	Cash flow through the years (C_t) [rub]	Discounted cash flow through the years (C_{ty}) [rub]	Discounted cash flow C_{ty} with progressive total [rub]
0	0.15	1.000	0.00	0.00	0.00
1	0.15	0.870	491100470.00	427043890.00	427043890.00
2	0.15	0.756	2455502350.00	1856712550.00	2283756440.00
3	0.15	0.658	1473301410.00	968719590.00	3252476030.00
Total			4419904230.00	3252476030.00	

The discounted capital investment, cash flow and income through the years for the building construction in Krasnoselsky District are calculated in the same way. The results of calculation are presented in the (Tab. 10)-(Tab. 12).

Table 12. Calculation of the income through the years (Krasnoselsky District)

Year of investing (t)	Discount rate (E)	Discount coefficient (y)	Income through the years (C_t) [rub]	Discounted income through the years (C_{ty}) [rub]	Discounted income C_{ty} with progressive total [rub]
0	0.15	1.000	133652500.00	133652500.00	-133652500.00
1	0.15	0.870	689872330.00	599888980.00	-733541480.00
2	0.15	0.756	1105819150.00	836158150.00	102616660.00
3	0.15	0.658	629749410.00	414070460.00	516687120.00
Total			912043730.00	516687120.00	

Using the results of the (Tab. 10)-(Tab. 12) NPV and profitability index are calculated for the building construction in Krasnoselsky District in the same way. NPV = 516687120 rub; $I_p = 1.189$.

After all, one more cost efficiency parameter of the residential building construction is defined. It is a payback period. It is defined using the figures presented in the (Tab. 7), (Tab. 8), (Tab. 10), (Tab. 11). Then special cash-time diagrams are created with Microsoft Excel software which show how the values of the discounted capital investment and cash flow with progressive total change depending on the period of the building construction. These diagrams about the residential building construction in Petrogradsky and Krasnoselsky districts are shown in the (Fig. 1), (Fig. 2).

There are several bright examples which we can compare the results of our paper with. First of all, it has to be compared with [5,7]. The sources conduct the same cost efficiency analysis of residential building construction. The construction object is also meant to be one of the several types: site-cast concrete building, brick building, monolithic building with brick spandrel walls or frame-panel building. The authors of [5,7] define the economic feasibility in the same way calculating such parameters as NPV, profitability index and payback period. Their results for 25-storey monolithic building with brick spandrel walls are 257799640 rub (NPV), 1.067 (I_p), 3 years (payback period). The other source [27] results are 490889620 rub (NPV), 1,175 (I_p), 3 years (payback period). These figures are close to each other or they are of the same order. The difference of values is caused by different average construction cost and different land acquisition cost. It means the dwellings are constructed in different parts of the city.

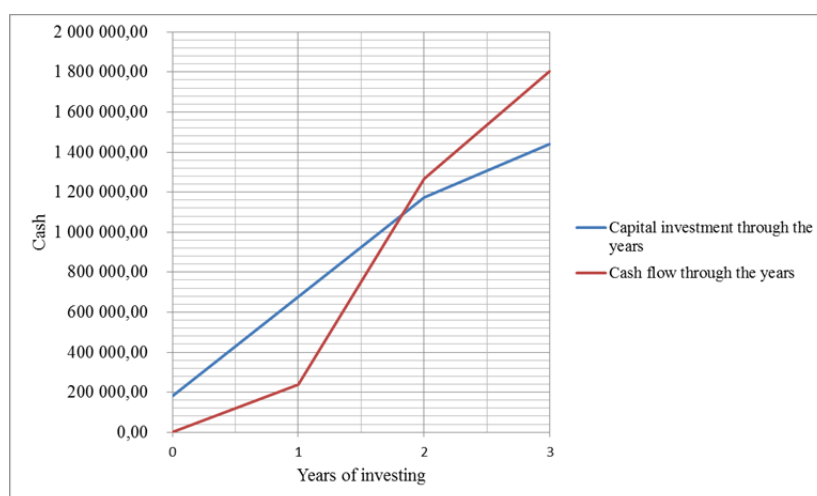


Figure 1. Cash-time diagram for defining the payback period of the residential building construction in Petrogradsky District

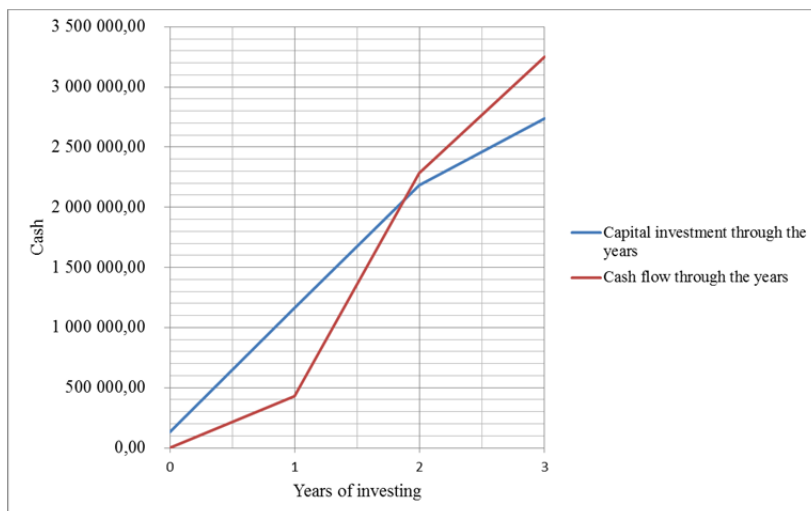


Figure 2. Cash-time diagram for defining the payback period of the residential building construction in Krasnoselsky District

4. Conclusions

Comparing the cost efficiency parameters of the residential building construction in two different parts of Saint-Petersburg it is possible to say that NPV for the construction in Krasnoselsky District is higher than that one in Petrogradsky District (516687120 rub. in comparison with 36238390 rub.). It is connected with a massive construction (that exactly means a number of floors) and the big amount of the capital investment. On the other hand, profitability index for the construction in Petrogradsky District is higher than that one in Krasnoselsky District because here the difference between cash flow and capital investment is bigger than the second one. It is caused by possibility to make planned savings for 1 m² of living space greater (that is exactly 50% in comparison with 40%). Also in the case of the construction in Petrogradsky District there is no need to deal with such a big amount of the capital investment because of the small amount of construction. The payback periods of the construction in both districts are equal because the construction periods are equal to each other (3 years). And the distribution of the capital investment and cash flow through the years in both districts has the similar percentage ratio.

The difference between the cost efficiency parameters is influenced by factors listed in the introduction. Every building site has its own cadastral value of 1 m² of land (the land of Petrogradsky District is much more expensive than that one in Krasnoselsky District). The second reason is the average construction cost for 1 m² of living space (that is approximately 84360 rub. in Petrogradsky District and 55680 rub. in Krasnoselsky District) that influence on the general estimated cost for the building construction. The other construction type of the building in Krasnoselsky District (the living space is bigger because the building is higher than that one in Petrogradsky District) gives the bigger value of NPV. On the other hand, sales profitability index of residential buildings in Petrogradsky District is higher than that one in Krasnoselsky District that allows to set the bigger planned savings for 1 m² of living space there and to increase the profitability index.

Considering all the parameters and taking into account some social, cultural and historical factors it becomes possible to conclude that nowadays the residential building construction is much more economically feasible if it is going on the outskirts (Krasnoselsky district) of the city where there is a possibility for massive construction and integrated urban development.

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Экономическая эффективность жилищного строительства в больших городах

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КЛЮЧЕВЫЕ СЛОВА

экономическая эффективность
строительства;
жилое здание;
срок окупаемости;
индекс рентабельности;
чистый дисконтированный доход;

АННОТАЦИЯ

В виду высокого уровня урбанизации территории под застройку существуют как в центре города, так и на его окраинах. Возникает вопрос экономической эффективности строительства жилых объектов в разных районах города. Задача статьи – провести сравнительный анализ экономической эффективности строительства жилого здания в центральном районе города и в районе, находящемся на его окраине. Для этого необходимо определить ряд параметров, характеризующих экономическую эффективность строительства подобных объектов, а также учесть факторы, которые влияют на эти величины и которые характерны для таких крупных городов, как Санкт-Петербург. К таким факторам можно отнести расположение объектов строительства в разных частях города, что сказывается на разнице высотных регламентов, средней стоимости строительства и стоимости земельных участков. По полученным результатам анализа будут сделаны выводы о том, почему в Красносельском районе (на окраине города) строительство можно считать более целесообразным с экономической точки зрения, чем строительство в Петроградском районе (в центре города). На основании этих выводов можно будет рассчитать экономическую эффективность строительства жилых зданий в любом районе Санкт-Петербурга, а также распространить результаты анализа на другие подобные крупные города.

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