Criteria for reconstruction of urban environment on principles of harmonizing nature, society and human being

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Abstract. A completely new scientific approach investigating biotechnosphere development theoretical background and operation of urban life support systems based on the symbiosis of urban and natural environment is proposed in the paper. This approach facilitates creation of a new conceptual scheme for understanding public interests and development on its basis of urban redevelopment methodology; it is based on the supposition of self-organization of urban areas. Biotechnosphere humanitarian balance is taken as a main criterion for analytical estimation of the dynamics of system changes of social, demographic, ecological and economic parameters of the development of urban areas. Balance biosphere relationships are built on the basis of the hypothesis of the existence of stable functional relations between time-dependent characteristics of the condition of the constituents and components of social, natural, technological life support systems. Integrated indices characterizing compatibility of urban areas with the natural environment and the level of the implementation of city functions based on the values of standardized and minimum required in terms of human potential development parameters are proposed to be used as quantitative analysis variables.

1. Introduction

The reconstruction of urban areas is a qualitative transformation of life, and is aimed at the renewal of urban built-up areas and change of the type of human living activities and existing production relations and reduction of the negative impact on the natural environment. Reconstruction in urban planning is a radical change in the planning structure of territories in order to increase the functional comfort of their use.

The issue of the quality of urban environment, irrespective of its creation under conditions of white lands or its formation in the process of transformation of the already developed area with the change of its function, is becoming one of the main issues. The need for redevelopment of urban systems is determined by the goals of safe human living environment and creation of comfortable conditions for living in towns and settlements against the backdrop of the heightened challenges of our time [1].

At the same time, in the cities there is a source of degradation of the Biosphere. “…the source of Biosphere degradation is concentrated in towns and there its consequence – people degradation – is manifested …” [2]. It is becoming apparent that a town as an artificial environment of human living is the area of increased hazards and discomfort, and anthropogenic and technogenic factors of hazards facilitate appearance and development of emergency situations which have not been typical for these
areas before. This is explained by the fact that urban science considers town as an managerial and engineering system, “a developed complex of facilities and economy being an agglomeration of architectural and engineering structures ...” [3]. In this regard a longstanding successive development of town’s ecosystem is destroyed, which ultimately results in aggravating of psychological problems and social conflicts among townsfolk.

In recent decades fundamental research has been carried out in the field of self-sustaining development of urbanized areas and the formation of modern principles of information interaction between a human being and the natural environment [4-6].

Within the framework of the concept of sustainable development accepted by the world community and the imperative of tolerable risks, several areas are distinguished, from a purely technocratic approach according to which it is proposed to limit risks in various spheres of life activities, improve technical means of protection, develop resource-saving environmentally friendly technologies and search for alternative energy sources, waste recycling technologies, non-waste production and other innovations, ending with new ideas for today, based on the balance of intellectual, natural and labor resources.

In this regard, only technologies that enhance the life potential of the Biosphere are recognized as "innovations" [7]. These innovations in world and Russian practices are intensified by globalization, environmental and demographic challenges, as well as closed cycles of resource use and technological potential used in different economic sectors. One of the incontrovertible conditions for the redevelopment of urban areas and innovative urban planning practices is the relationship between a human being and the environment.

2. Statement of the research problem
One of the no-alternative conditions for the reconstruction of urban areas and innovative urban practices is the synergistic relationship between man and the environment. An important role in the scientific solution of the problem of redevelopment of urban systems ensuring safe and comfortable living conditions is assigned to the investigation of new principles of human living activities and their transfer to the level providing comfortable living conditions and progressive development of urbanized areas on the basis of the increasingly recognized concept of the union of towns and natural environments excluding the destruction of the "main productive force, the Biosphere." [8].

The key aspect in solving this problem is the formation of a person's mindset through cognitive, emotional and spiritual interaction with the environment, overcoming the antagonistic attitude towards nature.

The fundamentally new scientific approach is proposed for the redevelopment of urban environment, the essence of which is the study of theoretical foundations for the development of biotechnosphere and the functioning of life support systems for urban areas on the principles of the symbiosis of urban planning systems and their natural environment.

Such a creative approach is aimed at changing the philosophy of being, in the framework of which all global problems of our time - economic, social, political, environmental and many others - in all their diversity, are not the problems, but the consequence of one problem - unjust relations between a human being and nature [9].

A biosphere-compatible urban economy is based on the patterns of functioning of social, natural and technical life support systems that ensure self-preservation, self-regeneration and progressive self-development of urbanized areas.

3. Results
The solution of the problem of redevelopment of urban areas for safe and comfortable living conditions is considered from the humanitarian standpoint on the biotechnosphere mechanisms and is the ability to see ourselves as part of the overall Biosphere.

To build a model of security threats to engineering and construction facilities and urban systems, the estimation, meeting the objectives of redevelopment, of the state of the facilities is required. Such
an estimate is based on the identification of the risk of destructive processes in the urban environment ("residence risk") and is carried out according to the parameters of hazards.” [10].

The parameters of hazards are considered as characteristic quantities of dangerous events. The analysis of human living activities shows that zero risk can be achieved in no kind of activity. When constructing the risk functions for engineering and construction facilities and urban systems, probability of adverse or hazardous events in the urban environment is estimated and their connections with negative consequences (complex events): morbidity and mortality associated with air, water, soil pollution are determined.

The sequences of observations of hazardous events are represented by their time series, each of which relates to a certain engineering and construction facility in the urban system.

The probability of hazardous event $C$ is determined from the distribution function $P(c) = P(C < c)$ which is found empirically [11]. In most cases this function follows the log-normal distribution law.

For discrete events $\sum_{i=1}^{m} P_i = 1$, for continuous random qualities $\int_{0}^{\infty} f(c)dc = 1$, where $i$ is the current number of observation of events at different time points, $m$ is the number of observations, and $f(c)$ is the random variable distribution function and $c \geq 0$.

All potentially hazardous events can be estimated according to the hazard factor taking into account the safety limit of the hazardous process by means of danger coefficient determination:

$$K_{im} = c / I,$$

where $I$ is the threshold (level) of safety impact on the engineering structure; $C$ is the hazardous event (e.g. concentration of hazardous substances in the atmosphere).

This allows us to sort out hazardous events identified for the purpose of urban areas redevelopment, and to rank them according to the level of danger. Ranking is usually performed for a certain type of negative impact using different safe levels (for example, for pollution of the environment they are daily average MPC, maximum one-time MPC., RfC, ARfC, etc.).

If all the events are independent, the probability of a complex event equals to the product probability of simpler events:

$$P_{ac}(c) = P_1(c_1) \cdot P_2(c_2) \cdots P_n(c_n),$$

where $c_1, \ldots, c_n$ are the hazardous events.

For dependent events the complex event probability equals to:

$$P_a(c) = R_1(c_1) \cdot P_2(c_2) \cdots P_n(c_n),$$

where $P_i(c_i)$ are the conditional probabilities, calculated supposing the fact that all adverse events have occurred; $P_a$ are the corresponding distributions.

Probabilities of such events can be estimated empirically by means of the determination of distribution of complex and simple events and examination of their interrelation. So, the probability of the hazardous event $j$ is determined in the form of the risk function (“civil engineering risk”) for the given impact type:

$$R_j(c) = w_j(c) \cdot P(c),$$

where $w_j(c)$ is the conditional probability of doing damage to a person (biosystem, engineering structure) in case of the actualization of the hazard of the adverse events occurrence $j$; $P(c)$ is the probability of a hazardous event.
Probability of a complex hazardous event $j$ is determined in the form of a risk function for a certain impact type (chronic, acute, reflex, carcinogenic etc.):

$$R_j(c) = \sum_{i=1}^{m} w_j(c_i) \cdot P(c_i),$$  \hspace{1cm} (5)

where $w_j(c_i)$ is the conditional probability of doing damage to a person (biosystem, engineering structure) in case of the actualization of the hazard of adverse events occurrence $j$; $P(c_i)$ is the probability of hazardous events; $i$ is the current number of the event observation at different time points; $m$ is the number of observations.

And hazardous events form a complete group of disjoint events, i.e. $\sum_{i=1}^{m} P(c_i) = 1$.

The concept of the redevelopment of urban areas, providing safe and comfortable living conditions, is based on the mutual influence of natural, infrastructural and social components [12].

Between the person and the living environment there is a continuous exchange of substances, energy, information, the result of which are characteristic states of interaction in the system "human being – living environment - nature". In these terms, urban systems are complex dynamic natural and social and technical structures [13]. Moreover, the inclusion of a number of components of natural and social environments in the structures under consideration is determined in each particular case by the importance of their impact and the contribution they make to the processes of ensuring safety and comfort in a particular area. And the natural urban complex is regarded as the most important regulator of its functional and spatial development [14].

The probability of the implementation an adverse event for engineering structures of a natural and man-made urban system due to the sources and damaging factors in social and natural environments and the technosphere is determined as a probabilities functional:

$$P = F_p\{P_{N}, P_{T}, P_{S}\} = \sum_{i=1}^{\#}[F_{ps}\{(P_{N}, P_{T}, P_{S})\}],$$  \hspace{1cm} (6)

where $P_{N}$ is the probability of the implementation of an adverse event in the natural environment; $P_{T}$ is the probability of the implementation of an adverse event in the technosphere; $P_{S}$ is the probability of the implementation of an adverse event in the social environment; $N, T, S$ are the factors and sources of the negative impact in natural, social environments and the technosphere.

For a natural, social and technical urban system, a complex event is an integral characteristics [15-16], and in it’s turn it can be represented as the sum of separate events relevant for a certain type of the impact on the components of such a system:

$$C_1 = C_{11} + C_{12} + \ldots + C_{1n} = \sum_{j=1}^{\#} C_{1j}.$$  \hspace{1cm} (7)

Therefore, according to the formula (2), the probability of a complex hazardous event for natural, social and technogenic urban system facilities is:

$$P_j = P_{N_j}(N_j) \cdot P_{T_j}(T_j) \cdot P_{S_j}(S_j).$$  \hspace{1cm} (8)

At the same time, hazardous events can be perceived as subjects of the natural and man-made urban system as an environmental impact, having both a stabilizing effect (without changes) and the stimulating influence of many factors on the development of urban areas [15]. For example, the amount of technogenic and domestic waste processed by an innovative production and infrastructure component, has the effect of compensation of the harmful effects of this component on the natural environment. In general, many components of natural, social and technological urban systems are
affected by changes in their state, i.e. the parameters of consumption of natural resources, the conditions of formation and the possibility of neutralizing emissions, the effectiveness of environmental measures, and so on.

In the course of redevelopment, as a result of direct and indirect impacts of the urban system, the possibility of evolutionary development of flora and fauna ensuring safe and comfortable living conditions of the population is determined.

To achieve safety objectives, priority in urban policy should be given to ‘green’ construction, sustainable development technologies, and biosphere-compatible projects.

Urban planning decision-taking for the reconstruction of the urban environment should be carried out on the basis of the following data: information on the volume of investments in green industries of the town’s economy, on the reduction of energy consumption for human living activities, on reducing carbon dioxide emissions, on the degree of renovation of the area and its involvement into business activities, on housing affordability and availability of other urban infrastructure facilities for the population, relying on the results of a quantitative assessment of the state of the living environment as benchmarks of highly professional urban development activities [16].

In quantitative terms, the following are proposed to be the criteria for the redevelopment of urban systems on the principles of harmonization of nature, society and human being:

- indicators of ecological balance and balance of the biotechnosphere, defining ecological states of facilities of the natural and technogenic urban system [17]. These indicators reflect, for example, the maximum permissible number of residents, meeting the desired standard of living for these natural resources of the urban area;
- the indicator of biosphere compatibility of the area, characterizing environmental conditions in urban areas [18]:

\[
\eta_{BC} = \sum_i \sum_k \left( B_{ik} - C_{ik} \right),
\]  

(9)

where \( B_{ik} \) is the quantitative indicator of biosphere state under the impact of \( k \)th elements of urban infrastructure; \( C_{ik} \) is the value of the volume of \( i \)th pollutants, formed due to the impact of urban infrastructure with maximum concentration, admitting the development of urban areas;
- indicators of efficiency estimation of construction technologies based on the 'complete resource cycle' model [19]:

\[
E_{OB} = \left( O_1 \cdot B_{sa} C_{sa} P_{sa} F_{sa} E_{sa} \right)^{1/n} < 1,
\]  

(10)

where \( O_1 \) is the index of non-waste construction technologies, \( B_{sa} \) is the indicator of air pollutant emission, \( C_{sa} \) is the indicator of waste water discharge into water basins, \( P_{sa} \) is the indicator of soil pollution, \( F_{sa} \) is the indicator of land resources excluded from the settlement management of natural resources (e.g. lands used for waste landfills), \( E_{sa} \) is the indicator of energy content of construction products;
- indicators of time-space and territorial accessibility to various categories of the urban population of essential and socially important facilities;
- indicator of urban functions implementation showing the satisfaction of rational needs of people from different social strata;
- values of human development index and evaluation of the effectiveness of management decisions on the implementation of program activities.
Some complex and any simple properties of a construction object can be measured using the absolute property indicator, $Q_i$ (i = 1, n, where n is the number of properties of the object being evaluated).

The obtained values of $Q$ are expressed in specific units to each property. For measurements can be used metrological, expert, and analytical methods.

All of the properties that form the object of interest to us is the quality, form a hierarchical tree structure properties. The lower tier of the tree (the tree root) is the most complex property the quality of the object, and the higher tier branches are simple and quasi-property.

For comparison of various properties measured in scales of different range and dimension, a relative dimensionless indicator is used, reflecting the degree of approximation of the absolute property indicator $Q_i$ to the maximum $Q_{max}^i$ and minimum $Q_{min}^i$ indicators. The relative indicator is described by the dependence, $K_i = f(Q_{min}^i, ..., Q', ..., Q_{max}^i)$, which can be represented by the normalizing function [20]:

$$K_i = \frac{Q_i - Q_{min}^i}{Q_{max}^i - Q_{min}^i}.$$  \hspace{1cm} (11)

To compare the relative importance of all the properties included in the "property tree", dimensionless weight coefficients are used $G_i$. For convenience, it is usually assumed that $0 < G_i < 1$, and $\sum_{i=1}^{n} G_i = 1$.

Values of weight coefficients are determined with the involvement of varieties of expert and non-expert (analytical) methods. In consequence, the quantitative assessment of quality $K_k$ is expressed using the following formula [21]:

$$K_k = K_{0} \sum_{i=1}^{n} G_k G_i.$$  \hspace{1cm} (12)

where $K_{0} = 1$ for all indices that form the final general index of quality (comfort and safety) of an engineering construction object.

The general index of quality (comfort and safety) of an engineering construction object itself is calculated as the geometric average of all of those characteristics.

On the basis of scientific research in many fields of knowledge, the limits of permissible impacts of human civilization on the surrounding environment (‘the limits to growth’) are determined [22] and conceptual notions about the further development of society are established, under which these limits are guaranteed.

Today, signs of integration of the urban structure and the natural environment can be seen in the creation of multifunctional urban zones and complexes, contact-joint zones of residential and production entities, public spaces, multipurpose urban development units, high-rise buildings [23]. In fact, it’s a complex urban redevelopment that gives the urban environment an integral quality.

The degree of the systems stability can be assessed according to the state of the urban environment, it’s optimal structure and the balance of natural and artificial components.

4. Conclusion
The term ‘redevelopment’ traditionally concerns the technical constituent and does not reflect the system nature of this process i.e. harmonization of population and living environment.

The proposed principles for the redevelopment of urban systems providing safe and comfortable conditions of living are based on the informational interaction with the natural environment, take into...
account social, demographic, ecological and economic indices of the conflict-free in terms of the nature development.

The key element of redevelopment based on the principles of biosphere compatibility is a humanitarian biotechnosphere balance that defines the strategy of the development (population size restriction, resettlement and migration) and reflects innovations in the urban economy (green building, renovation and urban areas reorganization, waste recycling).

The humanitarian constituent of the balance includes the creation of new progressive aspects of living activities and the destruction of negative ones, use of knowledge and abstention from natural resources consumption.

Quantitative estimation of fundamental characteristics of the quality of living aimed at safe and comfortable conditions of living in urban areas should involve integrated indicators characterizing compatibility of urban areas and natural environment and the level of the implementation of city functions based on the values of standard and minimum necessary in terms of human potential development parameters taking into account environmental requirements.

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