

# Environmental graphic method for creating area of permissible impact

**Mikhail Slesarev**

Moscow State University of Civil Engineering, Yaroslavskoye shosse, 26, Moscow, 129337  
Russia

E-mail: [slesarev\\_m@mail.ru](mailto:slesarev_m@mail.ru)

**Abstract.** The methods of ecological optimization of influences developed by the author are presented, including: - 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. In the paper, linear equations of action with constraints and with two variable factors of influence were considered. If we go over to linear relationships with three variable factors of influence, then they will describe the plane in the three-dimensional impact space; the system of linear constraints is a polyhedron, as the domain of permissible impacts in the three-dimensional impact space. Studies carried out by the graphical method of constructing the region of permissible impacts in solving ecological problems of linear programming have shown its effectiveness and visibility, in comparison with the results obtained by calculation. The most effective is the development of environmental safety management systems for construction related to sources, definitions and categories of wastes, as well as the composition and treatment of waste streams, in order to promote waste prevention and the establishment and implementation of mechanisms to prevent generation and minimize waste, as well as recovery and recycling systems waste construction industry.

## 1. Introduction

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

## 2. Graphic method of creation area of admissible influences by the solution of problems of linear programming

The line equation with two variable factors of the influence expressed in influence units of measure, for example: in monetary units, it can be written  $a_1 x_1 + a_2 x_2 = b$ . To construct this equation, we will find points of intersection with axes of coordinates. At  $x_1 = 0$  we will receive  $a_2 x_2 = b$ , from where  $x_2 = b / a_2$ . At  $x_2 = 0$  we will have  $a_1 x_1 = b$  and  $x_1 = b / a_1$  (Fig. 1).



We will divide the left and right members of equation by  $b$  and we will rewrite the equation which we will call the equation of admissibility of influence in pieces:

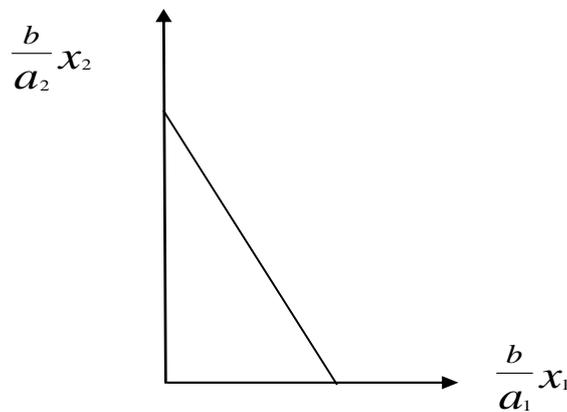
$$\frac{a_1}{b} x_1 + \frac{a_2}{b} x_2 = 1 \tag{1}$$

or

$$\frac{x_1}{b/a_1} + \frac{x_2}{b/a_2} = 1 \tag{2}$$

or

$$\frac{x_1}{\alpha_1} + \frac{x_2}{\alpha_2} = 1 \tag{3}$$

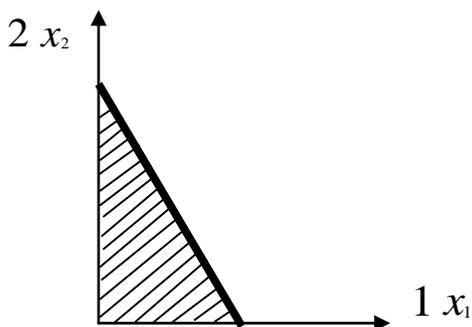


**Figure 1.** Diagram of the line of influence of variable factors  $x_1$  and  $x_2$

Such representation of the equation of influence is convenient for creation of a straight line as sizes  $\alpha_1$  and  $\alpha_2$  are the pieces cut by an influence straight line on those axes which are specified in numerator. For example,  $2x_1 + x_2 = 2$  or in the form of the equation in pieces:

$$x_1/\alpha_1 + x_2/\alpha_2 = 1, \text{ or } \alpha_1 = 1, \alpha_2 = 2.$$

Now about inadmissibility of influence in restrictions on extreme value. If the line equation of influence with two variable factors  $2x_1 + x_2 = 2$  it can be presented to a straight line on the thickness, inadmissibility of influence in the form of restriction  $a_1 x_1 + a_2 x_2 \leq b$  it is represented as the half- thickness.



**Figure 2.** The shaded half- thickness – area of admissible influence of variable factors  $x_1$  and  $x_2$

Admissibility of influence in the form of restriction on maximum permissible influence  $2x_1 + x_2 \leq 2$  represents the shaded half- thickness which coordinates of all points, that is variable factors  $x_1$  and  $x_2$  satisfies to the set restriction (Fig. 2). We will consider creation of system of line inequalities:

$$\left\{ \begin{array}{l} x_1 + 4 x_2 \leq 14 \\ 3x_1 + 4 x_2 \leq 18 \\ 6 x_1 + 2 x_2 \leq 27 \\ x_1 \geq 0 \quad x_2 \geq 0 \end{array} \right. \quad \begin{array}{l} (4) \\ (5) \\ (6) \\ (7) \end{array}$$

or in shape, similar to the equations in pieces:

$$\left\{ \begin{array}{l} \frac{x_1}{6} + \frac{x_2}{9/2} \leq 1 \\ \frac{x_1}{14} + \frac{x_2}{7/2} \leq 1 \\ \frac{x_1}{9/2} + \frac{x_2}{27/2} \leq 1 \\ x_1 \geq 0 \quad x_2 \geq 0 \end{array} \right. \quad \begin{array}{l} (8) \\ (9) \\ (10) \\ (11) \end{array}$$

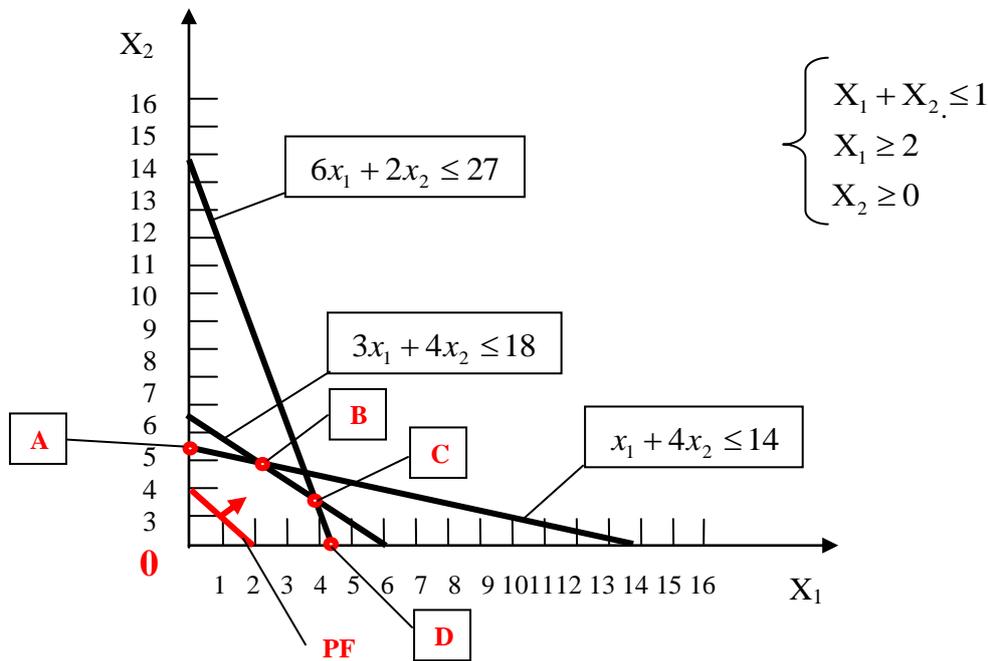
We will construct each inequality in the system of coordinates  $x_1$  and  $x_2$  in the form of the respective half- thickness. The solution of this system of restrictions are coordinates, all points belonging to area of admissible influences, that is area of admissibility of influence *ABCD* (Fig. 3.). As in the field of admissible influences the infinite number of points, so the considered task has the infinite number of admissible decisions.

So, we considered the line equations of influence with restrictions and with two variable factors of influence. If to pass to the linear dependences with three variable factors of influence then they will describe the thickness in three-dimensional space of influences; the line restriction characterizes a half-space, and the system of the linear restrictions — a polyhedron as area of admissible influences in three-dimensional space of influences.

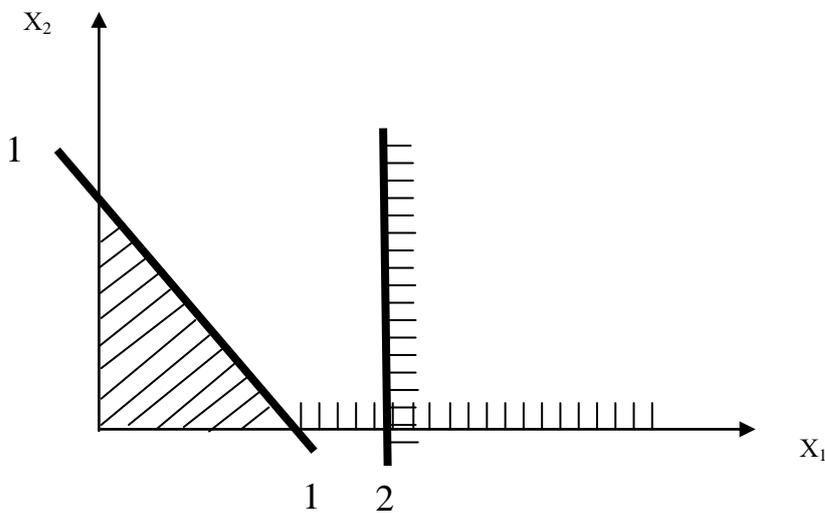
From Fig. 4. it is visible that there are no such points which would satisfy all restrictions of system. With increase in number of variable factors of influence higher than three, geometrical interpretation is impossible as the system of restrictions area of admissible decisions in  $k$ -dimensional space.

if restrictions are set by inequalities, then  $k = n$  where  $n$  — number of variables; if restrictions in the form of the equations, then  $k = n - t$ , where  $t$  — number of the equations. If it is necessary to find extreme influence, then have to accept criterion function. Let's say we want the influence to be extreme in sense of minimization of emission of pollution in the environment in general.

Not any system of linear restrictions has area of admissible influences that is admissible decisions, for example, we will construct system (Fig. 3.):



**Figure 3.** Creation of area of admissible influences for the system of the restrictions corresponding to influence of variable factors  $x_1$  and  $x_2$



**Figure 4.** The system of linear restrictions has no area of admissible influences

If it is necessary to find an extreme effect, then they must adopt the objective function. Let's say that we want the impact to be extreme in terms of minimizing the release of pollutants into the environment as a whole. Then the target function of the impact:

$$\min L = x_1 + x_2 \tag{12}$$

We will put to L, equal any number (any), for example 2, and we will construct the equation of criterion function:

$$\frac{x_1}{2} + \frac{x_2}{2} = 1 \tag{13}$$

As we need to find the extreme solution at which the minimum is reached *min L*, we will move the line of criterion function in the direction of reduction *L*. It is obvious that point coordinates will be an optimal solution *C*, equal *x\*<sub>1</sub>*, *x\*<sub>2</sub>* at the same time *L = L\**. From here it is possible to draw an extremely important conclusion: extreme influence — coordinates of top of area of admissible influences.

**3. Model of identification of dangerous innovative influences simplex method**

We will consider a problem of detection of the dangerous innovative plan of production for the purpose of definition of the most dangerous impacts on the environment (Table 1).

**Table 1.** The source of data

Natural resource	Norm of a payment for emission of pollution and/or expense of resources				Maximum allowable concentration
	Π <sub>1</sub>	Π <sub>2</sub>	Π <sub>3</sub>	Π <sub>4</sub>	
Soil	1	1	1	1	16
Air masses	6	5	4	3	110
Water masses	4	6	10	13	100
Penalties	60	70	120	130	—
Plan of emission of pollution	<i>x<sub>1</sub></i>	<i>x<sub>2</sub></i>	<i>x<sub>3</sub></i>	<i>x<sub>4</sub></i>	—

Decision. Mathematical model of a problem of identification of dangerous influences:

$$\left\{ \begin{array}{l} \max L_1 = 60x_1 + 70x_2 + 120x_3 + 130x_4; \tag{14} \\ x_1 + x_2 + x_3 + x_4 + y_1 = 16; \tag{15} \\ 6x_1 + 5x_2 + 4x_3 + 3x_4 + y_2 = 110; \tag{16} \\ 4x_1 + 6x_2 + 10x_3 + 13x_4 + y_3 = 100; \tag{17} \\ x_j \geq 0(j = 1...4); y_i \geq 0(1...3). \tag{18} \end{array} \right.$$

We will enter additional variable safety into restrictions of the task *y<sub>1</sub>*, *y<sub>2</sub>*, *y<sub>3</sub>* also we will rewrite a statement of the problem in the form of the equations:

$$\left\{ \begin{array}{l} \max L_1 = 60x_1 + 70x_2 + 120x_3 + 130x_4; \tag{19} \\ x_1 + x_2 + x_3 + x_4 + y_1 = 16; \tag{20} \\ 6x_1 + 5x_2 + 4x_3 + 3x_4 + y_2 = 110; \tag{21} \\ 4x_1 + 6x_2 + 10x_3 + 13x_4 + y_3 = 100; \tag{22} \\ x_j \geq 0(j = 1...4); y_i \geq 0(1...3). \tag{23} \end{array} \right.$$

This environmental statement can be rewritten in the form the first table of the simplex method.

**Table 2.** The first simplex table

Basis security	Free members	Free variables			
		$x_1$	$x_2$	$x_3$	$x_4$
$y_1$	16	1	1	1	1
$y_2$	110	6	5	4	3
$y_3$	100	4	6	10	13
Index line	0	-60	-70	-120	-130

**Table 3.** Second simplex table

Basis security	Free members	Free variables			
		$x_1$	$x_2$	$x_3$	$x_4$
$y_1$	108/13	9/13	7/13	3/13	0
$y_2$	1130/13	66/13	47/13	22/13	0
$x_4$	100/13	4/13	6/13	10/13	1
Index line	1000	-20	-10	-20	0

**Table 4.** Third simplex table

Basis security	Free members	Free variables			
		$x_1$	$x_2$	$x_3$	$x_4$
$x_1$	12	1	7/9	1/3	0
$y_2$	26	0	-1/3	0	0
$x_3$	4	0	2/9	26/39	1
Index line	1240	0	50/9	-40/3	0

**Table 5.** Last simplex table

Basis security	Free members	Free variables			
		$x_1$	$x_2$	$x_3$	$x_4$
$x_1$	10	1	7/18	0	...
$y_2$	26	0	-1/3	0	...
$x_3$	6	0	13/6	1	...
Index line	1320	0	70/9	0	...

From the table it is seen:

1) In the column of free members of all elements is positive, it means that the solution is valid in the mathematical sense.

2) In an indexed string for all the elements is also positive. This means that the solution — identifies the most dangerous impact on the environment, that is, maximizes the objective function. This dangerous plan will be;  $x_1^o = 10$ ,  $x_3^o = 6$  (so they are basic);  $x_2^o = x_4^o = 0$  (because they are free), the objective function  $L = 1320$ .

From Table 5 it also follows that basic safety variable  $y_2 = 26$ , and security free variables  $y_1 = y_3 = 0$  that is the most dangerous in terms of natural resources: soil and water body, the safety of which is equal to zero, since they are contaminated to the limit. And the safety reserve of air masses  $y_2 = 26$ , which indicates its relative safety.

#### 4. Method of formation of steady control systems of ecological safety of construction

At a research of ecological extreme tasks it is important to reveal admissible area of change of parameters of a task at which the decision remains. The set of optimal solutions of a task is discrete, and for each of them there is a range of values from a continuous interval of parameters. Having defined compliance between discrete set of decisions and a set of intervals, it is possible to speak about areas of mathematical stability of the solution of a task. We would consider an ecological problem of linear programming:

$$\left\{ \begin{array}{l} \max L = 1,2x_1 + 1,4x_2 \\ 40x_1 + 25x_2 \leq 1000 \\ 35x_1 + 28x_2 \leq 980 \\ 25x_1 + 35x_2 \leq 875 \end{array} \right. \quad (24)$$

$$40x_1 + 25x_2 \leq 1000 \quad (25)$$

$$35x_1 + 28x_2 \leq 980 \quad (26)$$

$$25x_1 + 35x_2 \leq 875 \quad (27)$$

The optimal solution includes  $x_1 = 16^{29/31}$  and  $x_2 = 12^{28/31}$ .

Dual estimates of safety correspond to the solution of system of the equations:

$$\left\{ \begin{array}{l} 40y_1 + 25y_3 = 1,2; \\ 25y_1 + 35y_3 = 1,4; \\ y_2 = 0. \end{array} \right. \quad (28)$$

$$25y_1 + 35y_3 = 1,4; \quad (29)$$

$$y_2 = 0. \quad (30)$$

Let the coefficient 1/4 in criterion function be replaced with casual parameter  $C$ .

Dual estimates of safety of  $y_1$  and  $y_2$  in this case are equal:

$$\left\{ \begin{array}{l} y_1 = \frac{42 - 25C}{775}; \\ y_2 = \frac{40C - 30}{775}. \end{array} \right. \quad (31)$$

$$y_2 = \frac{40C - 30}{775}. \quad (32)$$

Positive values of safety are necessary for an optimal solution of a task  $y_1$  and  $y_2$ :  $42 - 25C \geq 0$ ;  $40C - 30 \geq 0$ . From this it follows that decision  $x_1 = 16^{29/31}$  and  $x_2 = 12^{28/31}$  remains optimum for the following interval of values:  $0,75 \leq C \leq 1,68$ . If parameter  $C$  goes beyond an admissible interval of values, it is necessary to receive the new solution of a task.

The similar research can be executed for identification of intervals of change of resources in restrictions. Let the system of restrictions have an appearance:

$$\left\{ \begin{array}{l} 40x_1 + 25x_2 + d_1 = 1000 + 2\lambda \\ 35x_1 + 28x_2 + d_2 = 980 + \lambda \\ 25x_1 + 35x_2 + d_3 = 875 + 3\lambda \end{array} \right. \quad (33)$$

$$35x_1 + 28x_2 + d_2 = 980 + \lambda \quad (34)$$

$$25x_1 + 35x_2 + d_3 = 875 + 3\lambda \quad (35)$$

where  $d_1, d_2, d_3$  free variables;  $\lambda$  — casual parameter. In an optimal solution  $d_1 = d_3 = 0$ , and, therefore, the solution of this system of the equations will have an appearance

$$\left\{ \begin{array}{l} x_1 = 16 \frac{29}{31} - \lambda / 155; \\ x_2 = 12 \frac{28}{31} - 14\lambda / 155; \\ d_2 = 12 \frac{28}{31} - 202\lambda / 155; \end{array} \right. \quad \begin{array}{l} (36) \\ (37) \\ (38) \end{array}$$

This decision has only structural stability for an interval of values  $\lambda$  from  $142 \frac{6}{7}$  to  $19 \frac{187}{202}$ . Thus, on the basis of solutions of an optimizing ecological task the steady control system of ecological safety of construction can be created.

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 [4-6], and immediately at the moment of decision on the project, the modeling and analysis of prevailing ecological situation [5-12]. 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 [6-18]. These simulation mathematical models allow to identify the imbalance of plans and forecasts to actualize the objectives of the environmental activities, to justify their actual and potential natural production and technological capabilities [7-21].

## 5. Results and conclusions

1. 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 research is 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.

2. The research is 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.

3. The conducted theoretical research 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.

4. 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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