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Original article

Main Scientific Principles of a Systematic Approach to the Determination of Negative Factors Affecting Urban Environment

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Abstract

Introduction. With the modern active development of urban areas, the problems in the field of environmental safety are becoming increasingly relevant. These problems cannot be solved without an in-depth analysis of the factors that disrupt the ecological balance and cause negative consequences for the components of the environment. At the same time, construction industry is one of the main elements of human economic activity that forms technogenic loads. This is due, among other things, to the fact that, unlike some other areas, the pace of construction work has increased significantly over the past year. So, as of March 2023, 2 460 developer organizations were registered in the Russian Federation, which was 14% more than in the previous period, that is, the speed and scale of construction work most of all affect the population of cities from a socio-economic point of view. At the same time, we should not forget about the environmental side of the issue. Many years of research in this area has shown the lack of a structured approach to assessing the environmental safety of urban areas, including the selection of an optimal list of environmental measures. At the same time, scientific approaches based on the ecological characteristics of the totality of natural conditions, determining the maximum permissible anthropogenic loads, identifying environmentally significant environmental parameters, such as the amount of oxygen in the atmospheric air or the availability of natural water resources, require significant time and labor costs, and also, as a rule, are not tied to specific objects of the urban environment. However, urban planning spaces, depending on their functional purpose, contain typical anthropogenic objects, among which capital construction and landscaping facilities predominate. The nature of the negative impact on the environment from such facilities is obviously also typical. In this regard, the aim of the study was to systematize and unify numerous negative factors affecting the territory of a particular object of capital construction and landscaping, depending on the functional purpose of the territory and the types of objects located on it. The authors propose to perform such transformations automatically within the framework of the developed online platform.

Materials and Methods. To assess the negative impact on the urban environment, it was proposed to use a methodological approach based on the concept of functional zoning of the territory. According to the Urban Planning Code of the Russian Federation, each functional zone is characterized by the presence of certain capital construction and landscaping facilities. To achieve this goal, we used methods of comparative and system analysis and generalization. Thus, the results were obtained and systematized in the work, which showed the similarity of the nature of the negative impact from the same types of capital construction and landscaping facilities.

Results. The assessment of the negative impact of capital construction and landscaping facilities on the environment was part of the research work prepared within the framework of the state program "Priority 2030". A systematic approach in analytical studies of negative factors of urban environment will allow structuring information, significantly speeding up its analysis and making appropriate decisions due to the relationships we have established between the parameters of negative factors, types of objects and functional zones in which they were located. The proposed approach was implemented within the framework of the online platform developed by the authors. At the same time, the

main principle that guided us was quick access to the task of ensuring environmental safety of the territory due to accelerated automated assessment of negative factors from a given capital construction object or urban improvement.
Discussion and Conclusion. The obtained research results, which include the systematization of negative environmental impact factors on the territories of capital construction and landscaping facilities, depending on the functional zones of their location, are the basis for further development of methods for ensuring environmental safety of the urban environment. The fullest possible identification of all environmentally hazardous factors will ensure an effective assessment of the negative impact on the environment of capital construction projects and urban improvement.

Keywords: environmental safety, negative impact assessment, environment, capital facilities, landscaping, urban environment

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Научная статья

Основные научные принципы системного подхода к определению негативных факторов, воздействующих на окружающую среду городских территорий

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Аннотация
Введение. В современных условиях активного развития городских территорий проблемы в области обеспечения экологической безопасности приобретают все большую актуальность. Они не могут быть решены без глубокого анализа факторов, нарушающих экологическое равновесие и вызывающих негативные последствия для компонентов окружающей среды. При этом одним из главных элементов хозяйственно-экономической деятельности человека, формирующей техногенные нагрузки, выступает строительная отрасль. Это связано в том числе с тем, что, в отличие от некоторых других сфер, темпы строительных работ за последний год значительно возросли. Так, на март 2023 года в Российской Федерации зарегистрировано 2460 организаций-застройщиков, что на 14 % больше предыдущего периода, то есть скорость и масштаб строительных работ в настоящее время больше всего затрагивают население городов с социально-экономической стороны. Но при этом нельзя забывать и об экологической стороне вопроса. Многолетний опыт исследований в этой сфере показал отсутствие структурированного подхода к оценке экологической безопасности городских территорий, включающего в себя подбор оптимального перечня природоохранных мероприятий. При этом научные подходы, основанные на экологической характеристике совокупности природных условий, определении предельно допустимых техногенных нагрузок, выявлении экологически значимых параметров окружающей среды, таких как количество кислорода в атмосферном воздухе или наличие естественных водных ресурсов, требуют значительных временных и трудовых затрат, и они, как правило, не привязаны к конкретным объектам городской среды. Однако градостроительные пространства в зависимости от функционального назначения содержат типовые антропогенные объекты, среди которых преобладают объекты капитального строительства и благоустройства территорий. Характер негативного воздействия на окружающую среду таких объектов, очевидно, является тоже типовым. В связи с этим целью данного исследования является систематизация и унификация многочисленных негативных факторов, воздействующих на те или иные территории объекта капитального строительства и благоустройства, в зависимости от функционального

назначения и территории, и расположенных на ней объектов. Такие преобразования авторы предлагают производить автоматизировано в рамках разработанной онлайн-платформы.

Материалы и методы. Для оценки негативного воздействия на окружающую городскую среду негативных факторов предлагается использовать методический подход, основанный на концепции функционального зонирования территории. Согласно ГрК РФ, для каждой функциональной зоны характерно наличие определенных объектов капитального строительства и благоустройства. Для достижения поставленной в исследовании цели использованы методы сопоставительного и системного анализа и обобщения. Авторами получены и систематизированы результаты, которые показали схожесть негативных воздействий от одних и тех же типов объектов капитального строительства и благоустройства территорий.

Результаты исследования. Оценка негативного воздействия на окружающую среду объектов капитального строительства и благоустройства территорий является частью научно-исследовательской работы, подготовленной в рамках государственной программы «Приоритет-2030». Системный подход к исследованию негативных факторов городской среды позволит структурировать имеющуюся информацию, значительно ускорить ее анализ и принятие на ее основе соответствующих решений за счет установленных авторами взаимосвязей между параметрами негативных факторов, типами объектов и функциональными зонами, в которых они расположены. Предлагаемый подход реализуется в рамках разрабатываемой авторами онлайн-платформы. При этом для обеспечения экологической безопасности территории они руководствуются основным принципом, заключающимся в ускоренном проведении автоматизированной оценки негативных факторов, исходящих от объекта капитального строительства или благоустройства городской среды.

Обсуждение и заключение. Полученные результаты исследований, включающие в себя систематизацию негативных факторов воздействия на окружающую среду территорий объектов капитального строительства и благоустройства в зависимости от функциональных зон их расположения, являются основой для дальнейшей разработки методики обеспечения экологической безопасности городской среды. Максимально полное выявление всех экологически опасных факторов обеспечит возможность всесторонней оценки негативного воздействия на окружающую среду объектов капитального строительства и благоустройства городских территорий.

Ключевые слова: экологическая безопасность, оценка негативного воздействия, окружающая среда, объекты капитального строительства, благоустройство территорий, городская среда

Благодарности. Авторы выражают благодарность редакции и рецензентам за внимательное отношение к статье и указанные замечания, которые позволили повысить ее качество. Авторы признательны руководству за помощь, оказанную в процессе подготовки проекта.

Финансирование. Исследования выполнены за счет грантовой поддержки от Донского государственного технического университета по итогам конкурса «Наука-2030».

Для цитирования. Самарская Н.С., Котлярова Е.В., Лысова Е.П. Основные научные принципы системного подхода к определению негативных факторов, воздействующих на окружающую среду городских территорий. *Безопасность техногенных и природных систем.* 2023;7(4):20–29. https://doi.org/10.23947/2541-9129-2023-7-4-20-29

Introduction. The development of society is inextricably linked with the formation of an appropriate habitat. Scientific and technological progress, discoveries in various spheres of life, the widespread use of mechanisms made it possible to expand the human habitat even in areas that are difficult to develop. At the same time, the possible negative impact on the environment in the process of economic activity began to be talked about a little more than a hundred years ago, and the term "sustainable development" and its principles were first formulated in 1972.

Currently, the issue of ensuring environmental safety of both human habitat as a whole and the individual spheres of life or activity is extremely relevant and discussed. According to the authors, this is due to the fact that there is still no convenient systematic methodology for selecting environmental measures for capital construction and urban facilities. The first step to describe it is to systematize negative factors affecting the components of the environment. At the same time, the analysis of environmental problems shows that they are most clearly manifested primarily in the urban environment, where there is a replacement of natural biogeocenosis with urban- and agrocoenosis, as well as deep inseparable relationships between natural components and elements of highly urbanized territories appear. By highly urbanized territories, the authors of this work understand the territories of megacities, urban agglomerations, and large cities. Such forms of settlements occupy a significant part of the land; most of the world's population is concentrated on them.

The spectrum of impact of highly urbanized territories on the environment turns out to be extremely wide, with the maximum concentration of negative factors. However, as practice shows, project documentation for capital construction and landscaping projects does not prescribe the full range of negative influencing factors, and, as a result, the envisaged project measures to protect the environment do not give the proper effect, since they rely on standard solutions copied from project to project.

Materials and Methods. The works of such domestic and foreign scientists as Vetrov N.M., Verekh T.V., Bespalov V.I., Gerasimov E.B., Gagarin E.S., Mahmudi A., Shein S.G. and others, including the authors of this material, are devoted to the study of approaches to solving issues of ensuring environmental safety of urban areas [1, 2]. The research results show that a large metropolis almost completely changes the natural components: atmospheric air, soil cover, phytocenosis, relief, surface and groundwater, climate [3–5]. There are inextricable links between the elements of urban environment and natural components. Thus, a typical example is a city street, where the anthropogenic elements are buildings, motor transport, road surface; and green spaces and atmospheric air are natural components [6, 7]. Such a connection inevitably leads to a negative impact of elements of the urban environment on natural components, and the spectrum of this impact is so wide that it causes a number of problems characteristic of almost any modern city [8]. To achieve this goal, the authors used methods of comparative and system analysis and generalization. Having summarized and systematized the results of the conducted analytical studies, it was possible to present the totality of the most acute environmental problems of a modern city in the form of a diagram (Fig. 1).

Such a variety of identified problems is primarily due to the peculiarity of urban infrastructure [9, 10]. It includes not only industrial clusters and residential areas with high building density, but also shopping and entertainment complexes, urban facilities and recreational areas. As a whole, all elements of urban environment should provide favorable conditions for the population to live. Simultaneously with providing favorable living conditions, elements of urban environment should not have a negative impact on natural ecosystems. Therefore, the inevitable close interaction of a set of living beings and a highly urbanized environment generates interdependence and forms a special form of the ecosystem — an urbanized one.

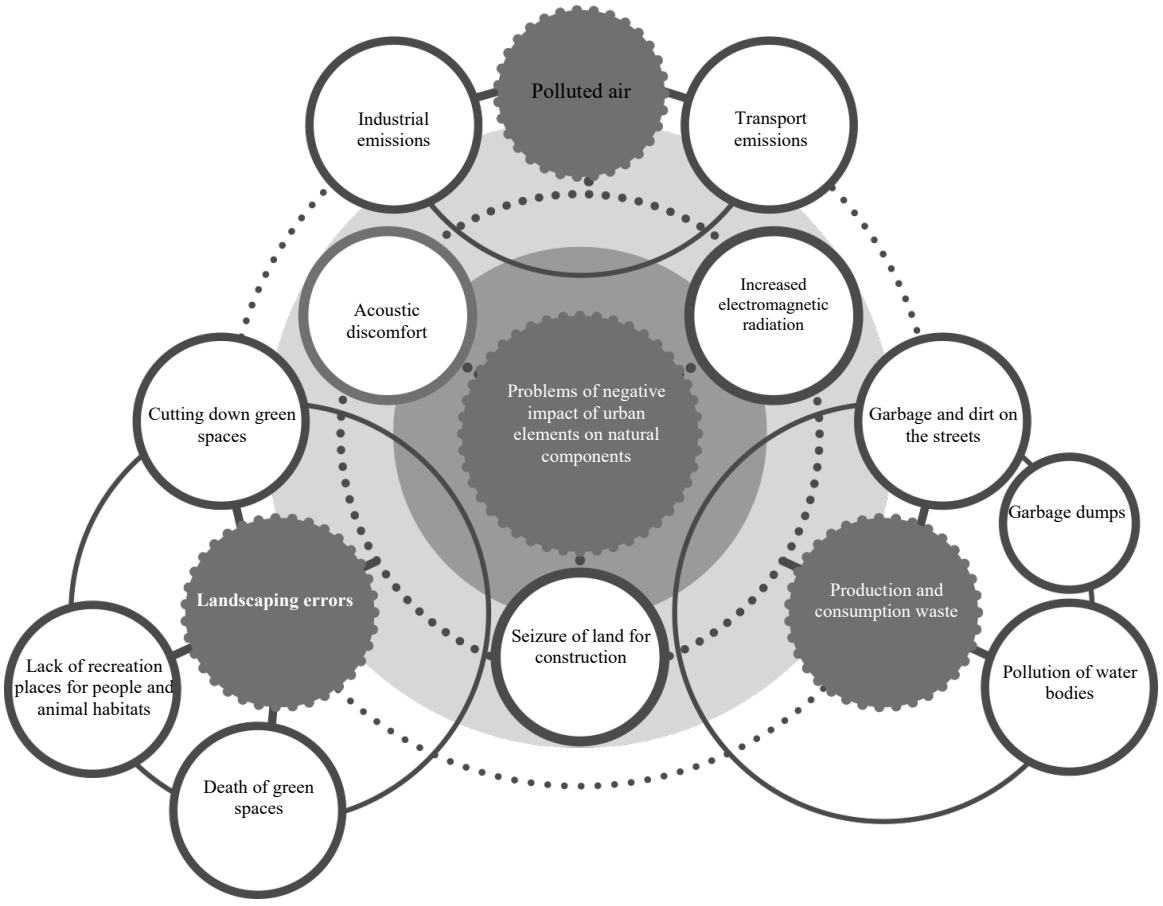

Fig. 1. The problems of negative impact of urban elements on natural components of the environment

It is obvious that the urbanized ecological system constantly consumes external resources and is not capable of self-regulation. Such a system develops not according to the laws of nature, but according to the needs of human economic activity. That is why the approach to solving the problem of ensuring balance in an urbanized ecosystem should be special, taking into account all the parameters of the properties of natural and anthropogenic components of the urban environment.

Results. The concept of "negative factor affecting the urban environment" implies, first of all, the specifics of the process of its impact on the surrounding components, during which the signs of negative change appear. Each process of negative change has its own impact characteristics and is determined by its nature, intensity, and source [11]. However, a comparative analysis of features of the impact of negative factors on the urban environment allowed us to systematize them by the nature of their impact on the natural components of urbanized territories.

The inevitable and, perhaps, the most negative factor in the urban environment is the use of land as a spatial basis for the construction and placement of objects of economic activity. Depending on the nature of use, the land is subject to depletion, preconsolidation, pollution, flooding, etc. The environmental requirements set out in Chapter VII of the Law "On Environmental Protection" regarding the placement of economic activities, their design, construction and reconstruction, as well as commissioning, do not fully ensure equilibrium in the urbanized ecosystem and lead to the above-described consequences.

Widespread pollution of natural components in the process of urbanized ecosystems functioning is associated with the active growth and development of industry, transport systems, construction of energy facilities and, of course, residential space [12, 13]. Of course, the degree of influence of pollution sources varies and depends on the level of improvement of urban neighborhoods and a number of socio-economic factors: legislative, political, demographic, personal and infrastructural [14, 15].

When it comes to the sources of environmental pollution of urbanized territories with chemicals, it can be assumed, that the most significant of them are the facilities and infrastructure of the motor transport complex. With every 15 thousand km, one car burns an average of 2 tons of fuel, about 30 tons of air, including 4–5 tons of oxygen, which is 50 times more than a human needs, while it emits carbon monoxide into the atmospheric air of cities — 700 kg/year, nitrogen dioxide — 40 kg/year, hydrocarbons — 230 liters, solids — 2–5 kg/year [16, 17].

The analysis of the results of long-term observations and studies allowed us to conclude that the greatest contribution to the air pollution of highly urbanized territories was made by cars running on gasoline, to a lesser extent — cars running on diesel fuel, the minimum contribution — cars running on gaseous fuel [1, 2, 8].

Pollution, as a negative factor affecting the urban ecosystem, largely came from industrial facilities, the maximum number of which was concentrated in highly urbanized territories and territories directly adjacent to them [10].

It was established that the main sources of pollution among industrial facilities were [7, 10]:

– at ferrous and non-ferrous metallurgy enterprises — crushing and grinding equipment, places of unloading, loading and pouring of materials, blast furnaces and open-hearth furnaces, installations for continuous casting of metals and others;

– at chemical, petrochemical and oil refining enterprises — technological equipment in the production of acids, rubber products, plastics, dyes and detergents, artificial rubber, mineral fertilizers, various solvents (toluene, acetone, phenol, benzene), in the production of phosphorus;

– at enterprises producing building materials — roasting furnaces, drying drums of various types, lime quenching reactors, crushing and grinding equipment, drying machines, glass furnaces, bitumen melting units, sorting machines, drying units, mixers, power units, etc.

The results of monitoring the quality of environmental components in the territories near the location of the above-mentioned facilities showed that the degree of negative influence of pollutants often exceeded several times the values established by regulations [12]. When it came to pollutants that were prioritized by the level of content in the urban environment atmosphere, special place certainly took carbon monoxide and dioxide, nitrogen and sulfur oxides, aromatic hydrocarbons, solids, including inorganic, with different content of silicon dioxide, compounds of lead, chromium, vanadium, mercury and other chemical elements, organochlorine substances, phenol, benzene and its homologues, formaldehyde, ammonia, benz(a)pyrene, hydrogen sulfide, carbon disulfide, volatile organic compounds, pesticides [13]. All this confirmed the fact of insufficiency or inefficiency of the envisaged organizational, technological and special engineering and environmental measures designed to ensure the ecological safety of the urbanized territory.

Despite active development of the principles of green urbanism, there was still a shortage of green spaces in large cities and the condition of the existing plantings was deteriorating. This was manifested in the violation of production process, deformation and thinning of crown, progression of dryness, as well as necrosis and chlorosis of leaves and needles. Such processes occurred not only due to pollution of components of the urban environment, but also due to a decrease in soil fertility, its compaction and pollution. The authors revealed that these negative factors were particularly intense in areas of multi-storey buildings. Therefore, solving the problem of planting of urbanized neighborhoods, it was necessary to investigate and take into account a whole range of negative factors that depressed vegetation and, as a result, led to the loss of its ecological functions. Green spaces deprived of their qualities were not only useless for ensuring balance in the urban ecosystem, but were also aesthetically difficult to perceive.

Along with the above negative factors, urban environment was subject to the intense influence of various physical fields: acoustic, vibrational, electromagnetic, thermal, radiation [6, 7]. At the same time, acoustic discomfort was created primarily by objects of the transport system: air, rail, road and water transport. Sports and entertainment facilities, industrial cluster and housing facilities, and communal services made a significant contribution to the acoustic pollution of the urbanized environment. Long-term studies also established that urban noise sources created an excess acoustic background, which negatively affected the health of the population living on this territory [5].

As a rule, a negative acoustic background in an urban environment increased the vibration effect from urban rail and road transport. It was known that prolonged regular vibration exposure of living components to the environment led to a change in the habitat of organisms and had a destructive effect on the human central nervous system [14].

Another significant negative factor in a highly urbanized urban environment was the electromagnetic field. The sources could be power supply complexes, extended power transmission lines, thermal power plants and transformer substations, cellular base stations, television complexes, radar installations, and radio stations [15].

Along with the electromagnetic field, the urbanized environment was negatively affected by the thermal field. Excess heat in the urban environment arose from such facilities as thermal power plants, nuclear power plants, boiler houses, heating mains, oil production and processing facilities, metallurgical plants, vehicles, subways, underground heated structures [16].

The most dangerous type of physical pollution in the urban environment was radioactive emission, which did not manifest itself under normal conditions of urban infrastructure development. The risk of this factor occurred during the liquidation of man-made accidents at nuclear power facilities. However, in recent years, much attention has been paid to the issue of ensuring safety of such industrial facilities, so the probability of the appearance of a nuclear radiation factor remains minimal.

The most uncontrolled negative factor in a highly urbanized environment could be considered biological pollution associated with the appearance and spread of pathogenic microorganisms in the atmospheric air, in water bodies or in the soil, leading to the threat of all kinds of changes in the health of the population, an outbreak of epidemics. The main sources of pathogenic microorganisms were the objects of drainage and water supply complexes, public catering facilities, cemeteries, medical and laboratory institutions, agricultural enterprises [17].

The detailed description of the types of negative factors affecting the environment of urban areas presented above showed, on the one hand, the variety of types of impacts, and on the other hand, the need to build relationships and systematize the listed parameters for the possibility of automated work with them.

During the study of the impact of negative factors on the city environment and the subsequent measurement of the ranges of their impact, the authors analyzed the functional zones of a typical urban area in order to identify the sources (objects) of the appearance of such negative factors. The conducted analytical studies showed a wide variety of factors that could negatively affect the environment of highly urbanized territories. The system approach proposed by the authors allowed structuring information, speeding up its analysis and making appropriate decisions in the subsequent selection of environmental measures for each specific case. At the same time, the main principle that guided the authors was the prompt solution to the problem of ensuring the environmental safety of the territory of a construction or landscaping object.

Any task assumes an array of source data, which should provide a complete picture of the intended course of solving the problem. In the situation under consideration, the array of initial data should obviously include such information as the process being implemented, as a result of which it is necessary to ensure environmental safety (construction or operation), the name of the object of research (industrial enterprise, shopping center, hotel, car wash, railway station, etc.), the functional zone in which this object is located (planned), a list of negative factors of the impact of the object in question on environmental components (physical, chemical, biological effects). In this regard, it is advisable to structure

this kind of information using the method of an interconnected hierarchy of functional zones and related construction and capital repair facilities with negative factors affecting the territories of the facilities and their parameters (Fig. 2).

With this method, the construction of a multi-level data system using a software package will allow you to visually present a large array of data quite easily. The entire path shown in Figure 2 can be automated by providing an analytical task to a software package. After going through several steps sequentially, the user will be able to quickly come to the goal — to get a set of those negative environmental impact factors that are characteristic of the particular object located in a certain functional area of the city.

The obtained exhaustive set of negative factors allowed us to determine further ways of work: carrying out instrumental measurements to determine the parameters of their impact, followed by a detailed selection of a list of environmental measures, or receiving recommendations on a list of possible measures to reduce the negative impact on environmental components without taking measurements.

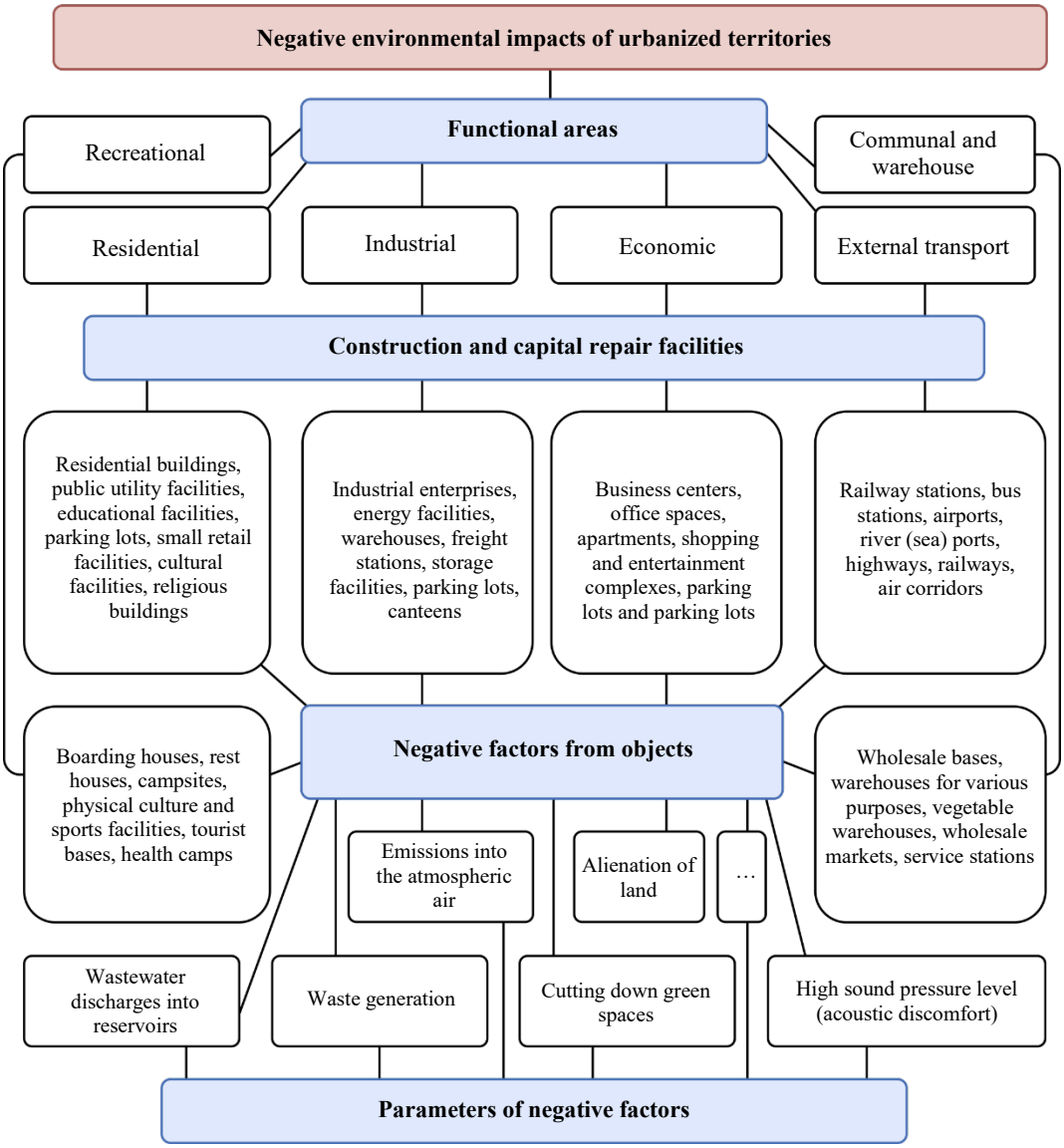

Fig. 2. Systematic approach to the assessment of negative environmental impact of the territories of capital construction and landscaping facilities, depending on the functional zones where they are located

Discussion and Conclusion. Ensuring environmental safety is an important condition for the widespread development of society. Therefore, it is necessary to reduce the negative impact on the environment from various types of human economic activity, including the entire range of construction work. The solution to the problems of ecological safety of urbanized territories is based on a deep analysis of the factors that violate the ecological balance and cause negative consequences in the environment. In modern conditions of electronic products development, the creation of a software package that implements the systematic approach proposed by the authors to determine the negative factors

affecting the territories of capital construction and landscaping facilities, taking into account the functional zones where they are located, seems very promising. The generated data array with the information about negative environmental factors from the functioning of various capital construction and urban facilities will optimize the selection of environmental protection measures for each specific case, reducing time costs by automating the process. The introduction and implementation of such measures will contribute to the balanced development of urban environment and improve the quality of life of residents.

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