UDC330.342.3:771.558

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THE MULTI-CRITERIA PLANNING MODEL
OF URBAN SPATIAL DEVELOPMENT
WITH REGARD FOR THE INTERESTS OF STAKEHOLDERS

Abstract. The present study is aimed at supporting the concept and making the model of urban spatial development as a complex architectural town-building and socio-economic system, as well as developing tools for reaching agreed multi-criteria planning decisions in the interests of stakeholders.

The study examines basic theories (such as pattern language and central places) and conceptual approaches to the formation of urban spaces of trade, recreational, healthcare, image, entertainment, environmental, and sports character. It reveals the possibility and substantiates the necessity of employing expert methods and methods of project management for analysing, generalising, and modelling of urban civic space planning. In addition, there search substantiates conceptual principles, sets out general requirements, and highlights the main tasks of decision-making planning.

Furthermore, a multi-criteria optimization model has been built to plan urban spaces in conditions of contradictory interests of stakeholders, under limited resources and in complete in formation. The implementation of the model is to increase the validity of planning decisions and, as a result, lead to higher standards of living due to expansion of existing and diversification of potential functions of urban public spaces. For the evaluation of architectural urban building, economic, social, cultural-monumental, and ecological results, the study lays down criteria depending on the extent the plan of urban public space development is put into action.The method of successive concessions has been shown as an efficient tool for reaching agreed co-created planning decisions by stakeholders.

The provided basic model of reaching optimum planning decisions satisfying certain criteria contains restrictions on potential urban spatial development, as well as on the sequence in which interconnected development projects are carried out, and on the balance between supply and demand for services (functions) of urban public spaces. The model, which has been modified by the method of successive concessions for achieving agreed planning decisions in the interests of stakeholders, is based on establishing a dominant optimization criterion, on expert justifying

of allowable optimality losses against initial planning decisions per criterion at each stage of subsequent calculations, and on reaching a consensuson a final decision.

Keywords: public space, a planning decision, spatial development, evaluation criteria, development potential, a model, interests of stakeholders, a co-creation method.

JEL Classification I00, L51, L83, Z10

Formulas: 16; fig.: 2; tabl.: 2; bibl.: 23.

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БАГАТОКРИТЕРІАЛЬНА МОДЕЛЬ ПЛАНУВАННЯ ПРОСТОРОВОГО РОЗВИТКУ МІСТА З УРАХУВАННЯМ ІНТЕРЕСІВ СТЕЙКХОЛДЕРІВ

Анотація. Метою дослідження є обґрунтування концепції та побудова моделі планування просторового розвитку міста як складної архітектурно-містобудівної та соціально-економічної системи, а також розроблення інструментів формування планувальних рішень узгоджених за багатьма критеріями, які відображають інтереси стейкхолдерів.

Розглянуто і проаналізовано базові теорії (мови шаблонів, центральних місць) та концептуальні підходи до утворення міських просторів (торговельного, відпочинкового, оздоровчого, іміджевого, розважального, природоохоронного, спортивного спрямування). Установлено можливість і обґрунтовано доцільність застосування експертних методів, а також соціологічних, економічних, математичних і методів проєктного менеджменту до аналізування, узагальнення та моделювання процесу планування розвитку громадського простору міста. Обґрунтовано концептуальні засади, встановлено загальні вимоги та окреслено основні завдання, які потребують вирішення у процесі формування планувальних рішень.

Розроблено багатокритеріальну оптимізаційну модель планування просторового розвитку міста в умовах суперечливості інтересів стейкхолдерів, обмеженості ресурсного потенціалу та неповної інформаційної визначеності. Упровадження моделі підвищить обґрунтованість планувальних рішень і призведе до зростання   якості життя населення внаслідок розширення наявних та урізноманітнення потенційно можливих функцій громадського   простору   міста.   Установлено   критерії   оцінювання   архітектурно-містобудівного,   економічного,   соціального,   культурно-пам'яткового   та   екологічного

результату від реалізації плану розвитку громадського простору міста. Аргументовано доцільність застосування методу послідовних поступок як ефективного інструменту співтворення стейкхолдерами узгоджених планувальних рішень.

Розроблена базова модель формування оптимальних за окремими критеріями планувальних рішень містить обмеження на потенціал просторового розвитку міста, черговість упровадження взаємопов'язаних об'єктів розвитку та збалансованість попиту і пропозиції послуг (функцій) громадського простору для мешканців міста. Модифікована за методом послідовних поступок модель формування узгодженого за інтересами стейкхолдерів планувального рішення базується на встановленні домінантного критерію оптимізації, експертному обґрунтуванні допустимої втрати оптимальності початкових планувальних рішень за кожним із критеріїв на кожному кроці подальших розрахунків та консенсному ухваленні остаточного рішення.

Ключові слова: громадський простір, планувальне рішення, просторовий розвиток, критерії оцінювання, потенціал розвитку, модель, інтереси стейкхолдерів, метод co-creation.

Формул: 16; рис.: 2; табл.: 2; бібл.: 23.

Introduction. Every city or town is changing all the time — infrastructural objects are either appearing or being renovated; existing areas are being transformed or new ones are being explored,accordingly, in a certain way forming and developing public spaces. This process is being caused by activity of internal and external factors, as the reaction on the urgent change of economic, social, environmental and other demands of residents of the city.

Accordingly, the planning of development or formation of urban spatial within the town building system should settle a complex and controversial issue of making harmonious urban space transformation, preserving it integrity and uniqueness, with satisfaction for the interests of stakeholders.

Public space is being more and more increasingly expressive understood as an object of planning in the process of city development.Planning of urban space is particularly crucial forUkraine since socioeconomic transformations taking place in the society are deepening the discrepancy between the needs of town dwellers and functional services offers by towns and cities. It may be accounted for by the fact that urban socioeconomic structuring is accelerating more quickly than the spatial one. Simultaneously, increasing standards of living and diversification of cultural environment make our lives more exciting,thus leading to the formation of new types of public spaces and decline in the traditional ones.

As mentioned above, urban spatial development planning (with due regard to its potential and the interests of stakeholders) should be considered as the process of reaching the whole set of alternative planning decisions with the justified choice of the best one among a number of them.

Research analysis and task formulations. Public space may be defined as a separate element of urban space shared by every citizen.

The theoretical foundations of urban spatial formation are sufficiently developed by the scientific community.There are quite a lot of scientific basic and conceptual theories covering urban spatial formation and its mechanisms. «The pattern language» theory produced by Christopher Alexander may be referred to as a basic one [1]. According to him, each pattern contains a description of a problem characteristic of urban spaces and offers a corresponding planning-spatial solution, which can be applied without numerous repetitions since each formed urban space is unique.Another basic theory which is used in town building and is connected with urban public spatial development is «the central places» theory by Walter Christaller, according to which a space is considered to be an object existing to provide services for the population. The efficiency of new spaces placing is evaluated by their accessibility to users [2].

From the economic point of view,any town or city may be seen as a service market with balanced supply and demand costs.Furthermore,the larger are the volume and diversity of functional offers (services) provided by towns, as well as the lower are expenditures of their consumers to satisfy their own needs,the higher is competitiveness of a town-building system.

In R. Park's view,the types of market competition for the existence at the biotic level at any development stage of socioeconomic systems are consistently modified from severe conflicts of interest to their adaptation and assimilation [3]. Thus it is suggested that initially competition for urban spaces takes the form of struggle for survival,whereas in the end its efforts are consolidated to reach agreed goals of stakeholders (urban communities, municipalities,and developers). Corresponding changes also occur during the process of planning — at first dominant interests of a municipality are reflected, but afterwards it is followed by joint efforts of all parties to co-create public spaces [4].

Since the condition and functional usage of pedestrian space are among essential characteristics of public space, certain indicators of Ukrainian urban pedestrian space are shown in *Table 1*.

Table 1

Indicators of pedestrian space forcertain Ukrainian cities, 2020

Indicators	City		
	Kharkiv	**Lviv**	**Kryvyi Rih**
1. Urban area, sq km	306.0	182.0	407.0
2. Population, thousand people.	1451.1	724.3	652.1
3. Percentage of the total area,%:			
3.1. Landscaping areas	4.74	4.51	3.19
3.2. Urban areas	0.02	0.06	0.02
4. Length of pedestrian arteries, thousand running m:			
4.1. Pavements	1106.3	936.5	304.2
4.2. Pedestrian alleys	7.2	11.6	18.7
4.3. Trails of landscape objects	556.1	349.1	138.8
5. Number of catering establishments, units:			
5.1. Trading centres	271	169	141
5.2. Shops	4500	4961	1674
6. Number of catering establishments of all types, units.	879	1189	313
7. Ratio of available functions (trade and catering)	18.5	34.7	15.2

Source: Sosnova N. S. Theoretical and methodological foundations of public spatial formation in Ukrainian urban areas. Lviv: NU «Lviv Polytechnic», 2021. 429 p.

To examine the public space in Lviv,a sociological survey, covering the central part of the town, was undertaken in 2019.The overall aim of the research was to identify spatial characteristics and the range of functions peculiar to certain districts of the town.

The use of the town territory was evaluated by functional saturation indicators, which are partially described in [5;6]:

- K_f — the coefficient of available functions per area unit. For monofunctional objects, it reflects the number of objects per area unit;
- K_d — the coefficient of public facilities density, reflecting the area of objects per area unit;
- K_m — the coefficient of route density, reflecting the intensity of pedestrian spatial arteries usage.

The evaluation scale used for K_f coefficient is as follows: $K_f < 10$ — very low; $K_f \in [10, p. 30]$ — low; $K_f \in [30, p. 60]$ — moderate; and $K_f \geq 60$ — high. It should be noted that there are areas ranging from high ($K_f = 61/0.87 = 70.1$), moderate ($K_f = 69/1.89 = 36.5$), low ($K_f = 40/1.72 = 23.3$) to very low ($K_f = 10/1.01 = 9.9$) coefficients of available functions. On the whole, according to *Table 1*, the coefficient is moderate for Lviv, low for Kharkiv, and very low for Kryvyi Rih.

The sociological survey conducted in high-rise areas of Lviv revealed that:

- 53% of dwellers aged between 18 and 26,47% of dwellers aged between 27 and 41, and 84% of dwellers aged between 42 and 55 use their adjoining territories;
- 12 % of dwellers spend 15 minutes per day, 25% of them spend from 15 to 30 minutes per day, and 63% of them spend over 30 minutes per day in their adjoining areas.The average time

- Children (89%) and young people (70%) visit adjoining territories more frequently than people in the 27—41 age group (51%)and those in the 42—55 age group (68%);
- 46% of dwellers up to 55 years old are ready to make use of occasional services (offered by parks, squares, trade entertainment centres and others) within the distance range of 2.5 kilometres from their adjoining territories, whereas 18% of them do not want to leave the territory if the distance exceeds 800 metres;
- at weekends dwellers spend their spare time in different places, including adjoining territories, other town districts and beyond.

Owing to the inadequacy of public spaces in most residential areas in Lviv with regard to specified allowable movement of their residents, it all points to the conclusion that almost 20% of them are not able to meet their needs in short-term recreational activities and socialising on residential premises, whereas 80% of residents have to spend about an hour to move in both directions for those purposes.Consequently, if we take into consideration the actual usage of urban areas and try to coordinate it with the expected one(which is specified in the General Development Plan of a town), the validity of planning decisions made during the preparation of the plan of urban public spatial development will definitely increase.

It is also worth bearing in mind that there are certain regulatory requirements concerning urban planning and development. To be exact, there should be enough space for each resident on residential premises (sq.m / person) : 0.7 for children of preschool and primary school age; 0.1 for recreational activities of adults; 0.3 for household purposes; and 0.2 for exercising. However, those requirements,as well as a number of environmental and social ones,are not always met during the formation of urban public space.

General requirements for the formation of public space, which are to ensure a proper quality of services, are given in *Table 2*.

Table 2

General requirements for the formation of public spaces

Requirements	Characteristics of requirements and means for their implementation
1. Suitability of the territory for the performance of its particular functions.	Reservations of certain functional spaces in town-building documentation.
2. Cost effectiveness, convenience and safety of user access to public spaces.	Overcoming the deficit in spatial structures. Optimization of transport and pedestrian facilities for public transport users.
3. Within public spaces, meeting the needs for: • maintaining cognitive balance of architectural-spatial forms, town-building environmentand space function; • providing physiological comfort (protection from adverse climatic conditions, noise, visual and environmental pollution).	Correspondence of architectural-spatial and visual patterns of spaces toactions init. Harmonization at the level of town-building zoning documentation and detailed plans of spaces. Developing planning decisions based on regulatory documentation and living standards of the population.
4. Maintaining social balance of using services in public spaces.	Coordination of stakeholders' interests. Standardization of commercial and public use of spaces in percentage terms.

Source: It is based on the findings of the study conducted by Town-Building Department of Lviv Polytechnic National University entitled'Planning and reconstruction of urban spaces in terms of social transformations' (2012—2017; state registration #0113 U005276; supervised by N. S. Sosnova).

The analysis performed on the basis of recent research findings and their practical applications in the sphere of urban spatial development indicates that it is important to establish and pursue the following primary goals while planning:
- to form features of spaces which are structuring and integrating new elements into the town system;
- to fulfil the true potential of towns with the aim of providing the environment meeting town-building, social, ecological, and economic living standards of the population;

- to make alternative planning decisions on urban development of public spaces and list them in order of priority on multi-criteria basis;
- to form arrays of primary and secondary information necessary for reaching planning decisions in the interests of stakeholders.

Therefore, the study is aimed at making instruments for developing and coordinating the existing public spaces, which are seen as elements of urban spatial development, by many criteria.

Methodology and research methods. Scientific theories on how town-building systems are organised and planning decisions are reached form the methodological basis of the present study [7; 8].

As for the research into urban spatial structure,it is based on methods used in town-building, sociology, economics,and project management.Mapping of urban functional usage is used as a town-building method; conducting surveys of public space users serves as a sociological method; parameter modelling of planning decisions is used as an economic method;and multi-criteria expert evaluation of alternative project decisions serves as a project management method [5; 9; 10].

The information database of the study contains both primary (such as sociological survey findings, data of the General plans of town development of Ukraine, management accounting etc.) and secondary data (regulatory and reference data, living standards of the population, statistical reporting data, and monographical researches).

The primary information has been obtained through statistical observation, individual surveys, mental mapping,and the formation of sample data arrays. As for the secondary information, it has been mainly gained by the so-called data mining' [11]. To systemise the acquired data,the general scientific methods of grouping, analysis, synthesis, generalisation and abstraction have been adopted.

The research findings. Based on the definition of town development as a permanent processwhich is always linked with the appearance of something qualitatively new or with a new combination of existing elements of urban spatial structure leading to new results,it can be represented in a triangular shape with the following vertices: P is the development potential of a town; F is performed functions of urban spaces; and R is results of functional realisation (urban, economic, cultural, social, and environmental) (*Fig. 1*).
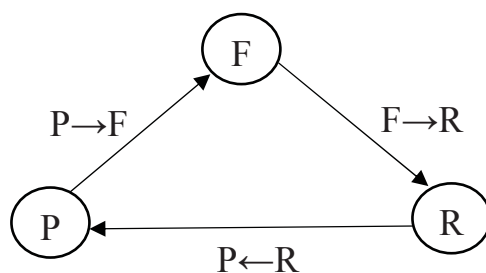

Fig. 1. **Our vision for urban development**
Source: outlined by the authors.

The development continuity is shown as a chain of undergoing transformations: … →P→F→R→P→… As mentioned above, the development planning of the town-building system should settle a controversial issue concerning its integrity, simultaneously focusing on public space transformations. Planning decisions agreed with the interests of stakeholders are possible due to modelling methods.

The development of urban spaces normally occurs by gradual implementation of its architectural, landscape, infrastructural, and other components. Its aim is to increase living standards of the population and achieve desired results. *Fig. 2* shows the main factors influencing the development of urban public spaces.
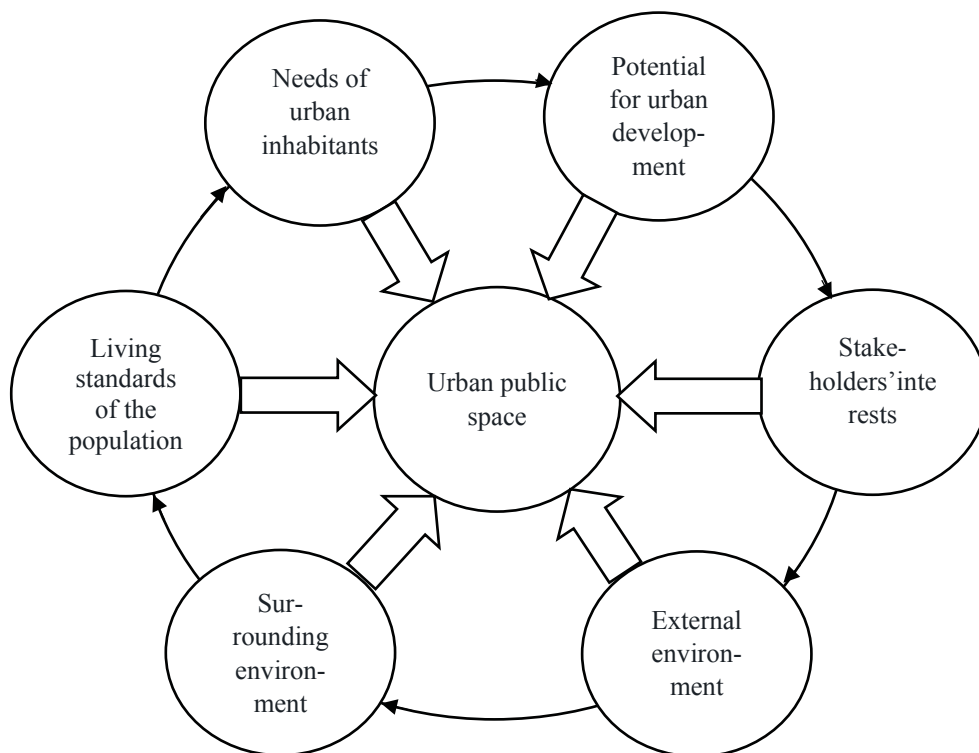
Fig. 2. **Factors influencing the development of urban public spaces**
Source: Outlined by the authors.

The implementation of planning decisions on transformation of existing or formation of new public spaces depends on potential for growth (available and prospective resources), the main elements of which are as follows [7; 8]: architectural resources (architectural and town-building monuments; valuable historic buildings; dominant and accented buildings; peculiar spatial forms of area organisation); town-building resources (engineering, transport, energy systems and networks); natural resources (territories; green belts; hydro networks of natural and artificial origin); investment resources (current and expected cost of land; business efficiency); financial resources (prospective amounts for landscape financing and implementation of objects, as well as their structural ratio estimates in terms of whether they are private, municipal or national); cultural-symbolic resources (spiritual, historic, and symbolic places); social resources (objects of socialinfrastructure);and organisational resources (initiative and perseverance of stakeholders in coordinating and safeguarding interests of urban spatial development).

There is also a model called «Stakeholder», which is extensively used in economics (while planning socioeconomic development of economic agents in particular). The fact is that the model may be also used in urban spatial development [12]. In this case, urban inhabitants, municipalities, tourists, sponsors, business people and others may be regarded as those in the interested group. Municipalities with their administrative-organisational, architectural, town-building, environmental and financial resources may be seen as active participants capable of exerting their influence on urban spatial development. As for urban inhabitants, they are relatively active because of their occasional participation in formation of public space. Political and public organisations may be considered as situational participants since they have information resources.

It should be noted that in order to prevent or resolve stakeholders' conflicts of interest,it is advisable to follow the co-creation methodology, which involves joint and agreed action of interested parties depending on their importance in the implementation of public space elements according to «power/interest» and «power / influence» matrices while the development of planning decisions [9].

The fact that stakeholders are highly variable in groups and interests is responsible for the necessity of multi-criteria evaluation of planning decisions. The research findings of both domestic [8; 13] and foreign [14—18] authors confirm that criteria should be divided into certain types (such

as economic, social, environmental, urban, and culturological) to assess functional results of various public spaces.

On the whole, there are the following types of urban public spaces: architectural, monumental,and cultural-symbolic clusters; shopping and entertainment areas; freely accessible residential areas; landscape and recreation areas etc. Each type meets the needs and preferences of consumers by serving appropriate functions.

The continuous development of public spaces as live urban material is taking place as a result of stakeholders' reactions to recognised joint needs of urban inhabitants (see *Fig. 2*). Thus the assessment of how current needs are provided for and future needs are identified is one of the principal tasks in urban public spatial planning.

When urban public spaces are evaluated, a range of criteria established for satisfying living standards of the population are adopted. Having analysed the scientific publications and based on our own research into public spaces of Lviv, it has been revealed that their formation and usage depend on architectural and town-building conditions, social peculiarities of space users, and area features. Moreover, their development is determined by economic expediency. Thereafter criteria indicators for urban public spatial evaluation may be divided into the following groups according to the expected results: architectural and town-building, economic, social, historic-symbolic, and environmental [12; 19; 20].

The whole set of criteria indicators should satisfy basic system-forming demands (such as regularity, independence, and consistency), as well as enable us to perform the following tasks [4]:

- to determine the level of development aim achievement according to criteria;
- to include the acceptable range of changes in indicators;
- to monitor for discrepancies between actual and allowable values of criteria;
- to carry out quantitative and qualitative assessments of current and future spatial conditions;
- to set the direction (priority) and development pace of spaces;
- to review and update criteria.

Criteria used for the assessment of architectural and town-building results define the architectural appeal of any town,its spatial organisation,its integration into the transport network etc. A town-generating effect, the key indicator of which is security, can be seen as an impressive outcome of introducing elements of public spaces [20; 21]. As for the security of urban environment, it is dependent on architectural-spatial area organisation,on provision of personal comfort in a space, and on making an area semantically valuable. In general, when the system is secure,it seeks to optimise its condition according to all the town-building indicators showing its architectural uniqueness, compositional integrity and appeal, accessibility of public spaces in terms of regulatory requirements, traffic management,and functional density per area unit.

According to economic efficiency criteria,a public space is the place for creating new jobs, increasing assets, and offering services. The most widely used economic criteria are as follows: the number of current and prospective places of work; the share of commercial construction; dynamics of real estate prices; investment attractiveness etc. The development of public spaces leads to an increase in the number of their users and profitability due to their increasing architectural-spatial appeal. For example, when public spaces in Seoul (South Korea) were modernised, land prices went up by 30—50% in the reconstructed areas and the flow of visitors has increased so that it makes a daily profit of 1.9 million dollars for the city [22].

As for social criteria, they specify social interaction in spaces, attractiveness to users,how spaces make us feel belonging to them etc.In fact, the social outcome of urban public spatial development is linked with the identification of urban inhabitants as part of their town through certain iconic objects and landmarks. In town-building history, squares of the Magdeburg law towns served as spaces providing their identification.In contemporary Ukraine, such illustrative examples are the embankment with fountains in Vinnytsia,the bridge over the Uzh and Peteffi Square in Uzhhorod, as well as the square in front of Lviv Opera House. Another indicator of social outcome is the density of the population as the basis for prospective social activities [13].

Indicators which evaluate historic-symbolic attractiveness of spaces are those characterising them in their group identity, showing how places influence human memories,and how public spaces are perceived [19].

The ecological criteria for urban spatial development are laid down to characterise the conformity of planning decisions to balanced development of urban areas, as well as the level of physiological comfort achieved by space users in terms of environmental conditions.The green belt share per area unit may be seen as a generalised indicator of ecological results [23].

The assessment of urban spaces by a set of criteria is carried out by establishing empirical values of indicators and comparing them with the corresponding standard values. Since urban spaces are defined by the whole range of indicators (criteria), there is the necessity to compare vector values. However, the comparison hardly ever shows the relation order unambiguously. The scalarization method (i.e. the method of collapsing vector estimates to a scalar form, taking into consideration the weight of each criterion or sets of criteria) is used as the most appropriate for the solution of the problem.

It is also worth mentioning that weights of criteria (sets of criteria) for certain types of public spaces may differ, depending on their functional peculiarities [19]. The empirically analysed characteristics of public spaces and needs of their users indicate that:

- social and culturological development results should be given priority in citywide central spaces, which are responsible for evoking feelings of identity, recognisability, and uniqueness;
- economic development results are essential for spaces adjacent to public objects, which are investment dependent;
- an ecological component of the development is of paramount importance to public spaces (open and undeveloped) based on natural or artificial landscapes, as well as biologically active constituents;
- social and urban (security in particular) results are important for public spaces in residential areas, which are primary spaces for social activities with stricter social control based on members- non-members' principle and accessible to every age group.

Since the plan of urban spatial development may be represented as a number of projects(each of which affecting its state and functions and calling for appropriate resources), there is the necessity for the balanced multi-criteria development plan, which will simultaneously meet the aim, requirements, and the potential of public spatial development. It should be noted that reaching the living standards of the population is the major goal of public spatial development,the potential of which is defined by its resources. As for its requirements, listing the development projects (groups of projects) pertaining separate public spaces or their combinationsin order of their implementation should also be included.

As far as the plan of implementing development objects is concerned, it should be drawn up in such a way so that to comply with constraints on resource provision, which may change over time, and reach optimal values of development criteria. Moreover, each development object should be implemented in one of the planned time intervals. Accordingly, there is a certain implementation listing of development objects in order of priority, as well as their alternatives in the plan.

In our study, the following criteria are considered to be optimisation criteria, based on the selected groups of development indicators of urban public spaces:

- criteria of architectural and town-building results

$$F_1(x) = \sum_j \sum_t u_j x_{jt} \rightarrow \max, \qquad (1)$$

- criteria of economic efficiency

$$F_2(x) = \sum_j \sum_t f_j x_{jt} \rightarrow \max, \qquad (2)$$

- criteria of social results

$$F_3(x) = \sum_j \sum_t v_j x_{jt} \rightarrow \max, \qquad (3)$$

- criteria of cultural and monumental results

$$F_4(x) = \sum_j \sum_t c_j x_{jt} \rightarrow \max, \qquad (4)$$

- criteria of ecological results

$$F_5(x) = \sum_j \sum_t g_j x_{jt} \rightarrow \max, \tag{5}$$

where x_{jt} is a variable characterising whether object j is included ($x_{jt} = 1$) or not included ($x_{jt} = 0$) into the plan of urban public spatial development at t time interval; u_j, f_j, v_j, c_j, g_j are relevant consolidated assessments of certain achieved results (architectural and town-building, economic, social, cultural and monumental, ecological) coming up with the implementation of j objects.

It is not recommended to introduce any additional restrictions on threshold values of criteria (1)—(5) since they are already aimed at achieving maximum results.

As for resource potential, it is an essential restriction placed on urban public spatial development while making optimal planning decisions. In fact, resource restrictions are a prerequisite significantly affecting the development of any social-economic system, towns in particular. Such resource categories as territories, finances, cultural-symbolic assets, human resources, administrative and organisational resources, objects of administrative, trade, transport, engineering, and social infrastructure are among resources for urban public spatial development. Moreover, their synergy makes them ideal for public spatial development.

As for the so-called free resources or their availability, they may be regarded as prospects for public spatial development. For example, wastelands and abandoned areas are a prerequisite for the development of local public spaces. Additionally, social activities of urban inhabitants (as human resources) not only act as a catalyst for public spatial development at educational, recreational, trade and entertainment, sports, cult, sacred,and other objects, but also trigger the search for sources of financial security. Consequently, the urban area arrangement (initiated by the public) supported by the administration and (partially) done at the expense of the town budget, receiving financial support from investors (equity participation), will lead to the desired results for every stakeholder: urban inhabitants will improve living standards; the town administration will have an increase in loyalty among the town community; whereas investors will have a rise in profits owing to the image result and capitalisation of areas increasing in value.

Restrictions on development potential have the following form:

$$\sum_j a_{rj} x_{jt} \leq A_{rt}, \tag{6}$$

where a_{rj} are expenditures of type r resources on object j implementation; and A_{rt} is the volume of resource provision for a planned t time interval.

It is important to ensure the implementation of interdependent objects of urban public spatial development in compliance with a certain list of priority. Objects are considered a top priority if they satisfy the requirement of accessibility to the population or provide them with it (transport infrastructure → trading places; residential facilities → social infrastructure etc).

In general, the restriction on the order in which objects of public spatial development are implemented has the following form:

$$S_{i,t-1} + \sum_m s_{im} x_{m,t-1} \geq \sum_k d_{ik} x_{kt} + D_{it}, k, m \in J, \tag{7}$$

where k and m are indices of interdependent objects which offer ($j = m$) and require service ($j = k$) of type i; s_{im} is the offer of the service of type i by object m; d_{ik} is the requirement of object k to get the service of type i; $S_{i,t-1}$ is an available service offer of type i at time interval (t–1); D_{it} is an available requirement for the service of type i at time interval t; J is a set of objects of urban public spatial development. Restriction (7) reflects the requirement to balance the supply and demand of services of type i in time.

The constraint on the discreteness of the values of of variable x_{jt} has the following form:

$$\sum_t x_{jt} = 1, x_{jt} = \{0; 1\}. \tag{8}$$

Models (1) — (8) makes it possible to come up with the optimal plans of urban public spatial development for each separate criterion. In order to draw up the plan agreed with all the criteria and meeting interests of certain groups of stakeholders, the methods of the so-called compromise programming should be applied. Among those methods, the method of successive concessions may be seen as the most close to the co-creation methodology.

How basic models (1) — (8) is transformed to find a compromise plan to develop public spaces by the method of successive concessions may be illustrated with the example of the task of forming a public space for a residential area requiring the construction of trade and entertainment objects, as well as a whole group of objects of social infrastructure, within the area at the intersection of motorways of town and district importance. Variations within the plan of urban spatial development may be attributed to the availability of competing projects dealing with placing of certain objects.

The compromise may be found either through reduction in the capacity of the object (the number of simultaneous visitors) or making the system more diverse, namely providing services with the highest social demand which have not been provided so far to users (within towns, planning districts, and residential areas).

The transformed model of public spatial development looks like this:

- the priority criterion of development according tko experts marks

$$F_1(x) = \sum_j \sum_t u_j x_{jt} \to \max; \tag{9}$$

- restrictions on allowable reductions in optimal economic results $F_2^*(x)$, which may arise due to the priority implementation of urban infrastructural objects

$$\sum_j \sum_t f_j x_{jt} \geq (1 - \lambda_f) \cdot F_2^*(x); \tag{10}$$

- restrictions on allowable reductions in optimal social results $F_3^*(x)$ for certain groups of the population owing to the closure of small retail outlets within the radius of newly-created trading and entertainment centres

$$\sum_j \sum_t v_j x_{jt} \geq (1 - \lambda_v) \cdot F_3^*(x); \tag{11}$$

- restrictions on allowable reductions in optimal cultural and monumental results $F_4^*(x)$ due to the priority implementation of urban infrastructural objects and redistribution of the flow of urban public space users

$$\sum_j \sum_t c_j x_{jt} \geq (1 - \lambda_c) \cdot F_4^*(x); \tag{12}$$

- restrictions on allowable reductions in optimal ecological results $F_5^*(x)$ due to building up and paving of biologically active areas, as well as the intensification of transport flows

$$\sum_j \sum_t g_j x_{jt} \geq (1 - \lambda_g) \cdot F_5^*(x); \tag{13}$$

- restrictions on the resource potential of development, which depend on the area of construction sites, their configuration and town-building conditions

$$\sum_j a_{rj} x_{jt} \leq A_{rt}; \tag{14}$$

- restrictions on the implementation order of development

$$S_{i,t-1} + \sum_m s_{im} x_{jt} \geq \sum_k d_{ik} x_{kt} + D_{it}, k, m \in J; \tag{15}$$

- restrictions on allowable values of variables

$$\sum_t x_{jt} = 1, x_{jt} = \{0; 1\}, \tag{16}$$

where $\lambda_f, \lambda_v, \lambda_c, \lambda_g$ are the allowable share in optimality losses of the corresponding results $(0 < \lambda < 1)$, agreed by stakeholders.

The whole process of looking for a compromise solution to the problem of public spatial development is interactive and multistage, with adjustments of $\lambda_f, \lambda_v, \lambda_c, \lambda_g$ values at each stage, until reaching an acceptable compromise. In order to apply the method of concessions efficiently, there is a need for coordination among groups of experts (stakeholders) while calculating and adjusting values of allowable share in optimality losses of development criteria.

Conclusions. The following conclusions may be drawn from the findings of the present study:

1. The development of Ukrainian urban public spaces is one of the most pressing tasks since the radical transformation of the post-communist society was not accompanied by corresponding spatial changes in urban environment.

2. Under limited resources, urban public spaces are growing in importance as planning objects with multi-criteria assessment of their results.

3. The basic model (built for finding planning decisions optimal for each criterion),and its version (modified according to the method of successive concessions) make it possible to reach agreed multi-criteria decisions.

4. Separate consideration is required for such methods as the method for the substantiation of characteristics defining introduced objects and resource provision and the method of expert estimation of economic, ecological, social, cultural and monumental, and security results obtained from the implementation of public spatial development projects.

5. Territory is the most important resource in town-building and in public spatial planning in particular. However,in its absence,if all other criteria are favourable for achieving expected results of implementing an object, it is necessary to modify the development model in such a way so that certain objects are removed from a public space, thus forming a required resource. It is realistic, because both towns and territories are changing all the time.

6. The usage of modelling methods, compromise programming, expert estimation and graph-analytical visualisation provides an information basis for the formation and analysis of alternative planning decisions. On the other hand, the final planning decision should be achieved based on agreed joint opinion of stakeholders.

7. The scientific novelty value of the present study lies in its development of planning tools for urban public spatial development based on the methodology for co-creation by stakeholders.

The model, which estimates the state and opportunities of public spatial development, as well as reaches an agreed planning decisions by the method of successive concessions, has both theoretical (an analytical component of urban spatial development planning) and practical (the application of the sociological surveying and expert estimation methods for the research into spatial functions and user's needs) values.

Therefore, the implementation of the plan of urban public spatial development will lead to the agreed optimisation of architectural and town-building, economic, social, cultural and monumental, and ecological results.

Our further research work will be aimed at modifying the basic model for the needs of certain types of public spaces and developing an interactive technology for the method of successive concessions.

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Статтю рекомендовано до друку 07.07.2021　　　　© Тимощук М. Р., Соснова Н. С., Фещур Р. В., Шишковський С. В., Копитко С. Б.

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The article is recommended for printing 07.07.2021　　　© Tymoshchuk M., Sosnova N., Feshchur R., Shyshkovskyi S., Kopytko S.