

Volume-planning and town-planning organization of mixed residential development in the complex development of the territory

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Abstract. The study is devoted to the issues of forming the concept of a mixed residential environment. The relevance of the research topic is due to the growth in housing construction in commuter belts of megacities and adjacent territories. Relevance of the study is also substantiated by such prerequisites as uneven distribution of housing among various categories of citizens, problems of territory insecurity with the whole complex of infrastructure necessary for the population, problems of significant territorial remoteness of jobs from places of residence. Moreover, a faceless, depressing and largely anti-human environment is created during the development of large territories due to the architecturally unattractive, heterogeneous, non-ergonomic high-rise high-density buildings. All the above-mentioned reasons cause the necessity for searching for new methods of organizing residential development that is comfortable for citizens and cost-effective for the developer. The scientific novelty of the study is to justify and define an integrated approach to understanding mixed residential development, to propose the principles, methods and tools of mixed residential development in the integrated development of the territory in the commuter belts of the metropolis, based on the most progressive foreign analogues studied. Also, scientific novelty lies in studying the index of mixed use according to the world analogues of the projects of Integrated Territory Development and recommendations on implementing this approach in Russia when planning projects of the Integrated Territory Development (ITD).

1 Introduction

The relevance of the research topic is due to the growth in housing construction in the commuter belts of St. Petersburg and the adjacent territory of the Leningrad Region, in conjunction with such prerequisites as uneven distribution of housing among various categories of citizens, problems of territory insecurity with the whole complex of infrastructure necessary for the population, problems of significant territorial remoteness of jobs from places of residence. Moreover, a faceless, depressing and largely anti-human environment is created during the development of large territories due to the architecturally

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unattractive, heterogeneous, non-ergonomic high-rise high-density buildings. All the above-mentioned reasons cause the necessity for searching for new methods of organizing residential development that is comfortable for citizens and cost-effective for the developer.

2 Literature review

The theoretical foundation of the study includes learned works of Russian and foreign architecture scientists, urban planners (including scientific dissertations), the results of socio-psychological research (Russian and foreign) in the field of urban planning. According to the analysis of domestic scientific literature sources, the problems of developing mixed residential housing in the conditions of undeveloped land invasion are clearly not studied enough by Russian scientists. Learned works of such domestic researchers as Khegay I.V. should be paid attention to (emphasis on mixed use development as a tool for overcoming population segregation by mixing the population with various incomes and social statuses). There are also learned works of such Russian scientists as Ikonnikov A.V. (explored methods of mixed use development in England), Zhogoleva A.V. (social address of designing the mixed residential development), Zakirov R.S., Vorontsova A.V. (on mixed zoning of the territory), as well as the works of Bokov A.V., Molchanov V.M., Trukhacheva G.A., Dektereva S. A., Vinnitsky M.V., Abdullaeva T.N., Skoblitskaya Yu.A., in which the features of multifunctional residential complexes were studied (considered in this study as one of the types of mixed residential development).

Modern trends in developing the peripheral zones of agglomerations and polycentric urban structures were studied by Denisenko E.V., Pomorov SB, Zhukovsky R.S., Prokhorskaya E.G., Limonov L.E., Batchaev A.R., Panasyuk M. V., Rudenko A.I., Sirina D.A., Zelikson D., Khmeleva G.A. Various aspects of integrated territory development are considered by Tyulyaev O.N. (aspect of financing ITD projects), Voinov D.S. (aspect of developing the public-private partnerships in ITD projects), Shishov D.A. (socio-economic aspect), Orlova M. (ITD as a principle of territory development), Aranovskaya M. (aspect of standardizing the ITD projects), Nurullina E.I. (aspect of forming the new residential environment), Peshina E.V. (features of "greenfield" and "brownfield" projects).

Features of designing a residential environment for various categories of the population, taking into account social and psychological parameters of the environment, are studied by Krasheninnikova A.V., Anisimova L.V., Bazhenova E.S., Nefedova V.A., Badamyan I.A., Grebenshchikova K.N., Durmanova V.Yu., Kartashova K.K., Ovsyannikova V.A., Whole E.A., Trutneva E.K., Safarova M.D.

Issues of the evolution of residential housing and urban quarters in different countries are addressed in the studies of Gutnov A.E., Bocharova Yu.P., Gabidulina S.E., Krasheninnikova A.V., Fedchenko I.G., Revzina G.I., Arakelyan R.G., Minulina I., Alekseeva S. The evolution of residential development in St. Petersburg is considered in the works of Sementsov S.V., Nikonorov P.N., Usanova K.Yu., Yurkova Z.V., Bukharkina P.E., Pervushina E.V., Kozyreva E.I., Gorshkova S.A.

In foreign scientific literature, studies on mixed residential development and integrated territory development are presented much more widely than among domestic researchers. Thus, learned works of the following authors should be noted among foreign studies on mixed residential development: Adrienne Schmitz (on compact solutions for mixed housing development); Phillips Alan (on best cases of mixed residential development); Mateo Babiano (on vertical mixed development); Johnson S. and Brophy P.S. (on socially mixed development); Michael Gentin and Scott Siegel, Caleb Sakei, James R. DeLisl, Terry W. Grissom, Joseph Rabyanski, Brazeuill Studi, Nancy A. Miller J., Jacobs D. (about mixed multi-functional development). Moreover, the following studies of foreign researchers

should be noted: Ndjagi R.V., Cryer L., Freya H., Goldhorn B. - on urban development using “urban blocks”; J. Hyde (on “greenfield” development projects), Jeff Speck (on the concept of a “walking city”), Ellen Dunham-Jones and Maria J. Pezzi (on the future of peripheral areas and suburb modernization).

1.1 Factors, which determine developing the principles of urban planning organization of mixed residential development with the integrated territory development in the peripheral areas of the metropolis and adjacent areas

The spatial characteristics of mixed residential development in terms of impact on people, the urban development principles of creating the *mixed residential environment* depend on a complex of *external and internal factors*. *External factors* are objective indicators affecting the living environment, further modification of which does not depend on interaction with a person or society. Insolation, urban planning, technical and economic aspects can be distinguished among them. *Internal factors* are subjective indicators affecting the living environment through interaction with a person or society [1].

Next, external and internal factors are to be considered in more detail.

1. The insolation factor is an important factor that has a beneficial effect on the well-being of a person, and should be used both in residential and public buildings, as well as in residential areas. It is necessary to take into account the normalized insolation time when designing spatial characteristics. The standardized duration of continuous insolation for the premises of residential and public buildings is set differentially depending on the type of apartments, the functional purpose of the premises, the planning zones of the city, and geographical latitude.

2. City-planning factors are related to the location of the development site in the city structure and include the following main categories: 1) Location in the planning structure of the city; 2) Type of building plot (there is a development/has not been developed before); 3) The size of the building plot; 4) The system of city-planning regulation of the rules of land use and development, depending on the location in the planning structure of the city; 5) Noise factor.

The location in the planning structure of the city, depending on the size of the building plot, through the system of urban planning regulations determines the development density indicators (land-to-building ratio is the ratio of the area occupied by buildings and structures to the area of the plot (quarter); floor area ration (FAR) is the ratio of the area of all floors of buildings and structures to the area of the plot (quarter)), altitude indicator, maximum tallness.

3. Technical and economic factor is associated with restrictions defined by the set of regulatory documents and terms of reference, as well as effectiveness for the developer.

Systems of regulatory documents affect spatial characteristics through a system for regulating fire breaks between buildings, a turnaround area for a fire engine, which largely determines the intervals between buildings, providing access to the building for evacuating residents. In addition, it should be noted that the construction of multifunctional buildings and complexes (vertically mixed multi-functional development as one of the types of mixed territory development) is regulated by the Code of practice. The following parameters should be highlighted among the important aspects of the terms of reference affecting the humane spatial characteristics of the living environment: total above-ground building area - affects the density, percentage and nature of territory development, number of storeys, geometry of residential premises; total living area; the number of living units (apartments), which determines the economic efficiency of the project; the number of additional functions, which affects the intensity of social connections.

Often, the economics of the development project comes to the fore due to desire of the developer to maximize benefits. As a result, a stereotype is formed - the higher the number of storeys, the greater the profit the project will bring. However, there are many examples that refute this point of view. Quarterly development of 9-storey buildings can give even more square meters than high-rise buildings. For example, according to the leading architectural magazine Project-Russia, a quarter of panel high-rise buildings (17 and 22 floors) with a density of 19.6 thousand square meters was compared with 6 quarters with 9-storey houses, the building density in the second case was more - 24 thousand square meters [2].

As internal factors that determine the development of the principles of urban planning organization for mixed residential development in the integrated territory development, the following factors can be distinguished: 1) the socio-psychological factor of the perception of the living environment; 2) the visual factor of the perception of the visible environment; 3) the behavioral factor of the perception of the living environment.

The socio-psychological factor is associated with the genetic aspect of perception (the stimulus energy and previous knowledge affect the perception of the visible environment), human needs (safety, socio-territorial connections, aesthetic needs). The visual factor is one of the key factors that determine the humane spatial characteristics of living space. The size and structure of the environment give a basic feeling about the well-being of a person in the environment. The behavioral factor is associated with forms of human behavior (communication, movement, stay, action), the geometry of socio-territorial ties, the movement speed of the inhabitant. An important aspect in the relationship between spatial elements and social activity is human behavioral needs. The nature of human movement is one of the key factors that determine the spatial characteristics of the street, as the main element of socio-territorial communications. The movement speed of a resident is an important factor affecting the size of the quarter, the dimensions of the inner courtyard space and the residential unit, as well as the activity of social and territorial contacts, in the context of compactness and high development density.

When designing a living environment, it is advisable to focus on slow and arbitrary pace of movement.

2 The principles of organizing the mixed residential development in the integrated development of the peripheral territories in the metropolis

A polycentric agglomeration structure is more preferable for a city like St. Petersburg than a monocentric one. Meanwhile, a polycentric structure can be formed only under the condition of the active development of the peripheral zones of the city, their functional self-sufficiency and economic development. It is, in turn, possible with the integrated development of peripheral territories with the aim of forming a mixed living environment.

Table 1. Comparison of the main housing construction types

Key Features	Dwelling house	Residential complex	Residential quarter	ITD
The area of housing being built, thousand square meters	Up to 25	70 – 100	150 – 200	More than 200
Unified development concept, unified architectural style	-	+/-	+	+
The presence of social (schools, kindergartens, polyclinics, libraries), public-business and shopping facilities	-	+/_	+	+

Development of inherent engineering and transport infrastructure	-	-	+/-	+
Development of public spaces	-	-	+/-	+

Thus, the basis of the analytical model of city-planning organization creating mixed residential development along with the integrated territory development is the basic principles (guidelines) for developing the mixed residential environment. Those principles are developed on the basis of an integrated approach to the initial issue, introduced in the first chapter, in conjunction with the factors considered in the previous section, as well as taking into account the productive patterns formed after analyzing the international practices. Sustainable development is recognized as one of the fundamental principles of new urbanism. It implies a process of economic and social changes, in which the exploitation of natural resources, the direction of investments, the orientation of scientific and technological development, personality development and institutional changes are coordinated with each other and strengthen the present and future potential for human needs and aspirations [3]. The proposed principles for developing the mixed residential environment in the integrated development of peripheral territories are ultimately aimed at the vector of sustainable territory development.

Based on the theoretical studies carried out within the framework of the research, it seems appropriate to highlight the following basic principles for the formation of a mixed residential environment, which can be recommended for implementation in the integrated development of the peripheral territories in metropolis:

1. The principle of efficient use of territories and infrastructure by providing people with everything necessary as close as possible to their places of residence. The presence of various functions within the boundaries of quarters and districts will contribute to the development of the economy, services and will not create dead office zones in the evenings, for example. Such an approach allows saving significant areas and satisfying the increased demand for housing in the city center and housing located near the places of employment. All this entails a decrease in traffic due to the increase in pedestrian accessibility of places of employment and a decrease in the number of trips by personal vehicles [4].

2. The principle of humanity and aesthetic appeal of the environment - a positive psycho-emotional perception of the surrounding reality (including the architectural environment) is very important for a person to form a feeling of comfort and satisfaction with the quality of the living environment.

3. The principle of effective organization of the road network and transport accessibility - developing an adequate level of the street network is important both for the formation of traffic flows and for attracting pedestrians and cyclists. In addition, a street network with arterial routes and local streets based on various speed determines the development structure of neighborhoods, streets, buildings, open spaces and landscape.

4. The environmental safety principle - varying degrees of well-being and cultural priorities of social groups imply their level of security and spatial isolation, which should be taken into account while developing the measures for safe environment, typical for various urban models. It is necessary to implement various spatial approaches to designing internal and external zones, due to the fact that in most residential entities, especially in our country, the quality of the internal space is identical to the external one. In most cases, this determines the confusion and spatial disorientation of residents.

5. The principle of bio-ecological sustainability of the environment implies the ability of the natural framework to maintain its structure and functions in the process of exposure to internal and external factors.

6. The principle of environmental economic sustainability implies the formation of such a mixed residential environment, which will provide the maximum number of residents of each quarter and the entire complex of developed territory as a whole with a sufficient

number of places of employment in order to avoid the spontaneous process of commuting. Such an environment also creates favorable conditions for business development by placing large business zones at the level of the whole complexly developed territory, it will also provide the opportunity to develop zones for small businesses in the community [5, 6].

3 Mixed territory use index as an important tool for mixed residential development in complex developed areas

Statutory regulation of the land use distribution (the structure of the developed territory as a percentage of development, of the road network, recreational zones and beautifying), as well as statutory regulation of the share of commercial areas in the general development structure ensures compliance with the principle of economic stability of the territory by establishing a balance of functions. Such regulation is possible through developing and implementing the Mixed-use Index.

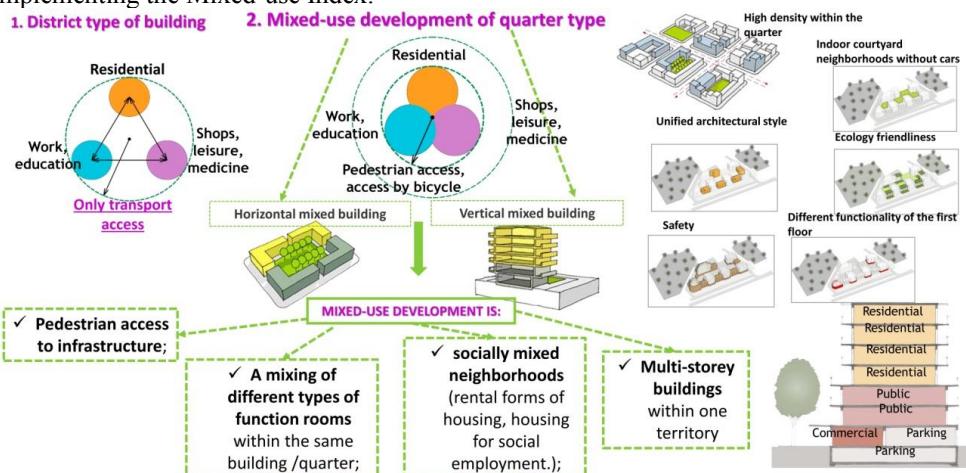


Fig. 1. Mixed-use development

The territory mixed-use index can be considered as an important tool for organizing mixed residential development within complexly developed peripheral areas. Analyzing the idea and possible adopted values of this index seems necessary and logical within the framework of the study. The results of studying the possible values of the mixed-use index based on the example of Holland are reflected in the learned works of urban researcher Just van den Hoek. In one of his studies, Just Van den Hoek notes that modern urbanization processes are accompanied by a reassessment of mixed use for developing the right conditions for urbanism, economics, consumption and the desire for compactness, contributing to sustainability. However, at the same time, since the theoretical rationale for mixed use is ambiguous (fragmented) regarding planning and development and does not give an understanding of what a good combination is, it remains unclear exactly how to use mixed development as a tool for planning strategy. In most mixed use studies, the task sharing is usually proclaimed as an ideology without specifying specific mixing proportions. Just Van den Hoek concludes that historically, in the central part of cities such as Amsterdam and Barcelona, the ratio of residential and non-residential functions is maintained in the proportion of 50% to 50%.

According to the research considered, the mixed-use index of the territory is two-part, the floor area of residential and non-residential use is expressed as a percentage of the total area in a specific district. According to this approach, the mixed-use index is equal to “the

share of residential areas" (%) / "the share of non-residential areas" (%) [7]. Such two-part approach (and the three-part approach considered below) follows the logic of urban density indexing of buildings (floor area index) - FAR, which is defined as the area divided by the land plot area. Mixed-use indexation is based on the ratio of the areas occupied by two (or three) elementary functions in the area.

Other (more recent) studies on the mixed-use index [8] are based on a different approach to understanding mixed use (the approach of the Urban Land Institute ULI), according to which, the term "mixed use" usually refers to the coexistence of three or more uses that bring significant income [9]. *Mixed use of territory (mixed development)* is defined there as a combination of three elementary urban uses, three following categories: "housing", "work" and "social amenities". Thus, the mixed-use index is represented by the following formula: the mixed-use index is equal to "the share of residential areas" (%) / "the share of workplaces" (%) / "the share of social security areas" (%). This method of defining mixing results in three percent values, which together make up 100%. The main difference between the categories of "workplaces" and "commercial amenities" is that there are more visitors in "amenities" than in workplace areas. The mixed-use index measures a functional mixture based on the share of the gross area of residential premises, workplaces, and commercial amenities occupying all the premises of city blocks. The "housing" category covers various types of residential buildings, including flats, apartments, semi-detached houses (townhouses). The category of "workplaces" includes offices, all types of industries and laboratories. The "amenities" category includes commercial activities (such as retail), educational activities (such as schools and universities), and leisure activities (such as stadiums, cinemas, and museums). Thus, according to the above-mentioned study [8], if the whole city is considered as one district, 60% of the existing space in Amsterdam is occupied by a residential function, 25% by workplaces and 15% by amenities. The share of housing, workplaces and amenities determines the liveliness and movement in the development area during the day and evening, the number of amenities affects the number of visitors and flows in the area. It is assumed that if a district has three equal amounts of each function, then one can expect diversity and revitalization in that area. Thus, in the considered study, a hypothesis is put forward that the optimal ratio of functions for mixed use of the territory may be a proportion closer to the following: the mixed-use index is equal to the ratio "housing" (33.3%) / "workplaces" (33.3%) / "amenities" (33.3%). Within the framework of this study, it is not possible to conduct such an analysis on the example of Russian cities. However, it seems obvious that a hypothetically optimal ratio of functions of 33% to 33% by 33% is unattainable in the existing Russian realities, as investors are not interested in reducing the share of residential development. According to the sustainable development principles of the territories of the international organization UN-Habitat [10], at least 40% of the constructed area in the developed territory should be allocated for economically viable use, monofunctional zoning should be reduced to no more than 10-15% of the total developed area [4].

Table 2. Features of ITD projects for residential development purposes

No.	Characteristic	In Russia	In the west
1	Responsible for laying all utility networks	Developer	Network Monopolist
2	The area of the ITD territory developed in the project	There are various approaches – from 10 ha, from 20 ha, from 50 ha, from 100 ha	From 500 acres (about 200 ha)
3	Functions that are maximized in the project	Housing, social and commercial infrastructure	Integrated approach – housing, social, commercial, transport infrastructures, open

			public spaces, workplaces
4	Duration of the territory development phase	10-20 years	5-7 years
5	Implementing the principles of mixed-use development in the development of the territory	Rare and random	Often, as this is one of the basic principles of new urbanism

Inexperienced urban planners, municipalities give up to 80% for residential development and present the project as mixed-used development, but it is virtually not. Nevertheless, it should be noted that it is actually quite difficult to convince the investor to abandon the stand of maximizing profits by erecting the maximum number of residential premises and switched to mixed-use development. Since the responsibility for the functionality of territory is not fixed by law, there are no regulations on the diversity of the territory, and existing norms and standards are interpreted towards mono-use. Therefore, local governments should be under a commitment of monitoring the functionality of the territory and designating the minimum necessary functional balance at the level of land use and development rules [11]. Vienna (Austria) can be used as a successful example, where the ratio of functions in each project is discussed with developers, representatives of city departments and local deputies. Sometimes contracts are concluded between the city and the developer, establishing the functional balance of the project [11].

3.1 Urban-block as a basis for a typology of mixed-use housing quarters of an integrated developed territory

The quarter was adopted as the planning unit of development within the framework of the research, and the use of the term “urban-block” was proposed as the basic unit of the mixed-use housing quarter. It should be noted that this term has long been used in city-planning in Europe. In Russia, the longer and more cacophonic phrase “group of residential buildings of the perimeter type” was used before “urban-blocks”. Currently, urban-blocks have gained relevance for Russia. In particular, according to the draft Regional Standards for Urban Planning of the City of Moscow, the renovation of Moscow quarters will be carried out using perimeter development of the quarter type, the urban-block also being the minimum unit of such development. According to the draft Regional Standards for Urban Planning of the City of Moscow, a microdistrict cannot have a radius of more than 500 m, no more than 300 m for a quarter, and no more than 100 m for an urban-block . Within the framework of the study, basic element of quarterly development is understood as “urban-block”, including residential buildings, house territories and built-in and attached service facilities. “Urban-block” is a kind of city-planning unit, which includes a residential building with day-to-day maintenance facilities on the ground floors and a courtyard with landscaping, areas for quiet relaxation and fire passages, closed to outsiders. A quarter is formed out of these urban-blocks, which also includes public areas with intra-quarter driveways, parking lots, recreational areas and intra-quarter landscaping, kindergartens, and day-to-day maintenance facilities. A clear division of space into private and public is extremely important for this approach. Private space includes a courtyard accessible only to residents of the urban-block, and public space includes recreational areas, intra-quarter driveways and social infrastructure facilities. The main feature of private territories is the absence of transport, except the special one [12]. Foreign scientists define the urban-block as part of the city territory that is isolated from the neighboring territory parts by streets; a typological element that can generate urban space, but one that can also remain uncertain and is determined by the order of the city structure of streets and squares and can consist of

one building or several buildings grouped together. Geographically, the urban-block is the smallest land planning area, surrounded by a continuous network of roads and streets [13].

Several types of urban-blocks are proposed within the framework of this design model, the first one is punctiform, which is one or two residential buildings (or "hotspots") and the territory adjacent to them. The privacy and inaccessibility of this territory for outsiders and vehicles is provided by fences. The second one is mixed, it implies the joint placement of ribbon and punctiform types of development, taking into account their features. The third one is ribbon with a closed building outline, in this case, the public and private spaces are separated by the frontage. The forth is ribbon with an open building outline, when fences that cover the distance between the houses can be used to separate the private space. The mixed type of urban-block allows diversifying the environment. The so-called "Open block" by Christian Urvoi de Portzamparc [14] is an analogue of the mixed type of urban-block.

Table 3. Typology of approaches to integrated territory development in the world

American Approach (USA, Canada)	Asian approach (Singapore)	European approach (Germany, Spain, France)
<ul style="list-style-type: none"> - continuous development of new territories; - global restructuring of residential quarters that have turned into slums, and abandoned industrial zones, actively operating in the 1960s; - priority in the construction of small residential complexes, where houses with a separate entrance to the apartment from the street prevail. 	<ul style="list-style-type: none"> - rationality and clear territorial zoning, separate administrative, dormitory districts, historical area, shopping and entertainment areas; - preference is given to mid-rise houses (5-12 stories) with their own territory. 	<ul style="list-style-type: none"> - polycentric structure of cities; - the feeling of closed territory due to architectural and planning solutions; - focusing on individual person in the design of residential areas, an individual approach.

In addition, the urban-block can be of ***two types - static and flexible***. Static involves building into a standard (for the developed model) rectangular urban-block. A flexible urban-block appears when additional design conditions are imposed, for example, a new diagonal boulevard. The theoretical model of city-planning organization of mixed-use residential development in case of the integrated territory development in the peripheral zones of the metropolis is based on the formation of mixed-use development quarters formed by urban-blocks using the main tool of the function balance method, which is the mixed-use index.

4 Analytical model of city-planning organization of mixed residential development in the integrated territory development in the peripheral zones of metropolis

The development of a universal analytical model allows clearly demonstrating the method of developing the peripheral territories of the metropolis, which was derived on the basis of the collected and developed information. The final theoretical model is the result of analytical summation of the most universal and effective patterns identified in international practice, which work according to adapted principles, embodied in five main areas (mixed-use residential environment, an integrated approach to the territory development, the development of public transport, walking distance, a sufficient amount of recreational green areas). The theoretical model is formed on the basis of six above mentioned principles.

The applied meaning of the theoretical model will, to some extent, be universal for the integrated development of the metropolis peripheral territories with the goal of creating a mixed-use living environment for the sustainable territory development. A feature of the developed theoretical model for integrated territory development is the formation of an adaptive structure of quarterly development based on the principles of a mixed-use environment, which allows taking into account the diverse and time-varying needs of residents.

The developed theoretical model consists of *six layers*: transport matrix, green infrastructure, engineering structure, layer of quarter blocks, layer of functional content, pedestrian networks.

4.1. The first layer – transport matrix.

Considering the transport matrix, the road network, the public transport network and the place for storing the personal vehicles should be singled out. *Road network*. The construction of roads (highways) that connects the developed area with other city areas and remote territories is supposed to be taken away to the borders of the developed area (along the perimeter of the developed area) in order to reduce noise and air pollution from a major highway. The territories of the commuting belts of the largest cities have low transport accessibility. A permeable, end-to-end network of streets and roads allows connecting an integrated developed territory to highways framing it, thus connecting the commuting belts to the busy part of the city. Walking and cycling are preferred, so the road network should be frequent enough to create pedestrian yards that are closed to vehicles. A system of bikeways is laid throughout the developed territory along each quarter, in addition, parking spaces for bicycles are provided. *Public transport network*. In order to reduce the movement of residents by private transport, it is planned to develop a convenient and dense public transport network, which includes bus routes, as well as a bicycle rental network operating as a collective transport. Every urban-block and every quarter is surrounded by bicycle paths. High-speed light rail transport will provide convenient access for residents of the new district to the city center. *Storage locations for personal vehicles*. The semi-buried parking lots are preferred for a integrated developed territory, due to the fact that building half-buried parking is more economically feasible than underground and more rational than ground. In the case of semi-buried parkings, the terrestrial territory is preserved for mixed-use residential development. Parkings should be constructed under each urban-block, in addition, a guest car parking should be provided (in central zone or along the border) on each main road between blocks.

4.2. The second layer – green infrastructure.

Green infrastructure is necessary for improving the ecology of the urban environment, for visual and aesthetic diversity, as well as for ensuring the division of space into private, semi-private and public. It is important to plan the deployment of green infrastructure after the development of the transport matrix for understanding the limitations on laying of utility networks. There are several following development trends of green infrastructure: 1. preserving the existing large green spaces, such as reserves and forest parks (if available within the boundaries of the developed territory); 2. development of green infrastructure, the creation of new parks, squares and alleys as a system of green corridors connecting parks and squares with each other, creating favorable pedestrian zones and an effective ecosystem with the inclusion of public functions (such as fitness centers, educational institutions for children of preschool and school ages, leisure facilities, sports facilities for adults and children). 3. The landscaping system along the highways, alley planting of low trees and

shrubs along the traffic serves as a noise protection and protection against air pollution. Green infrastructure is also included in the network of pedestrian spaces, providing a cozy natural environment. The creation of recreational park areas for residents of the entire district will increase the comfort level of the district territory.

4.3. The third layer – engineering structure.

In the case of integrated development of a large territory, it is necessary to provide it with a system of utilities that will be pre-connected to the territory prepared for new construction. *Engineering equipment* consists of the main utility systems, such as sewerage (including storm sewer networks), water supply, gas pipelines, electricity and telecommunications networks, as well as engineering solutions for fire safety, such as fire water supply with fire hydrants. All utilities have are located underground. Since the utilities of the underground establishments may require opening for repair or inspection, laying them under the carriageway should be avoided, the destruction and restoration of carriageway is associated with significant costs. Only storm sewer networks and through tunnels, which do not require opening in case of accidents, can be placed under the carriageway. The width of the streets and driveways is sometimes taken to be greater than is necessary, according to the terms of the location of utility networks. This is due to the sanitary and fire safety in accordance with technical necessity. All underground utilities should be traced in a straight line and parallel to the development lines of highways, streets and driveways. Stringing utilities (with individual trench laying) should be carried out in a certain sequence from the building line to the roadway. Underground networks are not allowed to be placed in the pressure distribution zone from the foundations of buildings and structures. Therefore, utilities requiring the least deepening should be stringed closer to the building, and utilities of greater deepening should be laid behind them. Unilateral underground utilities must be stringed in the following sequence from the building line to the carriageway: low-current networks, technological networks depending on their purpose, heat pipes (including trench laid ones), gas pipelines, water pipes, sewer networks, drains.

4.4. The fourth layer – quarter blocks.

The planning grid of orthogonal quarterly development is proposed for the designed analytical model. Most of the housing of the territory under development consists of quarters in the form of a square of a given standard size. Each quarter includes 4 rectangular urban-blocks with various development types inside the block, located in different directions (alternating perpendicular and parallel to the axis, according to which the orthogonal quarter grid is built). As a result of such development type, the quarter has an internal structure of streets, which is similar to a four-blade propeller of a helicopter on the general plan. Urban-blocks, in turn, will include residential buildings with integrated built-in and attached facilities for service, commerce and socially significant facilities (for example, private kindergartens). As a result, the quarter will consist of three following types of so-called planning cells of a certain size: cells of mixed-use residential development, cells for intra-quarter driveways, cells for inter-quarter driveways and main streets.

The planning organization of quarters and urban-blocks will allow the construction of residential buildings with a single frontage along the red lines in accordance with the principle of the efficient organization of the road network. The construction of buildings inside the formed urban-blocks is based on development principles determined for mixed-use residential development. Those principles include medium and high density of development, different heights and requirements for including public and business

functions in the residential development (horizontal or vertical integration with the development and improvement of public spaces in the block and quarter). There are different types of residential and non-residential premises in each urban-block according to the space-planning solution and height. The height of non-residential premises on the ground floor should be approximately one and a half times greater to ensure variability in the use of these premises for various types of entrepreneurial activity. Multifunctional block development allows pedestrian access to the developed territory. Mostly 5–9 storey (with point 12-storey) U-shaped and L-shaped buildings form cozy and secure courtyards. Inside (in the central zone) of each quarter between urban-blocks, a semi-private space is provided with a mini-garden or square. Along the perimeter of this space, in the lower floors of the urban-block buildings (external perimeter of the urban-blocks) there are service organizations (for example, hairdressers, housing-operational services), which contributes to the development of good neighborliness, increases the level of security. Various commercial organizations (cafes, private clinics, shops, leisure organizations, etc.) can be located on the outer perimeter of quarters in the lower floors of buildings, which increases the multifunctionality level of the environment. Due to compliance with these requirements, a mixed residential environment is created that is favorable for work, life and stay on an integrated developed territory. Underground parking is located inside each of the urban-blocks. Storage spaces for personal vehicles are developed in the form of underground or semi-underground parking inside the blocks with enter to the parking lot from the outside of the urban-block. Additional parking spaces should be provided between urban-blocks along the streets between the blocks with including the green zone.

4.5. The fifth layer – functional content.

It is formed by horizontal and vertical integration of the maximum number of diverse functions necessary for a comfortable stay of the residents. Depending on the types of the inhabitants and their needs, in addition to the residential function, the following functions are provided within walking distance for the residents of the quarters: public and business function, production function, commercial function, fitness and recreation function, communal, social and commercial function consumer services; educational function. It is possible to ensure such functional diversity by obligatory changes to the zoning order of integrated developed territories. The new functional zone should be introduced, a mixed-use zone, which is used taking into account the mixed-use index and allowing to set workplaces and educational function in close proximity to the residential function. The procedure for introducing such zone will be described in more detail on the example of the territory of testing this model.

4.6. The sixth layer – pedestrian networks.

In the compact quarter, various types of activities and facilities for different purposes are conveniently located close to each other, minimizing the time and energy required to reach them, and maximizing the potential for their interaction. The location of neighboring residential sections, mainly with a common firewall, allows for a compact, non-breaking blocking. When reducing distances from one object to another, compact neighborhoods require less extensive and expensive infrastructure. The advantage of movement is given to pedestrians, for this it is necessary to create a pedestrian environment that is comfortable for a person. To make a stay more comfortable, pedestrian streets along highways should be made as diverse as possible. Storefronts should be designed with showcases and covering elements that provide shelter for pedestrians, such as awnings. In addition to the traditional pedestrian street along highways, it is important to create pedestrian spaces inside urban

blocks and quarters that are closed to car traffic. Thus, services, cafes and shops will be located on both sides of the person's traffic, and their load will be carried out from the outside of the block. Also, pedestrian zones are protected from noise and pollution from roads inside urban-blocks. The improvement of pedestrian areas is carried out by creating different activity zones for residents, such as pedestrian streets and squares, passive resting areas, with the inclusion of small playgrounds (large playgrounds are noisy and should be away from business and housing). Pedestrian areas should have the proper lighting in the dark, so that pedestrian routes function around the clock. A network of pedestrian streets connects the blocks, the pedestrian directions of neighboring blocks are taken into account when designing the development of blocks, thereby creating a variety of directions and the comfort of pedestrians between blocks.

Thus, combining all the above mentioned layers that are formed on the basis of the developed principles, methods and tools for forming a mixed-use living environment, using the mixed-use index as the main tool of the function balance method, form an analytical model that can be applied in the integrated development of the metropolis peripheral territories. Following all the determined principles together gives the greatest potential for the formation of a favorable mixed-use residential environment within the quarter, microdistrict and the entire integrated development territory. The developed analytical model also provides opportunities for implementing a strategy for the further transformation of the territory.

5 Conclusions

1. The qualities of the spatial characteristics of mixed-use residential development regarding impact on person, the urban development principles of forming the mixed-use residential environment depend on a set of external and internal factors (insolation, urban planning, technical and economic external factors, as well as socio-psychological, visual and behavioral internal factors of perceiving the residential environment).

2. It is advisable to define six basic principles of developing the mixed-use residential environment, which, in turn, include methods and tools for implementing these principles (the principle of efficient use of territories and infrastructure, humanity and aesthetic appeal, effective organization of the road network and transport accessibility, environmental safety, bio-ecological sustainability of the environment, the principle of economic sustainability of the environment).

3. It is suggested to use the mixed-use index and normative balance regulation of the territory as the most important tools for organizing mixed residential development in integrated developed peripheral territories.

4. Since the responsibility for the functionality of the territory is not fixed by law, since there are no regulations on the diversity of the territory, and the existing norms and rules are interpreted in the direction of mono-use, local governments should be obliged to monitor the functionality of the territory and set the minimum necessary functional balance at the level of land use and development regulations.

5. The analytical model of the city-planning organization of mixed-use residential development in ITD projects, which is formed within the framework of the study, is based on the formation of mixed-use development quarters formed by urban-blocks. They are, in a certain way, city-planning units, which include residential buildings with day-to-day maintenance facilities on ground floors and a courtyard with landscaping, areas for a quiet rest and fire passages, closed to outsiders.

6. A feature of the developed analytical model for the integrated development of the territory is the formation of an adaptive quarter structure based on the principles of a mixed-use environment, which allows taking into account the diverse and time-varying

needs of residents. The model consists of six layers (engineering structure, transport matrix, quarter blocks, pedestrian networks, functional content and green infrastructure).

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