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The cost modeling of urbanized areas

In the context of rapid urbanization and urban population growth, cities enjoy particular attention in the spatial development agenda. The complexity of searching for promising city-forming factors, as well as insufficient investments into the development process do not allow to found new cities in Russia. At the same time, the experience of a number of foreign countries shows that solving this problem is not only feasible, but also cost-effective. Researchers, specializing in urban planning, architects and urbanists offer various development models for urban areas, agglomerations, and urbanized territories. However, in most of their works, the issue of the amount of financing required for the basic infrastructure in such territories remains unexplored. The co-authors formulate the principles of economic and urban planning modeling of cities in an effort to clarify the concept of "urbanized territories". The proposed criteria for scenario transitions, that accompany the development of urbanized territories, will allow to use the available resources more efficiently. As recommended by the co-authors, the distribution of costs among the main subjects of formation of an urbanized territory on the basis of principal infrastructure blocks will prevent any excessive pressure on the country's budget system. As a result of the cost modeling focused on the development of an urbanized territory with the population of 500 thousand people, it has turned out that the per-resident investment amount, needed to found a new settlement, reaches about 7.16 million.

Keywords: *urbanized areas, development scenarios, infrastructure for daily living activities, city-forming factors, agglomeration, urban design*

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Modern development processes, expanding from local zones and territories to global areas, most often arise, unwind, build momentum and fade away in cities. Hence, the importance of cities increases at all stages of an economic cycle. In the conditions of a recession, cities neutralize the negative impact of deteriorating living conditions, during the periods of recovery, especially at the initial phases, cities become poles of growth.

The development of most cities is primarily associated with economic and social conditions that have a decisive impact on education and urban development. In terms of economic geography, these conditions are usually called city-forming factors. The most common city–forming factors are the availability of minerals in the immediate vicinity, the extraction of which, taking into account the available technologies, will be economically efficient and environmentally acceptable, a good transport location and the possibility of efficient use of existing natural resources, primarily renewables. Given these factors, elements, forming the environment of urbanized territories, are created; they include industrial enterprises, transport highways, administrative, scientific, educational, cultural and other institutions, including those of extra-urban significance [1].

Only 5 new cities have been built in Russia over the past 20 years[1]. At the same time, if the experience of the People's Republic of China is considered, one can notice that since 1950, an average of 7 new cities appear in this country every year. As a result, the level of urbanization has increased from 10.6 to 59.6 % there, cities are the country's new growth points providing 56 % of the total GDP [2, 3].

The proposal to found new cities in Siberia, made by the Minister of Defense of the Russian Federation, has enhanced the role of cities in the modern economic policy, sovereign territorial integrity and defense[2]. New cities will serve as large scientific, industrial and economic centres. However, the main problem, that hampers the implementation of this initiative, is uncertainty in the amounts, sources and dates of funding to be provided for these purposes. Some experts believe that the cost of new cities to be built in Siberia will exceed 10 % of the budget of the Russian Federation (that is, over 2 trillion rubles). At the same time, the construction of one city with the population of 300 thousand residents will cost about 1 trillion rubles, half of which will be spent on the construction of the engineering and transport infrastructure[3].

Given the increasing role of cities, the accelerated pace of urbanization and the emerging trends in the establishment of new and development of old cities, the co-authors consider it appropriate to investigate the issue of the cost modeling of urbanized territories, which has predetermined the purpose of this study.

In the generally understood that urbanized territories are large and complex spatial formations consisting of many closely located metropolitan areas — megalopolises, urbanized regions [4]. In the European countries, such territories are referred to as urban areas, or the area surrounding the main city with an increased population density comparable to the density of the main city and (or) different from the density of the surrounding rural space [5, 6]. In Russia, such territories are associated with an urban agglomeration, which means the territory of

1 The youngest cities in Russia. Vectorme. URL: https://vectorme.ru/europe/russia/samye-molodye-goroda-russia.

2 Siberia will grow into cities: from the idea of Sergei Shoigu to the embodiment. Kommersant. Krasnoyarsk. URL: https://www.kommersant.ru/doc/4997799

3 Experts named the cost of building new cities in Siberia. FederalPress. URL: https://fedpress.ru/news/24/society/2803480

a city united with the territories of other municipalities by stable social, economic and business ties [7].

In an effort to generalize the terminology, in the study the co-authors suggest that urbanized territories, demonstrating several city-forming factors, encompass the territory of a large city, taken together with adjacent settlements, which are closely functionally and spatially interconnected by common labour, financial, resource and other flows. As a rule, the centre of urbanized territories is a large city, while poles of local growth may be located in these territories. Sustainable value chains are formed within the boundaries of urbanized territories.

At the same time, one of the key conditions for classifying a particular territory as urbanized, in addition to common borders, is the density of the population permanently residing in the territory (DP).

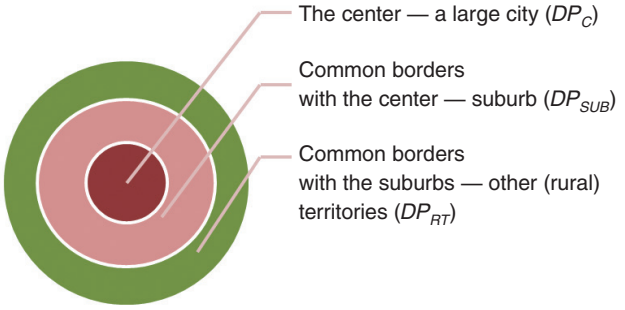
The principle of formation of an urbanized territory is shown in Figure, according to which (1):

$$\begin{cases} DP_C \geq DP_{SUB} \\ DP_{SUB} > K_D\, DP_{RT} \end{cases}, \quad (1)$$

where DP_C is the population density in the territory of a large city which is the centre of an urbanized territory, people/ha; DP_{SUB} is the population density in the territory of the suburb, which is within the boundaries of an urbanized territory, people/ha; DP_{RT} is the population density in the remaining (rural) territories which are beyond the boundaries of an urbanized territory, people/ha; K_D is the coefficient of the boundary population density, used to indicate the boundary of the transition from urbanized territories to rural ones and vice versa (in the study, the co-authors propose to take it as being equal to 1.5).

As of 2020, urbanized territories of Russia represent 129 agglomerations with a total population of about 93.5 million people (almost 64 % of the country population), occupying a total of about 700 thousand sq.km (only 4 % of the territory of Russia) [8]. In agglomerations, the population growth is concentrated mainly in agglomerations that have millions of residents and where a large city serves as the centre.

Specialists in urban planning research, architects and urbanists offer various development models for urban areas, agglomerations, and urbanized territories. V.L. Glazychev's works address the analysis of development of territories together with urban development problems: he considers the development of territories and evolution of the city as an organic whole [9]. Despite the fact that in his works the author presents a personal image of urbanization and development of the urban environment as a process, addresses the extensive foreign experience and suggests measures for the formation of comfortable urban infrastructure, the issue of the effective modeling of a high-quality environment in urbanized territories remains



The principle of urbanized territory formation

undiscovered. An urban development strategy based on "campus models", proposed by other researchers, as well as the modeling of urban development patterns using the theory of classical homogeneous structures do not take into account the features of our country and are not applicable to all types of territories [10, 11]. However, the issue of the required amount of financing of the basic infrastructure in urbanized territories remains unexplored by the basic theories and models of urban development.

Before proceeding to the cost modeling of urbanized territories, it is necessary to determine the strategy of their development in the territory of a country. The spatial development strategy of the Russian Federation for the period up to 2025 declares the development of large and largest urban agglomerations as the main focus [4]. This means that in the near future development is planned for 15–25 largest agglomerations with the population of 500 thousand people. From the point of view of economy, this approach is quite reasonable and logical. However, excessive centralization and consolidation of the country population in the context of its extensive territory involves geopolitical risks that threaten its territorial integrity. To mitigate possible risks, the co-authors propose to switch to decentralization and deurbanization of the western part of Russia with the even distribution of settlements across the territory.

Each city C_i consists of basic infrastructure elements: Social infrastructure S_i; Engineering infrastructure En_i; Public and business infrastructure P_i; Infrastructure of economic activities Ec_i; Housing infrastructure H_i; Transport infrastructure T_i.

The co-authors suggest that the modeling of the development of urbanized territories should entail different development scenarios, depending on the planned population size, and the target values are: 1) 300 thousand people; 2) 500 thousand people; 3) 750 thousand people; 4) 1,000 thousand people.

At the same time, the key is to develop step-by-step scenario-based transitions from small to big population numbers to ensure the sustainable development of an urbanized territory. Basic conditions for the transition to a new development scenario are:

1. Reaching maximum population numbers in an urbanized area (2):

$$H_i \rightarrow H_i^{\max}, \quad (2)$$

where H_i is the population number within the boundaries of an urbanized territory, people; $H_i^{\max}$ is the maximum population number entailed by the *i*-th development scenario, people.

2. Attaining the target value according to the evaluation criterion of capitalization of urban assets (3) [12]:

$$K_i^A = C_i^A \Big/ I_i > 1, \quad (3)$$

where K_i^A is the valuation criterion of the asset capitalization for the *i*-th development scenario (minimum value $K_{\min}^A = 11$); C_i^A is the total value of urban assets for the *i*-th development scenario, rub.; I_i is the total amount invested into the development of an urbanized territory for the *i*-th scenario, rub.

3. Generation of city-forming factors (clusters) in an urbanized territory in the process of its developent (4):

$$CF_i = CF_{base} + \left[CF_{add}\,(i-1)\right], \quad (4)$$

where CF_i is the minimum required list of core factors for the *i*-th scenario; CF_{base} is the basic city-forming factor that served as the basis for an urban area; CF_{add} are additional city-forming factors in different

4 Strategy of spatial development of the Russian Federation for the period up to 2025 : Decree of the Government of the Russian Federation dated 13.02.2019. No. 207-r.

areas necessary for the sustainable development of an urbanized area; *i* is the development scenario for an urbanized area (*i* = 1…4).

The general formalized cost model for the development of urbanized territories will be presented as formula (5):

$$C_i = \sum_{i=1}^{n} S_i + \sum_{i=1}^{n} En_i + \sum_{i=1}^{n} P_i + \sum_{i=1}^{n} Ec_i + \sum_{i=1}^{n} H_i + \sum_{i=1}^{n} T_i. \quad (5)$$

The structural elements of each infrastructure block are addressed in detail in Table that is used as a case modelling the cost of forming an urbanized territory with the population of 500 thousand people.

Having analyzed the Table 1 data, one can see that the total cost of building a new city with the population of 500 thousand people, including basic infrastructure elements, will amount to more than 3.58 trillion rubles, or 7.16 million rubles per future resident.

At the same time, it is noteworthy that when the infrastructure of economic activity is created, manufacturing enterprises with high-performance jobs must be the basis of this block of infrastructure and the city as a whole. This will allow not only to implement the task set by the President of the Russian Federation to the Federal Assembly of the Russian Federation in 2012, but also ensure the growth of the aggregate labour productivity, an increase in the standard of living, an increase in tax deductions, which will together affect the growth of the gross regional product. It is important to mention that the share of high-performance jobs in the total structure of jobs in a highly urbanized territory under the initial development scenario should exceed 60 % and gradually, in the process of transition to a higher-level scenario (*i* (*IX*) = 1,000 thousand people), this share will decrease, giving way to jobs in the industry of services offered to the local population.

The analysis of the breakdown of costs by infrastructure blocks shows that the largest cost share deals with the housing infrastructure (33.63 %), and the smallest one deals with the public and business infrastructure (0.31 %).

Given that the significant cost of building a new city in an urbanized territory, that entails a 1.5 budget overrun in terms of funds allocated from the federal budget each year and designated for national projects (from 2.2 to 2.7 trillion rubles for 2020–2023), it is necessary to provide co-financing tools together with private businesses. They should be based on the principles of mutually beneficial cooperation with a consensus of interests of both the public authorities (federal, regional, local ones) and business entities (small, medium, large ones), with regard for the opinion of society (residents, public organizations, non-profit organizations, etc.). The co-authors consider it appropriate to adhere to the following structure of financing activities when forming the cost part in the course of the cost modeling in an urbanized area (6):

$$\begin{cases} I_{UT} = \sum_{i=1}^{n} \left(I_{FB}^{i} + I_{RB}^{i} + I_{MB}^{i} \right) + I_{PB}^{i}; \\ \dfrac{\sum_{i=1}^{n} T_{UT}}{\sum_{i=1}^{n} C_{MI}} \geq 0, \end{cases} \quad (6)$$

where I_{FB}^{i} is the amount of the federal budget investments for the development of an urbanized territory in the *i*-th scenario, rub.; I_{RB}^{i} is the amount of investments from the regional budget for the development of an urbanized territory in the *i*-th scenario, rub.; I_{PB}^{i} is the amount of investments from the local budget for the development of an urbanized territory in the *i*-th scenario, rub.; I_{MB}^{i} is the amount of private business investments for the development of an urbanized territory in the *i*-th scenario, rub.; T_{UT} is the total amount of tax deductions within the boundaries of an urbanized territory in the *i*-th scenario, rub.; C_{MI} is the total cost of maintaining infrastructure within the boundaries of urbanized territories, rub.

The cost modeling of the urbanized territory development

No.	Element of the infrastructure block	The need per unit of measurement	The need for the entire urbanized area	The volume unit cost, thousand rubles[5]	The cost for the entire urbanized territory, million rubles
Social infrastructure S_i					
1	Pre-school education institutions	100 seats per 1 thousand inhabitants*	50,000	750	37,500
2	General education institutions	180 seats per 1 thousand inhabitants*	90,000	1,180	106,200
3	Educational organizations of higher education	170 students per 10 thousand people**	8,500	1,650	14,025
4	Professional educational organizations	270 students per 10 thousand people**	13,500	1,500	20,250
5	Urban-level healthcare institutions that provide assistance in hospitals	13.47 beds per 1 thousand people**	6,735	3,500	23,572.5
6	District-level healthcare institutions providing outpatient care	18.15 visits per shift per 1 thousand people**	9,075	1,510	13,703.25
7	Public gyms	200 sq. m of floor space for 1 thousand people*	100,000	53.0	5,300
8	Swimming pools	100 sq. m water mirrors for 1 thousand people*	50,000	93.5	4,675

Continuation of the Table

№	Element of the infrastructure block	The need per unit of measurement	The need for the entire urbanized area	The volume unit cost, thousand rubles[5]	The cost for the entire urbanized territory, million rubles
9	Planar sports facilities	1950 sq. m of the total area for 1 thousand people***	975,000	9.9	9,652.5
10	Universal sports and entertainment halls, including those that have artificial ice	9 seats for 1 thousand people*	4,500	2,540	11,430
11	Public (universal) libraries	1 per 100 thousand population***	5	230,000	1,150
12	Museums	4 items per city district***	4	128,000	512
13	Concert halls (houses of culture)	5 seats for 1 thousand people*	2,500	293	732.5
Total for block S_i					248,702.75
Engineering infrastructure En_i					
14	Power supply	2,640 kWh/year for 1 person*	1,320 GW	2,590	3,418.8
15	Heat supply	43.9 kCal per 1 sq. m^3	1,025 MW	340	348.5
16	Water supply and discharge	220 l/day. (6.6 cubic meters/month) for 1 person***	3,300,000 m^3/month	0.045	148.5
17	Gas stations	1 station for 1,200 cars***	125	4,650	581.25
18	General commodity warehouses for food items	77 sq. m for 1 thousand people*	38,500	25	962.5
19	General warehouses of non-food products	217 sq. m for 1 thousand people*	108,500	35	3,797.5
20	Landfills for solid waste disposal	300 kg per 1 person per year*	150,000 tons per year	4,015	602,250
Total for block En_i					611,507.05
Public and business infrastructure P_i					
21	City management institutions	1 item per city district***	9,450 m^2	39.2	370.44
22	Recreation and recreation facilities (parks, gardens, squares, boulevards)	10 sq. m/person*	500 ha	16,218	8,109
23	Municipal archives	1 item per city district***	3,000 m^2	43.0	129
24	District (city) courts	1 item per city district***	3,700 m^2	48.0	177.6
25	District department of internal affairs (2nd category, staff 300–450 people)	1 item for 150 thousand people*	4 items with a total area of 18,400 m^2	36.5	671.6
26	Housing and maintenance organizations	1 item per residential area with the population of up to 80 thousand people*	7 items with a total area of 9,100 m^2	36.5	332.15
27	Funeral service	1 item for 500 thousand people*	1 item with an area of 1,000 m^2	41.3	41.3
28	Fire depots	1 item per 100 thousand people*	5 type II fire depots for 6 cars	36,965 (for 1 car)	1,108.95
29	Wedding palaces	1 item per 200 thousand people*	3 items with a total area of 4,500 m^2	61.8	278.1
Total for block P_i					11,218.14
Economic activity infrastructure Ec_i					
30	Business centres	1 item per 250 thousand people****	2 items with a total area of 70,000 m^2	67.0	9,380
31	Shopping and entertainment centres	280 sq. m for 1 thousand people*	140,000	55.0	7,700

End of the Table

№	Element of the infrastructure block	The need per unit of measurement	The need for the entire urbanized area	The volume unit cost, thousand rubles[5]	The cost for the entire urbanized territory, million rubles
32	Consumer service enterprises	5 jobs per 1 thousand people*	2,500	2,500	6,250
33	Manufacturing enterprises (high-performance)	100 jobs per 1 thousand people*	50,000	20,980	1,049,000
34	Non-food trade establishments	70 sq. m for 1 thousand people*	35,000	65.0	2,275
35	Food trade institutions	30 sq. m for 1 thousand people*	15,000	75.0	1,125
36	Catering establishments	40 seats for 1 thousand people*	20,000	55.0	1,100
37	Bank branches	1 operating cash register for 30 thousand people*	5 items with a total area of 10,000 m^2	65.0	650
38	Hotels	6 beds for 1 thousand people*	3,000	1,100	3,300
39	Movie theatres	35 seats for 1 thousand people*	17,500	99.2	1,736
40	Theatres	8 seats for 1 thousand people*	4,000	3,459	13,836
41	Circuses	5 seats for 1 thousand people*	2,500	1,296	3,240
42	Pharmacy organizations	1 item per 13 thousand people*	39	2,500	97.5
Total for block Ec_i					1,099,689.5
Housing infrastructure H_i					
43	Residential buildings (including multi-apartment and individual housing)	40 sq. m for 1 person*	20,000,000	60.0	1,200,000
44	Municipal housing stock (1% of the population)	15 sq. m for 1 person*	75,000	55.0	4,125
Total for block H_i					1,204,125
Transport infrastructure T_i					
45	Streets and the road network	20 % of the built-up area of the city district***	21,200 ha*****	13,000	275,600
46	Automobile station	Passenger capacity with an estimated daily departure from 4,000 to 6,000**	250	1,000	250
47	Railway station	1 item per city[4]	1	15,000,000	15,000
48	Airport	1 item per city****	1	19,000,000	19,000
49	Metro	1 station per 100 thousand people****	5	19,000,000	95,000
Total for the block T_i					404,850
In total, in an urbanized area with the population of 500 thousand people					3,580,092.44

** The need was determined in accordance with SP 42.13330.2016[5].*

*** The need was determined in accordance with Resolution of the Government of the Krasnoyarsk Territory No. 631-p[6].*

**** The need was determined in accordance with Decision of the Krasnoyarsk City Council of Deputies No. V-299[7].*

***** The need was determined in accordance with [13];*

****** The cost was determined on the basis of data on similar items, as well as in accordance with Order of the Ministry of Construction and Housing and Communal Services of the Russian Federation No. 120/pr; 123/pr; 124/pr; 125/pr; 128/pr; 129/pr; 131/pr; 132/pr; 136/pr; 137/pr; 139/pr[8].*

5 Urban planning. Planning and construction of urban and rural settlements : (SP 42.13330.2016) : approved by Order of the Ministry of Construction and Housing and Communal Services of the Russian Federation No. 1034/pr dated 30.12.2016 with amendments and additions in ed. from 03.20.2020.

6 On approval of regional standards of urban planning design of the Krasnoyarsk Territory : Resolution of the Government of the Krasnoyarsk Territory dated December 23, 2014. No. 631-p.

7 On approval of local standards of urban planning design of the Krasnoyarsk city district : Decision of the Krasnoyarsk City Council of Deputies dated 04.09.2018. No. V-299.

8 On approval of enlarged Construction Price Standards : Order of the Ministry of Construction and Housing and Communal Services of the Russian Federation dated 11.03.2021. No. 120/pr; 123/pr; 124/pr; 125/pr; 128/pr; 129/pr; 131/pr; 132/pr; 136/pr; 137/pr; 139/pr.

At the same time, we propose to distribute costs among the main subjects of formation of an urbanized territory with regard for basic infrastructure blocks (7–10):

$$I^i_{FB} = C^i_S + 0{,}8C^i_{En} + 0{,}2C^i_{Ec} + C^i_T, \quad (7)$$

$$I^i_{RB} = C^i_{PI} + 0{,}2C^i_{En} + 0{,}2C^i_H, \quad (8)$$

$$I^i_{MB} = C^i_P + T^i_{UT}, \quad (9)$$

$$I^i_{PB} = 0{,}8C^i_{Ec} + 0{,}8C^i_H, \quad (10)$$

where IC^i_S is the amount of costs of creating social infrastructure in the *i*-th development scenario, rub.; C^i_{En} — is the amount of costs of creating engineering infrastructure in the *i*-th development scenario, rub.; C^i_T is the amount of costs of creating transport infrastructure in the *i*-th development scenario, rub.; C^i_{PI} is the amount of costs of creating public and business infrastructure in the *i*-th development scenario, rub.; C^i_H is the amount of costs of creating housing infrastructure in the *i*–th development scenario, rub.; C^i_P is the amount of costs for the population living within the boundaries of an urbanized territory in the course of their life, rub.; C^i_{Ec} is the cost of creating the infrastructure for the economic activity in the *i*-th development scenario, rub.

In the context of an emerging design and construction trend, the cost modeling of the development of urbanized territories, with account taken of an integrated approach to the formation of their infrastructure based on different scenarios and the proposed criteria for scenario transitions, will serve as an incentive for the sustainable development of not only these territories, but also the country as a whole, since more than 75 % of Russia's GDP is created by cities. Synchronization of existing and prospective state programs at all levels of management with the involvement of private investors and the formation of special tax regimes in urbanized territories will help to neutralize the "shock" effects that the country's budget is exposed to.

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Стоимостное моделирование урбанизированных территорий

В условиях стремительной урбанизации и роста городского населения особое внимание в повестке пространственного развития уделяется городам. Сложность поиска перспективных градообразующих факторов, а также недостаток инвестиций в развитие не позволяют создавать в России новые города. При этом опыт ряда зарубежных стран показывает, что решение данной проблемы не только возможно, но и экономически эффективно. Учеными-градостроителями, архитекторами и урбанистами предлагаются различные модели развития городских территорий, агломераций, урбанизированных территорий. Однако в большинстве их работ не изученным остается вопрос необходимого объема финансирования базовой инфраструктуры на такого рода территориях. Уточняя понятие «урбанизированные территории», авторы в статье формируют принципы их экономико-градостроительного моделирования. Предложенные критерии сценарных переходов при развитии урбанизированных территорий позволят более эффективно использовать имеющиеся ресурсы. Рекомендованное авторами распределение затрат среди основных субъектов формирования урбанизированной территории по базовым инфраструктурным блокам позволит избежать чрезмерной нагрузки на бюджетную систему страны. В результате стоимостного моделирования развития урбанизированной территории с населением 500 тыс. чел. выяснилось, что при создании нового поселения на одного жителя необходимо порядка 7,16 млн руб. инвестиций.

Ключевые слова: *урбанизированные территории, сценарии развития, инфраструктура жизнедеятельности, градообразующие факторы, агломерации, проектирование городов*

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