

URBAN PLANNING, PLANNING OF RURAL SETTLEMENTS ГРАДОСТРОИТЕЛЬСТВО, ПЛАНИРОВКА СЕЛЬСКИХ НАСЕЛЕННЫХ ПУНКТОВ



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Development of a Methodology for Decision-Making in Urban Planning and Design of Coastal Areas of Small Rivers in Cities

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Abstract

Introduction. The study is aimed at solving the problem of non-systematic use of coastal areas of small rivers in Russian cities. The relevance is due to the existing fragmentary approach to their urban planning and design, while global experience has been displaying complex solutions. The aim of the study is to develop a methodology for decision-making in urban planning and design of coastal areas of small rivers in large cities based on a multi-criteria analysis.

Materials and Methods. The object of the study are coastal areas of small rivers of large cities. The authors propose making use of a systemic approach that accounts for adjacent functional zones, their mutual influence and expert assessment of significance.

Research Results. A methodology for decision-making in urban planning and design of coastal areas of small rivers has been developed, allowing for the analysis of the functional purposes of individual sections and their interaction at the pre-design stage. In addition, an algorithm for identifying synergetic effects between different development zones has been designed.

Discussion and Conclusion. The approach proposed by the authors allows one to overcome the fragmentation of urban planning solutions regarding coastal areas of small rivers. The prospects of the study include expansion of the methodology due to incorporating environmental, economic, social and functional factors, as well as the application of the approach to a larger number of types of functional zones.

Keywords: urban development, small rivers, improvement, urban planning, urban design, multi-criteria analysis

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Оригинальное эмпирическое исследование

Разработка методики принятия решений при градостроительном планировании и проектировании береговых территорий малых рек в городах

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Аннотация

Введение. Исследование направлено на решение проблемы несистемного использования береговых территорий малых рек в российских городах. Актуальность обусловлена существующим фрагментарным подходом к их гра-

достроительному планированию и проектированию, в то время как мировой опыт показывает комплексные решения. Цель работы — разработка методики принятия решений при градостроительном планировании и проектировании береговых территорий малых рек в крупных городах на основании многокритериального анализа.

Материалы и методы. Объектом исследования выступают береговые территории малых рек крупных городов. Авторы предлагают использовать системный подход, учитывающий прилегающие функциональные зоны, их взаимовлияние и экспертную оценку значимости.

Результаты исследования. Разработана методика принятия решений при градостроительном планировании и проектировании береговых территорий малых рек, позволяющая анализировать функциональные назначения отдельных участков и их взаимодействие на предпроектной стадии. Кроме того, создан алгоритм выявления синергетических эффектов между различными зонами освоения.

Обсуждение и заключение. Предложенный авторами подход позволяет преодолеть фрагментарность градостроительных решений относительно береговых территорий малых рек. Перспективы исследования включают расширение методики за счет включения экологических, экономических, социальных и функциональных факторов, а также применение подхода для большего количества типов функциональных зон.

Ключевые слова: градостроительство, малые реки, благоустройство, градостроительное планирование, градостроительное проектирование, многокритериальный анализ

Благодарности. Статья опубликована в рамках субсидии из федерального бюджета образовательным организациям высшего образования на реализацию мероприятий, направленных на поддержку студенческих научных обществ.

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Introduction. Small rivers are the most common elements of the hydrographic network of the Russian Federation occupying vast territories with 30% of the country's population living in their drainage area [1]. In almost every major city there is at least one small river that passes through densely populated and promising areas. At the same time, there is still a problem of competent scientific and sensible use of their coastal areas with no urban planning mechanism in place for their planning and design. Hence creating an urban planning model for integrated planning and design of coastal areas of small rivers in large cities is becoming an essential element of the scientific and methodological foundations of urban planning and design of coastal areas of small rivers [2]. To this end, it is imperative that a decision-making methodology is developed for urban planning and design of coastal areas of small rivers with a multi-criteria analysis an indispensable part of this.

Materials and Methods. The decision-making process in urban planning and design is presently discrete, with gaps between its stages [3–4]. This is an obstacle to the integrated development of the urban environment accounting for the previously identified groups of factors. Any choice in urban planning practice should be justified and made comprehensive to various population groups, as well as account for a host of criteria and uncertainties, including temporary ones due to ongoing scientific and technological progress, as well as disaster risks (accidents at nuclear power plants, dams, earthquakes, flooding, etc.) and various interest groups.

At the same time, it is seldom that problems in the construction and urban planning spheres are one-dimensional (those with simple values). These are mostly multidimensional problems with complex values [5–8], where the consequences cannot be objectively and adequately assessed by means of one criterion (e.g., using monetary expressions). A systematic approach would cause changes to the practice.

It is to be noted that there have already been some examples of solving problems in urban planning, transport planning, and administrative and economic activities of territorial entities using multi-criteria selection described in a few papers (Table 1) making it possible to make use of this method in order to select and justify urban development scenarios for specific urban areas.

Table 1

Theory of decision-making with lots of criteria: practical examples based on the studies by R.L. Kini and H. Rife [9–11]

No.	Name of an example	Brief description	Conclusions based on the results of using multi-criteria selection tools
1	Air pollution problems	Systematization of the initial data, pollution problems with the release of individual substances, final results and control measures into a common model for assessing air pollution control programs	Using the results of the analysis and using them in forming and implementing air pollution control programs in New York
2	Activities of individual departments	Analysis of the work organization of the department using the example of a fire station, including the use of the utility function for response periods as the foundation for decision-making in operational activities	Obtaining a utility function for five criteria — response periods identifying the relative value of each minute of the response period, which generated a utility structure in the area
3	Disposal of wastewater treatment products	Four major goals (minimizing costs/water pollution/air pollution/land pollution) caused the issue of possible substitutions	Probabilistic distributions were designed in four directions and work stages on the disposal of wastewater treatment products were chosen.
4	Choosing a job or a place of work	The peculiarity is a profound personal decision, but a possibility of a formalized procedure for assessing the "advantages" of various situations with a large number of criteria.	Reducing the proposals to alternatives with a hierarchy of goals and criteria, systematizing choices based on Miller's goals and using the Tevels gradation of goals (security, confidence, independence, etc.)
5	Choosing technical solutions for environmental protection	Generalization and formalization of data and sequence of multi-criteria selection in choosing technical solutions for environmental protection	Choosing an option (equivalent options) of technical solutions for environmental protection system that is in compliance with the requirements of not absolutely all, but the largest number of the criteria involved
6	Analysis of the airport development problem for Mexico City	Analyzing alternatives from the perspective of each group of decision makers and citizens, designing a decision-making model identifying possible implications of the alternatives and conducting design experiments, assessing for a year and introducing time dependence	Making a decision based on a multidimensional utility function and considering scenarios for possible developments showing the implications of alternatives for subsequent changes to a city's development strategy.

Coastal territories of urban (small) rivers were chosen as the object of the study for structuring the methodology interacting simultaneously with the transport planning and natural and ecological frameworks, as well as with the adjacent functional zones and the engineering support system (Fig. 1).

For the basic scheme of multi-criteria selection (Fig. 2), a special mathematical apparatus was developed in order to simplify the calculation compared to the general case of decision theory including a preliminary analysis, structural analysis, a decision tree with two types of vertices, uncertainty analysis, and then utility and value followed by optimization procedures [9].

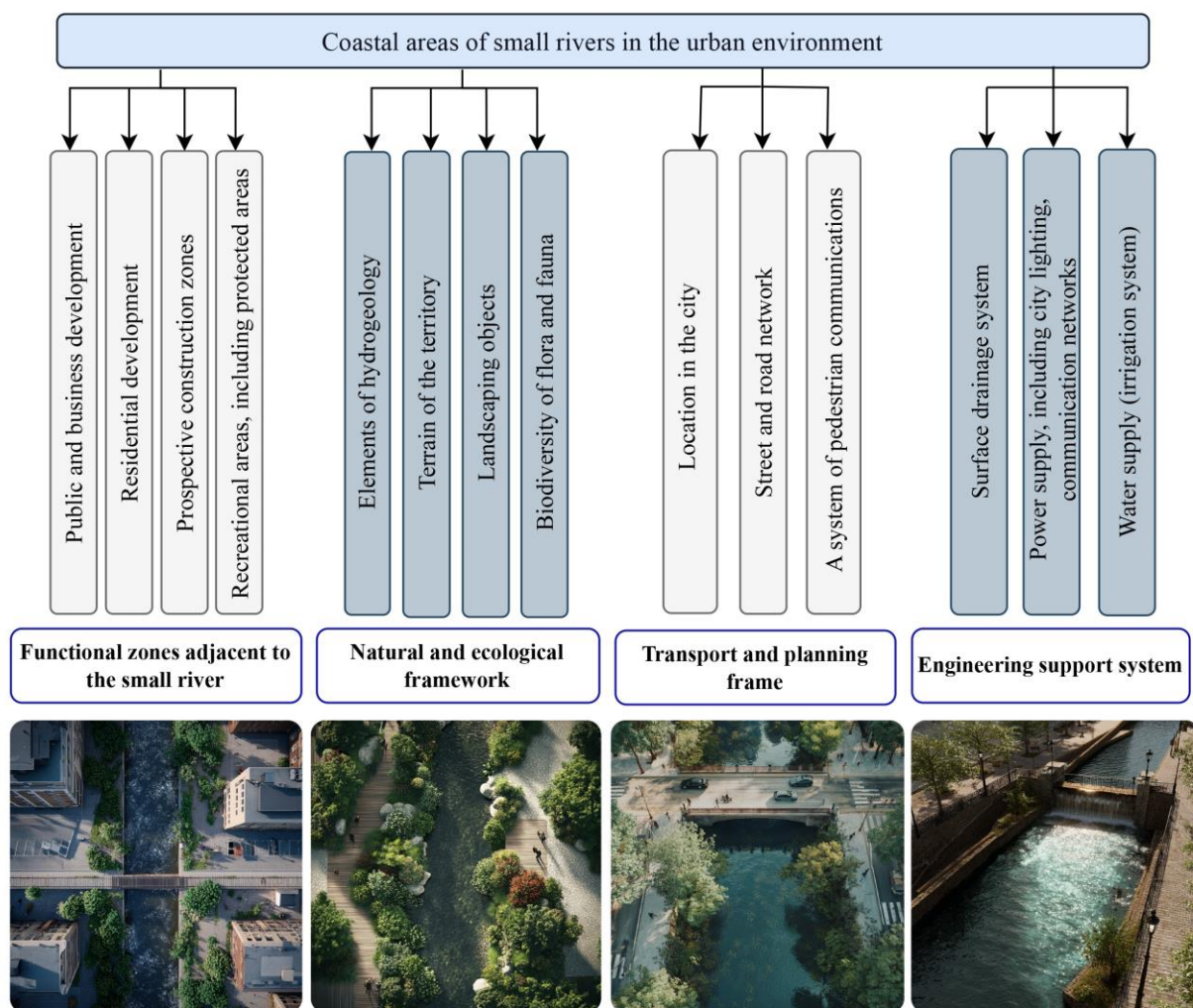


Fig. 1. Small rivers as part of an urban environment

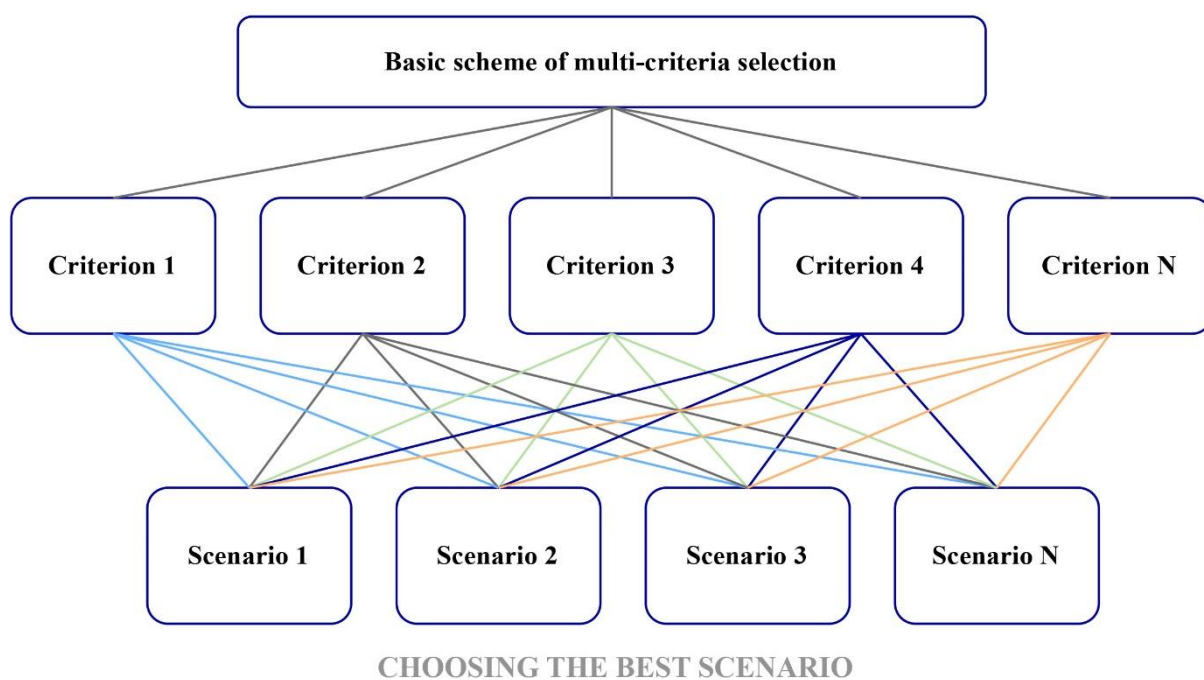


Fig. 2. Generalized structure of a multi-criteria selection scheme

Urban planning decisions include, among other things, the allocation of land in view of a range of restrictions, including environmental or cultural heritage-related ones. It is to be noted that an area in a city is valuable primarily from the perspective of making use of what is located in it. If it is assumed that this value can be formalized by means of a function that can be expressed numerically at the current level of the forecasting period and development of various interests, the task is to design an area distribution that would maximize the value of this function and thereby the value of land use. While designing such a function, it is to be noted that its variables are the criteria characterizing various factors in their measurement scales. Further formalization is associated with defining the options that cannot be improved based on at least one criterion without making it worse according to another one ("a Pareto set").

There are mathematically justified "value substitutions" of the selected criteria both in conditions of certainty and uncertainty. Within the framework of the process it is possible to assume the results of the transition of certain types of actions into implications by using multidimensional value functions [9–11]. Researching choices that require no formalization of the structure of preferences has led us to make some conclusions regarding their structuring for urban planning and the capacities of the suggested scientific approach.

Research Results. As a result of the study, it was found that in urban planning, the task of allocating areas in a particular territory depends on the replacement coefficient, i.e., which area of destination A we are willing to give away for incrementing the area of destination B by one unit. What is challenging is that the replacement coefficient is not constant, but varies depending on the ratio of areas: if the area of destination A is very small, the area of destination B is large. The replacement coefficient will thus differ from the opposite option or with equal-sized areas of assignments A and B.

It is considered possible to apply the general theory of multicriteria selection to a specific urban planning task, i.e., the distribution of coastal areas.

Two types of area distribution on the same site with a variety of distribution options were chosen, which simplifies the selection of the area from the boundary of the coastline to that of a specific functional area.

In order to form a systematic approach based on a multi-criteria analysis, let us assume that:

- a) restrictions have already been taken into account while selecting options for possible area allocation;
- b) specific features of a certain territory (relief, prospects for developing the neighboring areas, etc.) are not accounted for in order to design a basic model of the area.

Based on this, it is assumed that only the impact of different territorial assignments on each other is being assessed. Having accounted for the impact, the location of the selected areas is specified considering the functional features of the areas.

Hence the basic version of the system approach includes two purposes of areas: S_1 is for the placement of a recreational area, S_2 is for residential buildings (Fig. 3), and only the mutual influence of S_1 and S_2 is analyzed rather than their specific location and configuration to be considered at the next stage of the study.

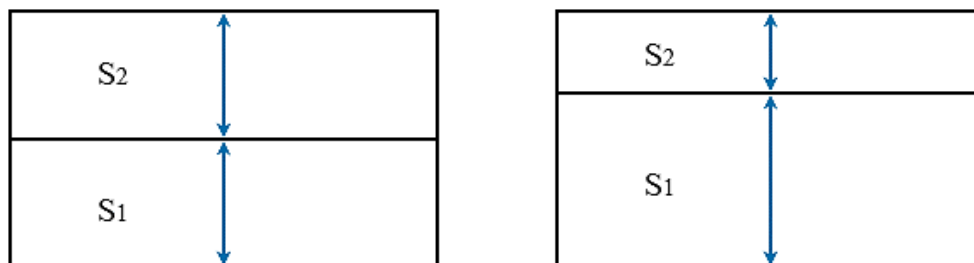


Fig. 3. Systematic approach by means of the allocation of two types of areas

Next, the substitution coefficient for various ratios needs to be used and a value function $W(V_1, V_2)$ where $V_1(S_1)$ and $V_1(S_2)$ needs to be designed. The values of S_1 and S_2 can be identified using it when W reaches its maximum value.

At the second level of the system approach, there might be a case with three types of area assignment (S_1 , S_2 and S_3). In this case, the ratio becomes three-dimensional and the substitution coefficient changes between each two area values that are also affected by the area of the third destination.

The third and further levels of the system approach are working with diagrams (areas) for 4, 5 or more purposes.

One of the tasks is thus to examine the possibility of mutual compensation of criteria values relative to each other (substitution by value). This is possible with their systematic structuring and use of an appropriate coefficient that might be influenced by the environment (the already built-up area around) and other factors.

The next stage might be to interview an expert or a decision maker (within the framework of a list of proposals) on changing the value of the areas, as well as accounting for the environmental, economic, social and functional factors characterizing the area as well as their combined groups (Fig. 4).

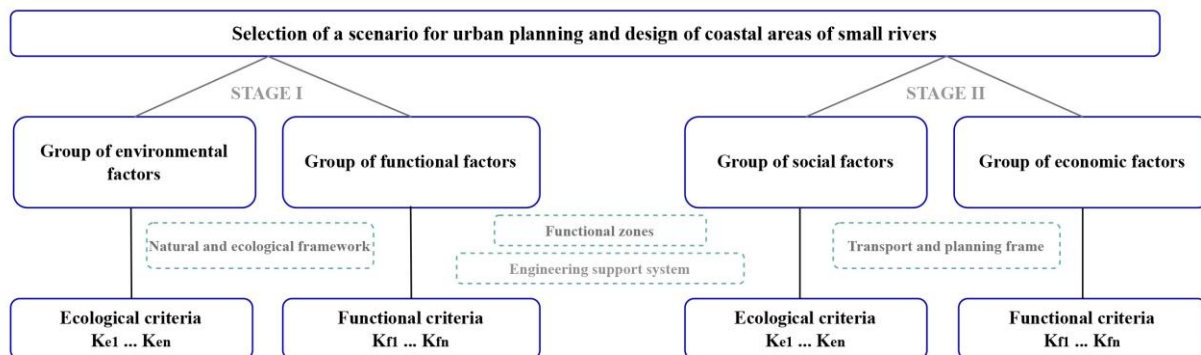


Fig. 4. Multi-criteria analysis while choosing a scenario for urban planning and design of coastal areas of small rivers

The decision-making methodology in urban planning and design of coastal areas of small rivers in large cities should also account for the interests of various population groups, including business communities and local as well as federal governments experiencing considerable changes over time. The results of the research will become part of the solution to the scientific problem of contradictions between the modern discrete approach to urban planning and design of coastal areas of small rivers and the need to move to an integrated step-by-step approach for planning and designing them accounting for socio-economic and environmental-functional factors.

Discussion and Conclusion. The study has thus confirmed the need to move from the existing discrete system of urban planning and design to a systematic approach in developing coastal areas of small rivers. The suggested method of multi-criteria analysis would help to address the fragmentation of decision-making and provide a scientifically sensible approach to the distribution of functional areas.

The major result of the work has been the development of a theoretical model based on the principles of multidimensional optimization and decision theory accounting for the mutual influence of various functional purposes of areas by means of a system of substitution coefficients allowing one to maximize the overall value of the selected area with no reference to a specific configuration at the initial stage.

The practical significance of the study is the formation of tools for comparing alternative scenarios for developing areas accounting for the relevant groups of factors, as well as increasing the validity of urban planning decisions.

The prospects for further research are to expand the number of functional purposes to be considered, to integrate the factor of the dynamics of changes in criteria over time into the model, to develop mechanisms for accounting for the interests of various stakeholders, and to test the methodology on real sections of the coastal areas of small rivers in a city.

It is our belief that the implementation of the suggested decision-making methodology in urban planning and design of coastal areas of small rivers in cities will contribute to designing a balanced and sustainable urban environment that makes an effective use of their potential considering the principles of biospheric compatibility.

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EV Kotlyarova: formation of the basic concept, aims of the study, preparation of the manuscript, calculations, conclusions.

VO Glagolev: revision of the manuscript, work with the illustrations, substantiation of the relevance of the study.

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