Mathematical modeling of environmental loads at stages of construction object

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Abstract. The methods of ecological optimization of influences developed by the author are presented, including: - interpretation of problems of linear programming in ecological statement; - model of the solution of ecological tasks of linear programming; - model of ecological balance of innovative development plans for the territory; - graphic method of creation of area of admissible influences by the solution of problems of linear programming; - model of identification of dangerous influences simplex method; - method of formation of steady control systems of ecological safety of construction. On simple numerical examples possibilities of mathematical modeling of environmental pressures at stages of life cycle of construction objects are illustrated. A significant part of the decision-making tasks in the environment are the tasks of allocating resources between technical and natural objects. Resources-components can be used by natural and technical production systems. It is required to determine what kind and how many systems should be retained for such a set to be the best for the adopted optimality criterion. The purpose of the task of allocating resources is established by one of the mutually exclusive statements. The first formulation of the problem: for the given available resources, to maximize the result obtained, for example, to approximate the environmental parameters, incl. biodiversity on the territory to the value of the reserve or zakaznik, reconstructing and / or reducing all or part of the industrial activity. The parameters of the reserve or zakaznik should correspond to the location of the optimized territory by geographic latitude and other habitat conditions; The second formulation of the problem: for a given result, minimize the required resources. For example, with the existing state of the environment, including production technical systems in the territory, minimize man-made impacts, that is, minimize consumed resources and pollution of the environment.

1. Introduction
The scientific method has been an engineering and technical science, the last hundred years to dominate the world participants of the construction progress and all disciplines of construction[1]. Architecture, projecting, technology, exploitation, and facilities are required the scientific method then the construction of civilization[2]. The scientific method not only for bistro the development of economic and social spheres of society [3], but also caused the global environmental crisis, the alienation of man from nature, and is of increasing dehumanization of the society [4].
2. Model of the solution of ecological tasks linear programming

Considerable part of problems of decision-making in ecology are problems of distribution of resources between technical and natural objects [5].

Let $m$ of types of components of the environment (the earth, water, air, flora, fauna, the person) have the corresponding volumes of resources. Presence of everyone $i$-th a type of a resource makes $b_i$ ($i=1...m$) in the corresponding units of measure. These resources components can be used by natural and technical productional systems - all $n$ of types of systems. Reference (reserved for natural systems and standard for technical) an ecological condition of unit of $j$-th of a type of systems it is necessary for providing and $ij$ units $i$-th a type of a resource component. It is required to define what look and how many systems it is necessary to keep that such set was the best for the accepted criterion of optimality [3].

We will designate through $x_j$, amount of the allowed quantity of $j$-th of a type of systems. Then for $i$-th a type of a resource component it is possible to write down:

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i,$$

where the left part of inequality expresses the need for a resource $i$-th a look, right — the located quantity of this resource. Extending to $m$ of types of resources, this restriction can be written down:

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i (i=1...m),$$

If to limit the nomenclature of types of systems to the extreme number and values of their volumes, then the following boundary conditions will register:

$$\frac{N_j}{n} \leq X < \frac{N_j}{j=1...n},$$

where $N_j$ — according to minimum and maximum and admissible volumes and/or quantity of $j$-s of a type of systems.

It is possible to enter additional variables into dependence(1). Then

$$\sum_{j=1}^{n} a_{ij} x_j + y_i \leq b_i (i=1...m),$$

In real tasks summary quantity of the mains of $x_j$; ($j=1..n$) and additional $y_i$; ($i=1...m$) it is always more variables, than number of dependences of $m$ therefore the system (1) has the infinite number of decisions. It is necessary to choose one from this infinite number — optimum, corresponding to criterion — the purposes of the solution of a task.

The purpose of a problem of distribution of resources is established any by one of mutually exclusive statements [3]:

1) at the set available resources to maximize the received result, for example, to bring closer environment indicators, including a territory biodiversity to value of the reserve or wildlife area, having reconstructed and/or having reduced all or a part of industrial activity, at the same time the reserve or the wildlife area have to correspond to a territory arrangement on the geographic latitude and other conditions of dwelling;

2) at the set result to minimize required resources, for example at the existing state of environment, including productional technical systems in the territory, to minimize technogenic influences, that is to minimize the consumed resources and environmental pollution.

The first statement will analytically register:
\[
\begin{align*}
\max & \quad L = \sum_{j=1}^{n} c_j x_j \\
\sum_{j=1}^{n} a_{ij} x_j & \leq b_i (i = 1...m) \\
N_j & \leq x_j \leq N_j (j = 1...n)
\end{align*}
\]  

(5)  

(6)  

(7)  

where \(x_j\) — amount of the allowed quantity \(j\)-s of the type of systems — a required variable \((j = 1..n)\); \(n\) — number of names of systems; \(c_j\) — the size showing what contribution to result the single system gives \(j\)-s of the type; \(b_i\) — the set quantity of a resource component \(i\)-s of the type \((i = 1..m)\); \(m\) — number of names of resources components; \(a_{ij}\) — resource consumption rate, that is what quantity of a resource component \(i\)-s of the type is consumed by unit \(j\)-s of the type of systems.

The solution of a task gives finding of the \(x_j\) values providing the maximum result at the set resources components. We will call the first and second tasks in which variable \(x\), enter in the first level, that is in the form of the linear dependences tasks of the linear ecological programming [3].

Each problem of linear ecological programming contains criterion function (4) or (7), restrictions (5), (6) or (8)-(10), boundary safety conditions (6) or (10), (11). Restrictions can include dependences both for resources components \((b_i)\), and for ecological indicators \((C)\). For the solution of problems of linear ecological programming we use graphic and analytical methods. The second problem definition will have an appearance:

\[
\begin{align*}
\min & \quad L = \sum_{i=1}^{m} y_i \\
\sum_{j=1}^{n} c_j x_j & \geq C \\
\sum_{j=1}^{n} a_{ij} x_j & \leq b_i (i = 1...m) \\
N_j & \leq x_j \leq N_j (j = 1...n) \\
y_i & \geq 0 (i = 1...m)
\end{align*}
\]  

(8)  

(9)  

(10)  

(11)  

(12)  

where \(C\) — minimum admissible value of required result. The solution of the problem gives finding the values \(x_j\), providing resources for given components to obtain the maximum result.

The first and second tasks in which variables \(x\), are of the first degree, that is, the linear dependencies, call the environmental problems of linear programming. Each environmental problem of linear programming contains an objective function (4) or (7), the constraints (5), (6) or (8)-(10), the boundary conditions (6) or (10), (11). Limitations may include dependences for resource components \((b_i)\) and environmental indicators \((C)\). For solving linear environmental programming using graphical and analytical methods.

Let it be required to determine the extent of the development of four types of production systems \(A, B, C, D\), whose existence made use of resources of three types: biological, land, water. The amount of each of the \(i\)-th resource for the existence of each \(j\)-th type of production system is called consumption rate and denote \(a_{ij}\).

The amount of each resource that is available, denoted by \(b_i\), (table. 1.). From table 1 shows that for the existence of a single production system, such as \(A\) required six units of biological resources, With
11 pieces of land resources, etc. The territory has 12000 units of water resources, 2000 land units, 800 units of biological.

On the basis of reference data on the natural resource features of environmental systems obtained in protected areas and production and technological capabilities of technical systems (production capacity, level of specialisation, the minimum production volumes) are set upper and lower limit of issue of each productive system (in physical or value units).

The original table data on the specific consumption of land and biological resources are rated according to the quality of a production system (at the enterprise regulatory and technological documentation, and on-site standards "reserve" or "inventory" of biodiversity). Thus, the rules of the size of the territory (habitats) for animals or plants and/or consumption of land resources for every produced in an enterprise of products (in construction: buildings, constructions, and structures) are contained in the relevant handbooks or conducted a special study.

Moreover, in the line "biological resources" shall stand consolidated environmental capacity of manufacturing buildings or structures, as the total for all manufacturing processes of this product. And in "land resources" — the rate of consumption of the most scarce (limited e.g. downtown) type of land taken for the resource units.

Table 1. The source data

| Resources (i) | View of a production system (j) | Resource (bi) |
|--------------|---------------------------------|--------------|
|              | View of a production system (j) | Resource (bi) |
|              | A      | B      | C    | D    |  |
| Biological   | 6      | 4      | 2    | 1    | 800  |
| Land         | 7      | 9      | 11   | 5    | 2000 |
| Water        | 8      | 4      | 5    | 6    | 12000|
| Border:      | 1      | -      | 3    | -    | -    |
| lower        | 12     | 2      | -    | -    | -    |
| top          |        |        |      |      |      |
| Forecast     |        |        |      |      |      |
| extension    |        |        |      |      |      |

However, there is a possibility of submission of all the original data table in monetary units (for example: 1 ha of nature reserve in Russia is not less than 30 thousand rubles). The specific consumption of land resources can be understood, for example, the use of land for the production system of each technical product or species is essential for maintaining the habitat type and/or of diversion of land for new construction or the reconstruction of existing production.

If the presence of each type of resource \((b_i, i = 1, 2, 3)\) are expressed in tab. 1 in monetary units, then, obviously, the total resources of the area is 14800 monetary units.

On the basis of input data required to create a mathematical model to determine the forecast of development of production systems.

The decision. Denote: \(x_1, x_2, x_3, x_4\) — the quantity of unit production systems of types \(A, B, C, D\), which is necessary to determine for the territory.

Now make restrictions. From table 1 shows that for the development of a single production system and required 6 units of biological resources. \(B, C, D\) — respectively 4, 2, 1 units of biological resources. Then the required biological resource for the development of all types of production systems will be equal to \(6x_1 + 4x_2 + 2x_3 + x_4\).

It is obvious that the required resource cannot exceed the disposable, i.e., the biological resource will be the following inequality holds: \(6x_1 + 4x_2 + 2x_3 + x_4 \leq 800\), where 800 is available online (table. 1).
If you make similar dependencies for other resources and add the maximum allowable value of the development of each type of production system, we get the system:

\[
\begin{align*}
6x_1 + 4x_2 + 2x_3 + x_4 & \leq 800 \\
7x_1 + 9x_2 + 11x_3 + 5x_4 & \leq 2000 \\
3x_1 + 4x_2 + 5x_3 + 6x_4 & \leq 12000 \\
1 & \leq x_1 \leq 12; \quad x_2 \leq 2; \quad x_3 \geq 3; \quad x_4 \geq 0
\end{align*}
\] (13) (14) (15) (16)

In this system of inequality, which establishes the dependencies for resource limits and maximum permissible values of variables — boundary conditions. In constraints, the left part of the inequality is the required resources, and the right — have.

If inequalities to introduce additional variables \( y_1 \geq 0, y_2 \geq 0, Y_3 \geq 0, \) we can write:

\[
\begin{align*}
6x_1 + 4x_2 + 2x_3 + x_4 + y_1 & = 800 \\
7x_1 + 9x_2 + 11x_3 + 5x_4 + y_2 & = 2000 \\
3x_1 + 4x_2 + 5x_3 + 6x_4 + y_3 & = 12000
\end{align*}
\] (17) (18) (19)

In this system of equations additional variables represent the difference between available and required resource and, consequently, equal quantities of underutilized resources, i.e. reserves and/or development potentials each type of resource.

Obviously a system with three equations and seven variables, has countless solutions, that is various variants of development of territory. All these variants are possible, including matching the value system of basic and additional variables are valid plans-forecasts of development.

So any, of course, correctly made the task of environmental planning of resources has an infinite number of feasible solutions. Which one to choose?

To answer this question, it is necessary to formulate the optimization problem in either of two mutually exclusive plays.

Let us denote: \( F \) resources, \( R \) is the result of their application. Then under the given dependencies and required resources result from the number of existing on-site production systems \( R = R(x_j), F = F(x_j) \) both the environmental performances of the resource allocation in the shortened record may be submitted to:

for the first environmental statement:

\[
\begin{align*}
L_1 = R(x_j) & \rightarrow \max \\
L_2 = F(x_j) & \rightarrow \min
\end{align*}
\] (20) (21)
for the second environmental statement:

\[
L_2 = F(x_j) \rightarrow \min ; \\
F(x_j) \leq F^*; \\
R(x_j) \geq R^*.
\]

(22) (23) (24)

where \( F^*, R^* \) — set (planned or predicted) sizes of resources and result.

For the model in any environmental setting would require more data on a single environmental efficiency of a production system and implementation of each type of production system (technical and/or natural), e.g. profits from the sale of units technical production and projected biodiversity in General in the territory in the presence of influences from all systems.

Let the production systems of types \( A, B, C, D \) it will be, respectively, 5, 6, 7 and 8 monetary units and biodiversity as a result of development of all systems must be at least 3000 units of money.

To the already structured system of constraints and boundary conditions are added to the target function and the resulting mathematical model for the first environmental statement:

\[
\begin{align*}
\max L_1 &= 5x_1 + 6x_2 + 7x_3 + 8x_4; \\
6x_1 + 4x_2 + 2x_3 + x_4 &\leq 800; \\
7x_1 + 9x_2 + 11x_3 + 5x_4 &\leq 2000; \\
3x_1 + 4x_2 + 5x_3 + 6x_4 &\leq 12000; \\
1 \leq x_i &\leq 12; x_2 \leq 2; x_3 \geq 3; x_4 \geq 0.
\end{align*}
\]

(25) (26) (27) (28) (29)

for the second environmental setting:

\[
\begin{align*}
\max L_2 &= y_1 + y_2 + y_3; \\
5x_1 + 6x_2 + 7x_3 + 8x_4 &\geq 3000 \\
6x_1 + 4x_2 + 2x_3 + x_4 + y_1 &\leq 800; \\
7x_1 + 9x_2 + 11x_3 + 5x_4 + y_2 &= 2000; \\
3x_1 + 4x_2 + 5x_3 + 6x_4 + y_3 &= 12000; \\
1 \leq x_i &\leq 12; x_2 \leq 2; x_3 \geq 3; x_4 \geq 0; y_1 \geq 0; y_2 \geq 0; y_3 \geq 0.
\end{align*}
\]

(30) (31) (32) (33) (34) (35)

Since \( y_1, y_2, y_3 \) — reserves resources, maximizing their amount minimizes the resources used.

Solution of the problem in two different formulations (tab. 2), it is clear that the solutions are different too.

In the first environmental setting \( \max L_1 = 3162 \) currency units. The total amount of resources used \( F = 4774 \) units. The resources were divided into two groups: limiting for whom \( y_i = 0 \), and not limiting, for which \( y_i > 0 \).

The first group includes land resources, the second biological, and water. Hence, the increase in reserves of the territories of protected land will help to find a new optimal plan and implement the production systems of all types, the implementation of which will increase the biodiversity on site, and
increase biological and water resources, and so there are reserves in volume $y_1 = 396$ and $U_3 = 9630$ units.

It follows that to increase the environmental efficiency of production systems (growth of biodiversity on the territory) is not required to increase the reserves of all resources, and only resources — limiting the development of (in practice, as a rule, tend to unreasonable build-up of inventories of all resources).

**Table 2. The results of the solution**

| Statement of the problem | The objective function | Boundary conditions | $R^o$ | $F^o$ | $x_1^o$ | $x_2^o$ | $x_3^o$ | $x_4^o$ | $y_1^o$ | $y_2^o$ | $y_3^o$ |
|--------------------------|------------------------|---------------------|-------|-------|---------|---------|---------|---------|---------|---------|---------|
| 1                        | $R^o \rightarrow \max$| $F \leq 4800$      | 3162  | 4774  | 1       | 0       | 3       | 392     | 396     | 0       | 9630    |
| 2                        | $F^o \rightarrow \min$| $R \geq 3000$      | 4531  | 137   | 1       | 0       | 3       | 371.75  | 416.25  | 101.25  | 9761.5  |

In the second statement, the total consumption of resources is somewhat smaller and amounts to $F = 4531$ units and all their types have reserves and/or development potentials.

Thus, the results after the optimization analysis are defined in both the environmental performances of the resource allocation problems can be done the following is very important for the effective environmental management of the territory (enterprises) conclusions:

1. implementation of the found optimal plan (forecasts) ensures the achievement of the objectives of the environmental management of the territory (enterprise) maximum environmental efficiency [or by the maximal value of the growth indicators of environmental quality or minimize environmental impacts — spending most important for the territory (enterprises) resources];

2. implementation of the found optimal plan (forecasts) will be possible even with the release of the funds associated in the excessive in excess of the required for the execution of these plans (forecasts), stocks of resources. It is clear that the realization of surplus stocks of resources within identified reserves will contribute to the further growth of the environmental performance of on-site, and hence the sustainability of its development.

3. The model of environmental balance innovative plans of development of the object, territory or industry

Let's imagine a situation, almost a genre to the current market conditions. Let Construction Company (CC) researched environmental market in the field of construction. Based on its potential and market opportunities, formulated their own goals activities on a long-term and short-term. In accordance with the objectives of the CC have developed a marketing strategy and programme, formed the economic portfolio [4-6]. There is no doubt that the contents of this portfolio (orders and contracts with preferably mainly real, i.e. paying customers), environmental management the optimal solutions obtained from the implementation of tasks similar to the previously considered [5-7].

It would seem that the management of CC everything was provided so that the area became a protected oasis, and the company became a market leader and has gained a stable market position in its strategic area of management. But this did not happen, quite the opposite: trees and bushes withered, released on the territory of birds and animals also did not survive, and the population continues to decrease. "Sluggish" sales of new and traditional products of the enterprises located on the territory, clearly does not cover the costs incurred. Besides came the timing of payments to suppliers, repayment of loans and mandatory payments.
It turned out that the environmental evaluators of environmental impacts have underestimated the significant environmental aspects and marketers overlooked the exit to the ecological market of just one competitor on innovative environmentally friendly products — analogues, more sophisticated in its consumer properties, has shifted the market demand. The first step in the direction of survival of the CC, and then stabilization of the financial state should be to prompt the development of innovative set of urgent anti-crisis measures.

These measures should include refinement of the immediate and long-term goals of the CC, its environmental activities, changes in environmental programs and plans for environmental cleaning of production and marketing of ecological products. But their implementation, restoring the competitive advantages typically involve long-term, beyond not one, but three or four generations of people on site.

A way out of this crisis situation can be the development of activities that will be environmentally and technologically similar to measures used previously. But, of course, they have to be innovative in the sense of more environmentally effective and competitive relative to the territories counterparts. Otherwise you will run the danger of competitive threats and then, inevitably, the desertification of the territory and degradation of the remaining public participation.

Updating of marketing environmental programs and environmental reconstruction of the site will be associated with the inclusion of innovative, more advanced projects, more demand for environment - and, primarily, its Central component is a population of people. In the justification of such an adjustment the results of the solution of ecological optimization of resource allocation plan-forecast of ecological development may be unbalanced by item, consumption and resource availability [6-9]. It is clear that development of the territory and the enterprises on it is on an unbalanced plan is impossible and therefore, the demand of ecological reconstruction without the necessary potential and availability of its resources impossible [7-17].

Balance plans according to the types of potentials and/or resources, you can check simulation modeling, and the response is not received at the end of the plan period, when nothing can be changed, and immediately at the moment of decision on the project, the modeling and analysis of prevailing ecological situation [4-18]. Here especially important is the creation of an environmental monitoring system that fills the reliable information your information base displaying all the processes in the environment [6-21]. This simulation mathematical models allow to identify the imbalance of plans-forecasts to actualize the objectives of the environmental activities, to justify their actual and potential natural production and technological capabilities [7-21].

4. Results and conclusions

1. Methods of ecological optimization of influences are developed, including:
   - interpretation of problems of linear programming in ecological statement;
   - model of the solution of ecological tasks linear programming;
   - model of ecological balance of innovative development plans for the territory;
   - model of identification of dangerous influences simplex method;
   - method of formation of steady control systems of ecological safety of construction.

2. The developed method of the decision of ecological tasks the linear programming consists in the following: are defined: - peaks of area of admissible influences as crosspoints of restrictions; - values of target function of influence in peaks; - the peak in which target function of influence acquires extremal (max or min) value, is optimum; - coordinates of optimum peak are best values of required variable factors of influence.

3. The researches passed on model decisions of ecological tasks by linear programming have shown its suitability for formation of control systems of ecological safety of construction for objects and territories where the solution of a problem of distribution of resources between technical and/or natural objects is necessary. The researches conducted by a graphic method of creation of area of admissible influences at the solution of ecological problems of linear programming have shown its efficiency and presentation, in comparison with the results received in the settlement way.
4. The researchers conducted on model of ecological balance of innovative development plans for the territory have shown its suitability for formation of plans and programs of development of objects and territories and also for monitoring of their realization with use of control systems of ecological safety of construction.

5. The conducted theoretical researches by method of formation of steady control systems of ecological safety of construction on the basis of solutions of an optimizing ecological task, have shown a theoretical possibility of formation of steady systems of construction, however experimental confirmation of reliability of this conclusion is required.

6. Development of the control systems of ecological safety of construction concerning sources, definitions and categories of waste and also structure and processing of streams of waste for the purpose of assistance to prevention of formation of waste and to creation and introduction of mechanisms of prevention of education and minimization of volume of waste and also the systems of recovery and recirculation of waste of construction branch is represented to the most ecologically effective.

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