

Methods of determination of territorial resources in conditions of compacted urban development (using Kyiv as an example)

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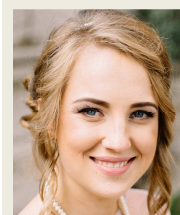
Abstract. The article highlights the results of the analysis of domestic and foreign experience of application of the applied coatings and a modified typology of roofs based on their geometric and structural features is proposed. The following factors that influence taking the decision on the need and directions of the use of the used roofs are provided.

On the basis of the analysis of the dynamics of the normative and actual indicators of urban development, the constant growth of the development density and growth of the lack of territory for greenery and other elements of the population service are proved.

The described methods for the determination of the resource potential of urban areas are normative method, comparative and calculation method. A new calculation method for identifying potential territorial resources of micro districts, blocks or individual plots due to the use of exploited roofs in conditions of compacted urban development has been proposed.

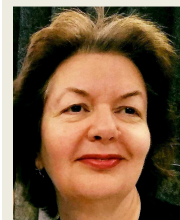
The mathematical model is based on taking into account the geometric type of the roof, type of historically originated development, its technical condition and the availability of the status of the cultural heritage monument.

Coefficients for the calculation of the potential territorial resource have been experimentally determined. Based on the example of Kyiv, using



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GIS-technologies, a specialized database for identifying a potential territorial resource has been formed.

The recommendations for placement on different types of objects on the exploited roofs depending on the frequency of their visit and the city-planning situation have been provided.

The methodical scheme for the determination of a potential territorial resource due to the use of exploited roofs in the development of urban planning, design and land management documentation has been proposed.

Keywords. The exploited roof, potential territorial resource, typology of roofs, typology of the development, mathematical model.

INTRODUCTION

A controlled and uncontrolled growth of the population in settlements, especially in the large and largest settlements, has been observed over the last decades both in the world as a whole and in Ukraine. This leads to a constantly growing shortage of territory for the placement of urban infrastructure and rendering of services and degradation of the urban environment quality.

The search for additional territorial resources generate a need for intensification of the use and development of urban areas, development of underground urban planning and use of exploited roofs.

The modern city seeks to develop, create and reconstruct objects under new, more progressive rules. The trend of promotion of the environmental and sustainable approach, from the design stage to the building phase or reconstruction of buildings, arose as a result of the deterioration of not only the environmental conditions of cities, but also the environment as a whole. The reasonable use of the territory at all stages with the use of the latest technologies and materials becomes a forced reality of the present.

Outstanding French architect Le Corbusier said: «... Indeed, this contradicts any logic when the area equal to the area of the whole city is not used and slate is admiring the stars! ...» [1]. The area under construction in large cities ranges from 5 % to 10 %, in the areas of manor development – up to 15 % to 30 %, and in historic areas and – even up to 70 % to 100 % of the area of the blocks' territory (Project of the general plan of the city of Kiev. The main provisions. Developed by Municipal organization “Institute of the general plan of Kiev”), in view of this, the inclusion of the roof area in the total area of territories free of development is a promising direction for increasing the territorial resources of cities.

PURPOSE AND METHODS OF THE STUDY

The study considers one of the most urgent issues of increasing the efficacy of using terri-

tories – the polyfunctionalization of urban space by including an additional territorial resource – roofs of the existing and projected buildings.

It is the exploited roof as a potential territorial resource in compacted urban areas is the subject of the study.

The purpose of the study is to substantiate (develop) a new calculation method for the determination of the potential resource of built-up areas with the use of exploited roofs for the purpose of increasing the efficacy of urban areas.

The methods of determining the potential territorial resource of urban space include: normative method, comparative method, and estimated method.

The normative method is a method that regulates indicators of territorial resources of development of blocks, land plots as part of the legislative and regulatory framework of design (DBN – state building standards, DSTU – state standards of Ukraine, SN – sanitary norms). The analysis with the use of the normative method allows to regulate territorial reserves and territorial resources of planned objects of different levels; the main technical and economic indicators of the block, land plot for each functional type of territory, in accordance with the normative documents.

Comparative method is a method that establishes the ratio of actual indicators of the use and development of the territory with the regulated ones. Theoretically, these indicators should coincide or be less regulated but, as a rule, they have differences, deviations from the standards.

Calculation method is a method that determines the potential territorial resources based on the combination of functions (polyfunctionalisation) of the use of urban areas. The method allows you to calculate the potential resource that can be obtained by using, in this case, roofs of houses located within quarters of urban development.

The results of the study are based on the analysis of a large amount of experimentally obtained data (using Kyiv as an example) with the use of the existing and proposed databases.

RESULTS AND EXPLANATIONS

The modern city seeks to develop, create and reconstruct objects under new, more progressive rules. The trend of promoting environmental and sustainable approaches, from design to construction or reconstruction, arose as a result of the deterioration, not only of the environmental condition of cities, but of the environment as a whole. The reasonable use of the territory at all stages with the use of the latest technologies and materials becomes a forced reality of the present. The study focuses on one part of the multifunctional use of the territory — the exploited roofs).

First, it is necessary to define clearly the terminology used in this study: in the scientific literature and normative documents, the following terms are distinguished [3]:

- *roof* refers to upper enclosure structure of the building and structure intended for protecting the premises from external climatic factors and impacts;
- *roofing* refers to an element of the roof that protects the building against penetration of atmospheric precipitation in it;
- *non-exploited roof* is not intended to withstand additional loads, except normative ones (snow, wind, dead load);
- *exploited roof* refers to a roof that is used for a specific purpose, for riding, walking or landscaping.

In addition, the exploited roofs are differentiated by the frequency of attendance of the roof [3]:

- *with objects of mass access*
- *with objects of restricted access.*

Mass access means that people (visitors) will be provided constant (or seasonal) access to the roof. Roofs with objects of restricted access is a roof that is created for a specific purpose, but the access of people on it is limited, that is, there may be only attendants, the roof is not intended to withstand any additional load caused by a large number of people and other possible objects.

The use of roofs of the existing buildings and facilities for the increase of the useful area of the territory is much more widespread abroad, however, and this practice is becoming

more relevant in Ukraine.

Summarizing the experience of Germany, USA, Republic of Colombia, Spain [2 – 6], and Ukraine, it has been proposed in this study to allocate the following four types of exploited roofs by types of their functional use (examples of exploited roofs are shown in Fig.1):

A. Roof with objects of the engineering infrastructure.

- *The «blue» roof* refers to a roof, the surface of which is covered with trays with gravel that are intended to hold and release rainwater slowly, reduce the peak load on storm drains. The principle of «blue» roofs is that they collect rainwater before it enters the sewage system in order to: a) filter it through artificially created filters (e.g. gravel, crushed stone, etc.); b) irrigate the surrounding landscape.

- *The «sun» roof* refers to a roof, the surface of which is covered by sources of renewable energy or hot water.

- *The «green» roof* refers to a roof, the surface of which is partially or completely covered with greenery. The "green" roofs consist of a vegetation layer that grows in the specially designed for "green" roofs soil (substrate) located on the drainage layer.

B. Roofs with objects of the transport infrastructure.

- *Roof-parking* refers to a roof that is created for a temporary or permanent parking/storage of motor vehicles.

C. Roofs for increasing energy efficiency.

- *«Cold roof»*, also known as «white» is a roof that is coated or painted with a material that reflects and does not absorb solar radiation.

D. Roofs with other functional objects.

- *A roof-terrace* refers to a roof that is intended for rest, walks, sports activities and other types of passive and active pastime.

- *A roof-water reservoir* refers to a roof, at which a water reservoir, swimming pool, artificial lake and other types of water structures are located.

- *A multifunctional roof* refers to a roof that combines several functions (for example: terrace with a garden, terrace with a swimming pool, it may be combined with types of roofs

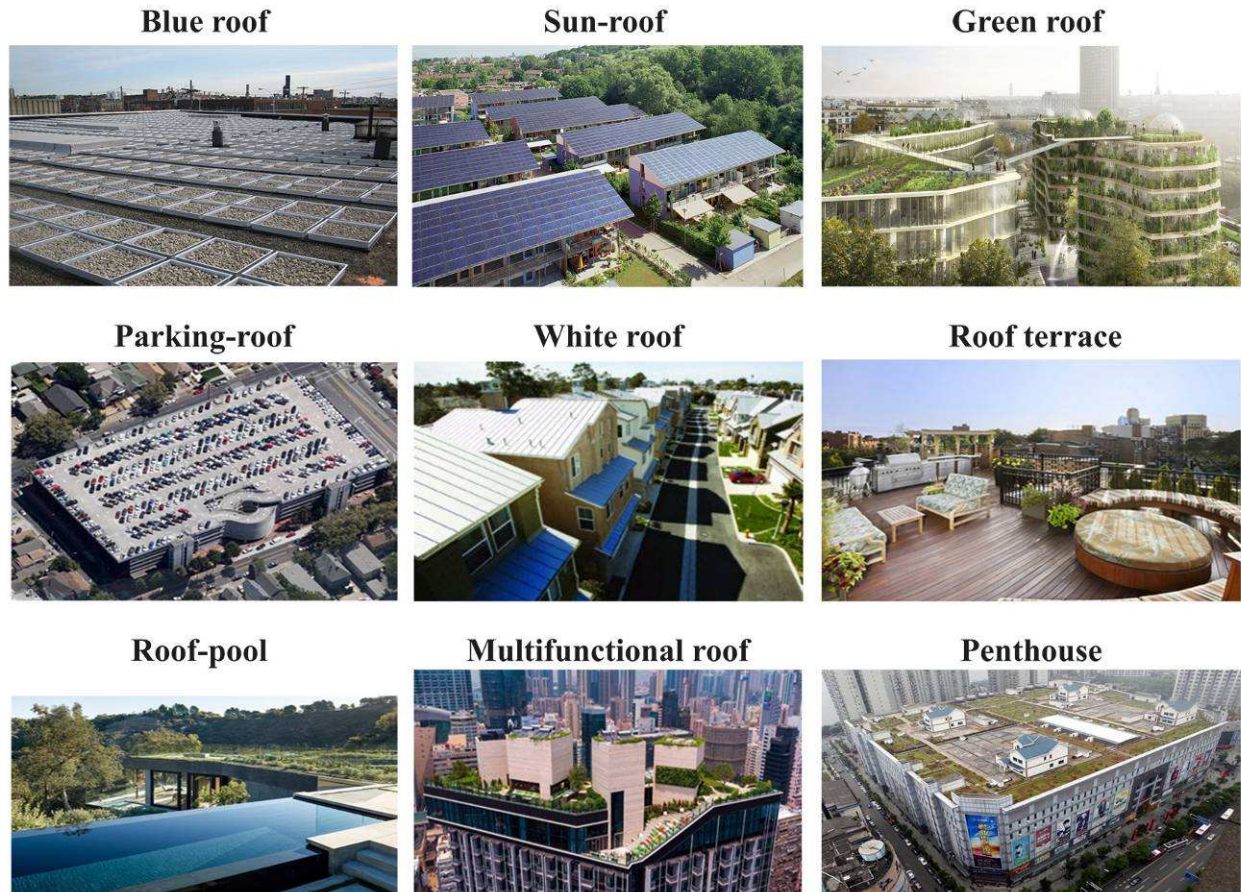


Fig.1. Examples of exploited coatings

of limited access).

The postindustrial period of society development is characterized by polyfunctionalisation of the urban space – a combination of different functional objects within a single planning element. The active saturation of the urban space, increase in the functional load requires a careful evaluation of the adopted design decisions to prevent the misbalance of the city plan.

Since the ultimate goal of the work is to increase the efficiency of using urban areas, the study has analyzed the main criteria for assessing quality of the city plan. These include [7] – *efficiency, intensity and manageability*.

Efficiency and manageability are criteria that work at the macro level or level of the city as a whole. In this case, the effectiveness of using urban areas is understood as a degree of the compliance of using land in the city's interests, urban development value of the terri-

tory; rationality of the placement of certain objects, taking into account the specifics of the city districts [7].

Manageability of development of urban areas is determined by the availability of a proper mechanism for the implementation of urban planning documentation – general urban area development plan and urban zoning plans or local building regulations [7].

At the local level – the level of a block, micro district or a separate land plot – the efficiency of the use and development is determined, above all, by its intensity of development. The intensity of the use and development of the territory is the level of its functional load.

From the perspective of the study conducted, this criterion was considered as the main one. The main indicators that characterize the intensity of the use and development of the territory are:

- area of the territory (ha);
- quantity of population (persons);
- average number of stories, storey;
- deterioration of fixed assets (physical, functional, external (economic) one);
- density of development, m²/ha;
- population density, persons/ha;
- density of fixed assets m²/ha;
- density of the value of fixed assets, UAH/ha;
- costs of the building surrounding grounds per 1 person, m²/person

Based on the methods for the determination of the territorial resources of the urban space, a comparative characteristic of relative indicators of the intensity of using the territory of urban development blocks has been developed.

The analysis of the dynamics of normative indicators regulating the intensity of the use

and development of territories has been carried out on the basis of construction norms and rules on urban planning of various periods (PiN 1929, SN 41-58, SNiP II-K.2-62, SNiP II-60-75, SNiP II-60-75**, SNiP 2.07.01-89, DBN 360-92**, draft of the new DBN “Town planning. Planning and building of settlements B.2.2-1-01”). At that, the normative method has been applied.

The conducted analysis shows the constant growth of the intensity of development of urban areas (see Figs.2 – 4).

Formation of the development of city districts and in particular districts of Kyiv in different historical periods in accordance with different regulatory requirements caused the unevenness of the intensity of development of urban areas. This, in turn, caused the unevenness of the existing territorial reserve of the existing development.

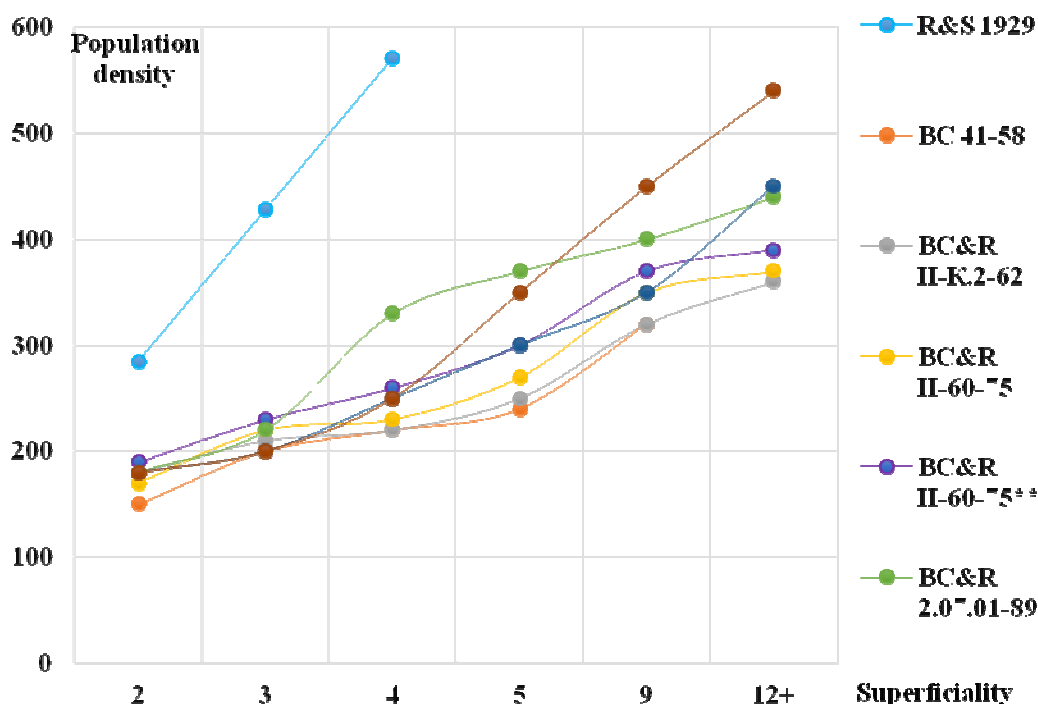


Fig.2. The dynamics of standard indicators of population density of microdistricts, persons/ha

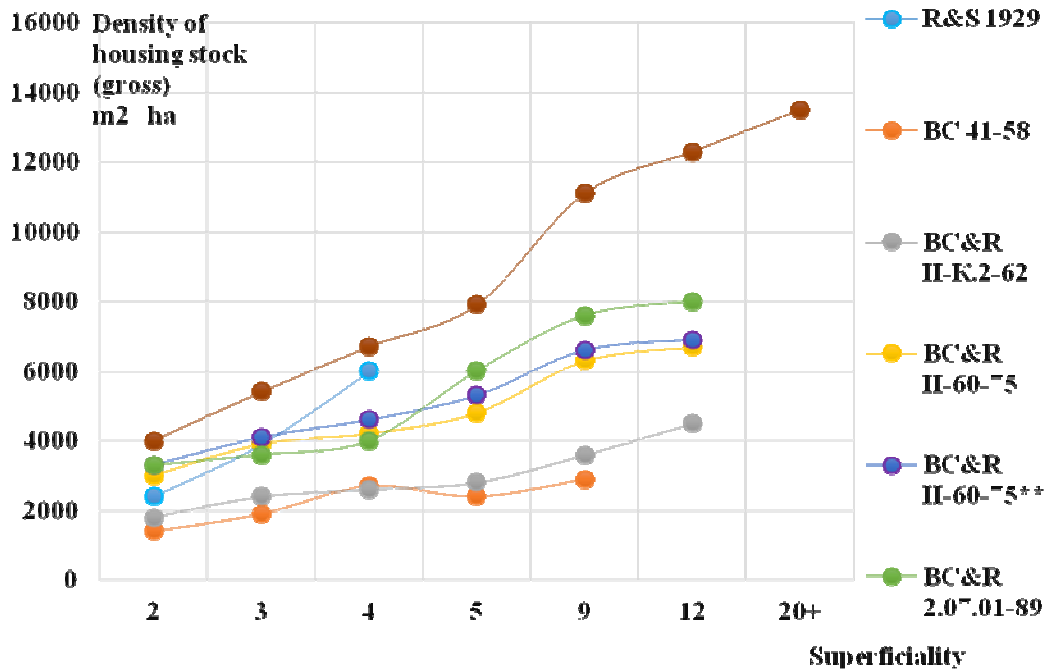


Fig.3. The dynamics of standard indicators depending on the density of housing funds stories, m²/ha

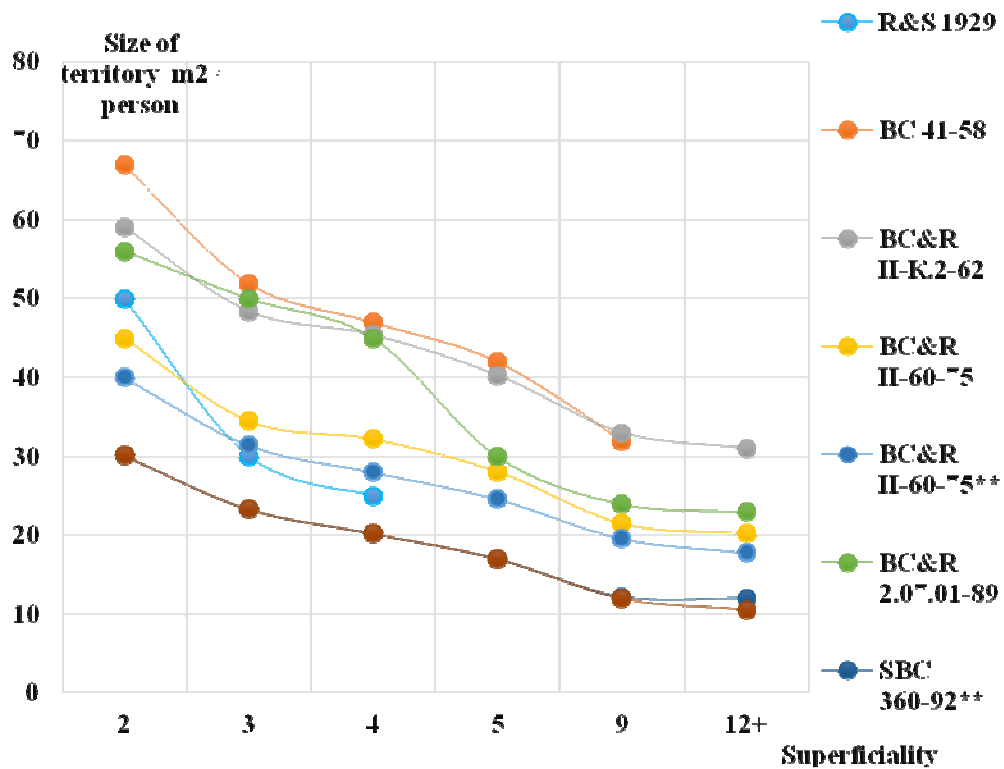


Fig.4. The dynamics of normative indicators of the cost of the adjoining territory per person, m²/person

It should be noted that, in this study, *the territorial reserve* is understood as the presence of an excess of free space in relation to the area normatively required for this type of the territory use. *The territorial resource* is understood as additional areas that may be involved due to the use of underground space or exploited roofs in the absence of an excess of normatively required areas.

For a detailed analysis of available territorial resources of urban development areas of different formation periods, a modified typology of them has been developed.

In the scientific literature, the classifications of the development is provided:

- by number of stories [Residential buildings. The main provisions DBN V.2.2-15-2005, Fire safety of construction objects DBN V.1.1.7-2002, [13];
- by the materials of walls [13];
- by period of construction [12, 13].

Much attention was paid to the classification of roofs. By the construction type, roofs are divided into: garret roof and built-up roof. The garret roof, in turn, may be: warm, cold and open [8]. The built-up roof may be: unventilated (warm), partially ventilated and ventilated [8].

In the course of the analysis done, the roofs have been systematized depending on its town-planning use and geometric form and grouped into four main types [8]:

1. Pitched roof:
 - 1.1. monopitch roof – flat roof, inclined roof;
 - 2.1. hip-and-valley roof – double-pitch roof (needle), cross-shaped roof, gambrel roof, pyramidal broach roof, trapezoidal roof, hip roof (jerkin-head roof).
2. Barrel roof:
 - 2.2. barrel (arched) roof;
 - 2.3. conical roof;
 - 2.4. conoidal roof;
 - 2.5. toroidal roof.
3. Dome-shaped roof:
 - 3.1. multifaceted dome, petal-type dome or pendentive dome.
4. Curvilinear roof:
 - 4.1. pyramidal broach roof

- 4.2. of double curvature is a roof made of shells of positive and negative Gaussian curvature; roof made of the hypercomponents, paraboloid, hyperboloid and hyperboloid-paraboloid roof.

For the analysis of the potential territorial resource, a modified typology of urban development blocks that is based on the construction period and geometric and structural features of roofs has been proposed. There were five types of development:

1. Historical development:
 - 1.1. medieval development;
 - 1.2. development of the middle and end of the XVIII century to beginning of the XIX century. (palatial, manor);
2. The development of the period of capitalism development – within the period from the end of the XIX century and beginning of the XX century:
 - 2.1. rental houses of prestigious type;
 - 2.2. rental homes of middle class prestige;
 - 2.3. rental houses of low-income for workers of barracks type or individual houses (workers' suburbs, workers' villages);
3. Development of the period of socialist industrialization:
 - 3.1. socialist cities/towns (socialist town, city);
 - 3.2. individual development of the period from 1925 to 1941;
 - 3.3. multistory development of increased comfort of the period from 1945 to 1955 («Stalin-era buildings»);
4. Post-war development (industrial housebuilding)
 - 4.1. development of the first mass series of industrial housebuilding of 50 – 60th of the XX century («Khrushchev-era buildings»);
 - 4.2. development of the 70 – 80 s;
5. Modern development
 - 5.1. multistoried development (up to 16 stories);
 - 5.2. development with the increased number of stories (over 16 stories). building floors high (over 16 floors).

The XX century has become the point of reference for the mass construction of buildings with flat roofs, this trend confidently has been holding its positions up to the present. Most modern residential complexes, individual high-rise buildings, public buildings have flat roofs that are almost not used in most cases. Thus, in a city, where there is no reserve of territory and plots are used with the greatest benefit, the area of the building's roofs that is usually equal to or even exceed the spot of development remains unused.

The necessity of using the exploited roofs should be based on the analysis of the availability of territorial reserves or an overregulated area of the territory within the bounds of the planned element under evaluation – micro-district, block or land plot.

There may be two principal variants of the availability of territorial reserves, ref. to formulas (1) and (2):

$$S_{\text{free spaces}} \geq S_{\text{necessary regulatory}} \quad (1)$$

$$S_{\text{free spaces}} < S_{\text{necessary regulatory}}, \quad (2)$$

where $S_{\text{free spaces}}$ is an area free from development within the site under evaluation, that is, the existing territorial reserve; $S_{\text{necessary regulatory}}$ – area of the site under evaluation that is free from development, that is in accordance with regulatory requirements, is necessary for the placement of facilities for land improvement and landscaping, that is, the territorial reserve is absent.

In the case of availability of a territorial reserve, there is no urgent need to use the exploited roofs, but this may be appropriate and possible for:

- the increase of energy efficiency of separate buildings and development in general;
- the increase of the ecological performance of the environment by increasing the number of greenery (the reduction of the effect of «urban heat island»);
- the increase of the aesthetic attractiveness and attractiveness of the development.

When there is not enough free space, there is no territorial reserve, the use of exploited roofs is extremely important for obtaining additional territorial resources. In addition to the

increase of energy efficiency, environmental friendliness, aesthetic attractiveness and attractiveness of objects, this will enable:

- to arrange regulatory required sites of different functional purposes;
- to obtain additional areas of greenery with a limited use;
- to place objects accompanying the main objects (objects of engineering and transport infrastructure);

When evaluating the permissibility of the use of exploited roofs and directions for their functional use, the following factors should be taken into account:

- *city-planning factors* (functional purpose of the territory; type of development; city-planning value; intensity of development; architectural and landscaping connection with the environment);
- *constructive factors* (geometric type of the roof; technical condition of the building; bearing capacity of building structures);
- *economic factors* (the cost of land; intensity of the territory use; profitability of the buildings management; increase in the value of the objects and territory);
- *ecological factors* (microclimate control; energy saving requirements; improving the level of land improvements and landscaping);
- *legal status* (presence of the status of a cultural heritage monument; presence of legal restrictions and encumbrances).

In order to increase the efficiency of using urban areas due to the use of exploited roofs, a new calculation method for determining the potential territorial resource of built-up areas, especially in densely developed areas, has been proposed in the study in the form of a mathematical model (see formula (3)).

$$S_{\text{pot. terr.res.}} = \alpha \beta \gamma \lambda \times S_{\text{dev.}} \quad (3)$$

where $S_{\text{pot. terr.res.}}$ is a potential territorial resource of the site under evaluation (microdistrict, block, land plot), m^2 ; $S_{\text{dev.}}$ is an area of development of the site under evaluation, m^2 ; $\alpha, \beta, \gamma, \lambda$ are coefficients that take into account the specific conditions and characteristics of the development.

The methods for determining these coeffi-

cients that were obtained using analytical and experimental methods are proposed below.

For this, using Kyiv as an example, based on the proposed building typology by the period of construction and design features, 51 blocks and separate plots with a total of 551 houses have been analyzed. Since about 82 % of the development of Kyiv is the development of the postwar period, a detailed analysis has been conducted precisely for the development of these periods.

1. α is a coefficient that takes into account the geometric type of the roof.

Since the predominant geometric type of the roof for post-war and modern development is an inclined roof (or rather, subtypes: mono-pitch roof, double-pitch roof, pyramidal broach roof), it is proposed to define this coefficient in accordance with the schedule (see Fig.5) depending on the angle of inclination of the roof.

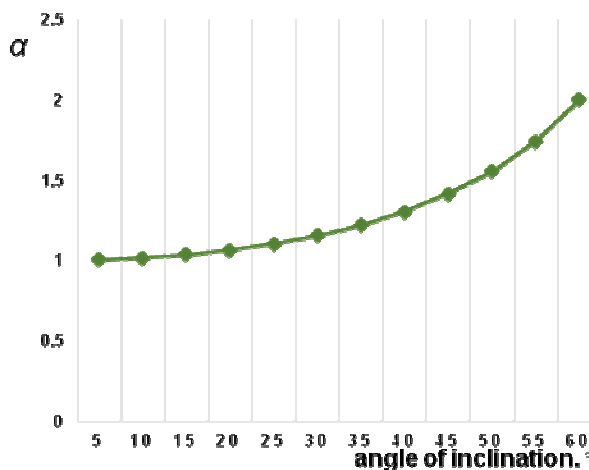


Fig.5. The dependence of the roof area on the angle of the roof.

2. β is a coefficient that take into account the features of the roof design, that is, the output of the useful area of the roof (excluding the area of ventilation shafts, elevator shafts, parapets, etc., design features of roofs, the area of which cannot be used), depending on the type of development (ref. to (4)).

$$S_{\text{roof}} = \beta \times S_{\text{dev.}}, \quad (4)$$

where S_{roof} is an area of the roof free of structural elements, m^2 ; $S_{\text{dev.}}$ is an area of the development of the site under evaluation, m^2 .

The value of coefficient β has been also calculated experimentally for each subtype of the post-war development. Their rough values are as follows:

- $\beta = 0,7$ to $1,25$ for the development of the first period of industrial housebuilding;
- $\beta = 0,7 \dots 1,2$ for the modern development.

Specific values are recorded in a specially created information database. [14],

3. γ is a coefficient that reflects the average weighted physical deterioration of the development within the area under evaluation. Its essence is that the higher the index of physical deterioration of the building, that is, the loss of the carrying capacity of the structural elements, the lower the probability of using its roof for any additional function.

In this case, the area of exploited roofs is determined by formula 5:

$$S_{\text{roof}} = \gamma \times S_{\text{dev.}}, \quad (5)$$

where S_{roof} is an area of the roof suitable for an additional function, m^2 ;

$S_{\text{dev.}}$ is an area of the development of the site under evaluation, m^2 .

The value of coefficient γ is determined by the formula 6:

$$\gamma = \frac{\gamma_1 S_{\text{dev.}1} + \gamma_2 S_{\text{dev.}2} + \dots + \gamma_5 S_{\text{dev.}5}}{\sum S_{\text{dev.}}} \quad (6)$$

where $S_{\text{dev.}i}$ is areas of the development with buildings with an appropriate index of technical condition (physical deterioration), m^2 ;

γ_i is a part of the development with buildings with the corresponding indicator of the technical condition (physical deterioration) of the total area of the development of the site under evaluation;

i is, correspondingly: 1 – good technical condition (physical deterioration of 0 % to 20 %), 2 – satisfactory technical condition (physical deterioration of 21 % to 40 %), 3 – unsatisfactory technical condition (physical

deterioration of 41 % to 60 %), 4 – dilapidated technical condition (physical deterioration of 61 % to 80 %), 5 – unsuitable technical condition (physical deterioration of 81 % to 100 %).

4. λ is a coefficient that takes into account the part of the development with buildings having the status of a cultural heritage monument in the total area of the development of the site under evaluation (ref. to formula 7).

$$S_{\text{expl. roof}} = \lambda \times S_{\text{dev.}}, \quad (7)$$

where λ is a coefficient that takes into account the cultural value of the development. It is determined by formula 8; $S_{\text{dev.}}$ is an area of the development of the site under evaluation, m^2 .

$$\lambda = 1 - \frac{S_{\text{mon.}}}{S_{\text{total}}}, \quad (8)$$

where $S_{\text{mon.}}$ is an area of the development with buildings having the status of cultural heritage monuments, m^2 ; S_{total} is an area of the development of the site under evaluation, m^2 .

Law of Ukraine “On the Protection of the Cultural Heritage” prohibits any interference and changes in the appearance of the objects under protection. Therefore, the decision on the possibility of arrangement of the exploited roof on such object should be taken very carefully and individually, and, respectively, the area of the development of such objects should be removed from the total area of the development of the site under evaluation.

The proposed mathematical model allows to calculate the potential territorial resource of urban areas by the involvement into the exploitation of roofs of the existing and projected buildings.

Such an analysis can be performed both at the city level, when developing master plans, plans for zoning the territory of settlements and detailed plans of the territory of individual planning formations, and at the local level, when performing pre-project proposals and sketch projects for the development of individual plots of land.

For the convenience of using the proposed method, in the course of the study, a special information base for Kyiv with the use of the

existing information resources and GIS technologies has been developed.

The formation of an information base included three stages:

1. *Stage of the formation of the output data database.*

The base material for mapping is geodetic surveying of Kyiv M 1:2000. Attributive information is formed in the form of tabular data characterizing the existing housing stock of the city. Information sources are official site – <https://www.municipal.kiev.ua/kyiv/>.

Output data contain the following information: country, city, district, address (street prefix, street, house number), complex, year of construction, physical deterioration, status of a monument, number of stories, wall material, series of the building, geometric type of the roof, roof area, angle of inclination.

Using the method of geocoding the Google Maps service, a dotted layer with tabular data for each building, which is assigned to the polygonal layer of the housing stock, has been obtained.

2. *Stage of development differentiation by types.*

The distribution of building according to the modified typology of residential development blocks and stages of development formation is to be done.

3. *Stage of the calculation of the potential territorial resource.*

The coefficients necessary for defining the territorial resource of the site under evaluation are calculated. Namely: a coefficient that takes into account the geometric type of the roof, (α), design features of the roof according to the type of development (β), the coefficient characterizing the technical condition (physical deterioration) of buildings (\square) and the cultural value of the building (λ).

According to the proposed mathematical model, the potential territorial resource for each selected block or land plot has been determined.

On the basis of the experimental part of the study, a spatial information-analytical model has been formed that makes it possible to calculate the potential territorial resource of the existing blocks of urban development. De-

tailed information on the structure and content of the information base can be found in the next publication [14].

Spatial informational-analytical bases can be formed for any settlement. This method and the proposed mathematical model can also be used for the determination of potential territorial resources of urban areas using the traditional method (without the use of GIS-technologies).

The methodical scheme of the application of the proposed calculation method for determining potential territorial resources of urban areas, especially in conditions of dense development, is given in Fig.6.

CONCLUSIONS AND RECOMMENDATIONS

Modern commercial real estate, like most existing buildings, is characterized, in most cases, by flat roofs, that is why their use is quite possible and is very important for the compensation of the shortage of urban areas. Application of multifunctional potential of exploited roofs allows not only to compensate the lack of territory, but also to form independent structural elements of the urban environment

The analysis of foreign and domestic practical experience of using exploited roofs makes it possible to formulate the following factors that lead to the formation of the development with the use of such roofs:

- *the need for territorial resources* in connection with the high cost and limited availability of land;
- *the tendency to the increase in the development density, especially in the central and middle parts of the city, that was formed historically.* The new construction or reconstruction may be only performed in stable, rather dense conditions, the use of exploited roofs will make it possible to compensate those objects that physically can not accommodate the area of the site;
- *high cost of land* that induces to create objects that will bring the highest income (with the maximum coefficient of the site development and the maximum height of build-

ings);

- *environmental friendliness*, the area of built-up and asphalted areas is increasing that negatively affects the environment;
- *investment factor*, the use of coatings, depending on the type and class of building – the exploited roof with the correctly selected function increases the cost of the property, makes it more competitive;
- *requirements for certification of the development according to «green standards»;*
- *increase of attractiveness and prestige of the development* – the exploited roofs with the sites arranged on them are the center of public attraction (of limited or mass access);
- *growing needs in recreational, green spaces;*
- *increased numbers of storey's* – with the increase in the number of the building, there is a growing need for sites for different purposes and greened areas;
- *the need to increase the efficiency of the use of the territory of urban development* – due to the multifunctional use;
- *growing demands for the environmentally friendly and comfortable urban environment.*

The proposed calculation method for determining the potential territorial resource due to the use of exploited roofs, especially in the conditions of dense development, will significantly improve the efficiency of using urban areas and level of comfort of the urban environment.

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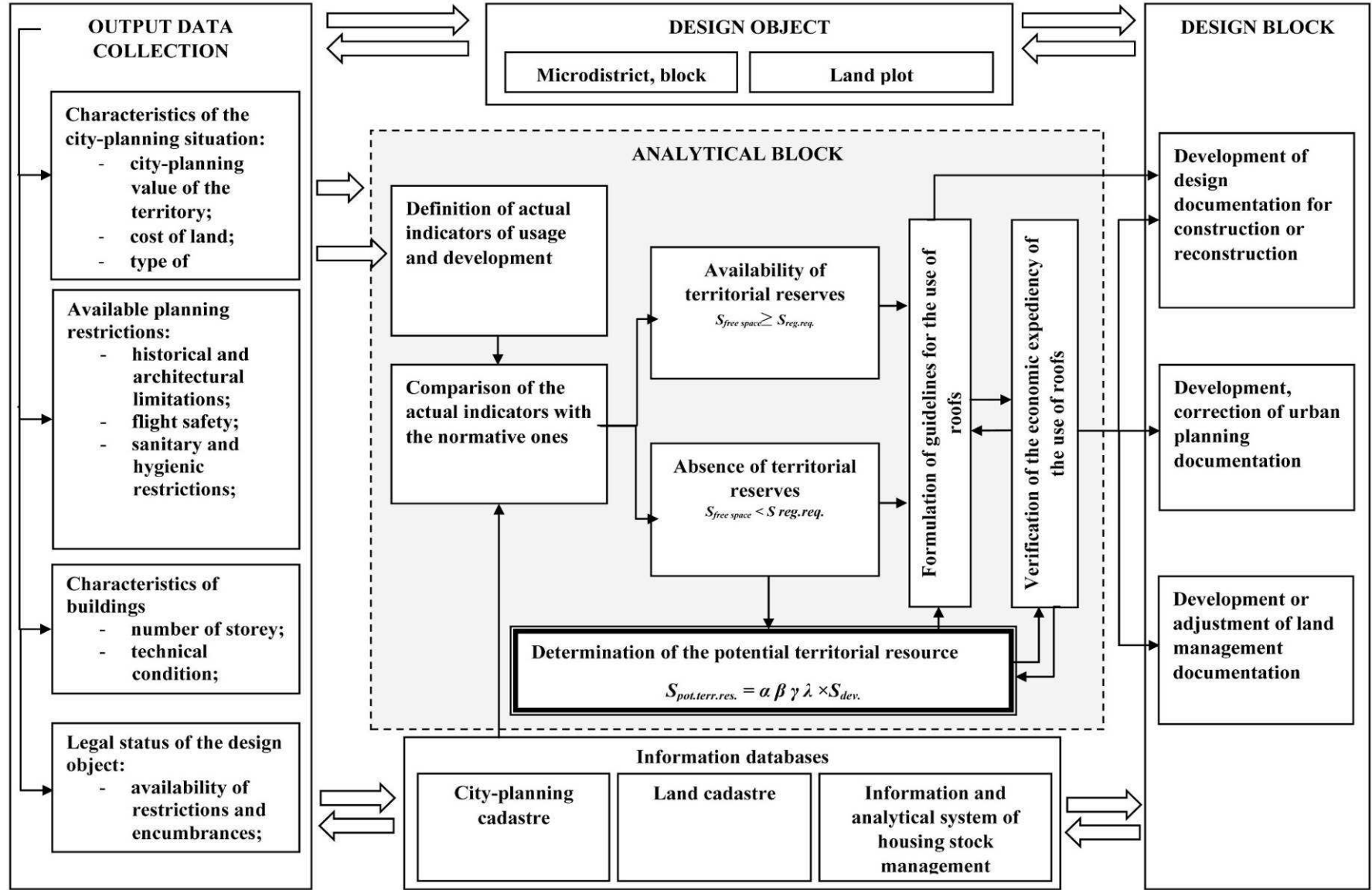


Fig.6. Methodical scheme for determination of potential territorial resource different planning elements with application of the proposed mathematical model

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Методы определения территориальных ресурсов в условиях плотной городской застройки (на примере г. Киева)

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Аннотация. В статье освещены результаты анализа отечественного и зарубежного опыта применения эксплуатируемых кровель и предложено модифицированную типологию кровель, основанную на их геометрических и конструктивных особенностях. Определены факторы, влияющие на принятие решения о необходимости применения и направлений использования эксплуатируемых кровель.

На основе анализа динамики нормативных и фактических показателей застройки городских

территорий доказано постоянное увеличение плотности застройки и нехватка территории для размещения зеленых насаждений и иных элементов обслуживания населения.

Охарактеризованы методы определения ресурсного потенциала городских территорий – нормативный, сравнительный и расчётный. Предложен новый расчётный метод определения потенциальных территориальных ресурсов микрорайонов, кварталов или отдельных земельных участков за счет использования эксплуатируемых кровель в условиях плотной городской застройки.

Математическая модель базируется на учете геометрического типа кровли, исторически сформированном типа застройки, ее технического состояния и наличия статуса памятника культурного наследия.

Приведены экспериментально установленные значения коэффициентов, используемые в математической модели, для расчета потенциального территориального ресурса. Приведены рекомендации по размещению на эксплуатируемых кровлях различных видов объектов в зависимости от частоты их посещения и градостроительной ситуации.

Предложено методическую схему определения потенциального территориального ресурса за счет использования эксплуатируемых кровель при разработке градостроительной, проектной и землеустроительной документации.

Ключевые слова. Эксплуатируемая кровля, потенциальный территориальный ресурс, типология кровель, типология застройки, математическая модель.