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The Assortment Approach to the Selection of Building Materials for the Construction of Real Estate

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Abstract. During the construction of real estate, the choice of building materials for the manufacture of building structures is carried out according to the regulatory requirements developed on the principle of unification (uniformity of technical characteristics). These requirements should be opposed to the optimization of building structures in accordance with their functional purpose and operating conditions in the building to reduce the growth of costs of resources of the construction industry. The normative approach is proposed to be combined with a more economical assortment approach. This approach taking into accounting of preferences of subjects of management of building materials and construction, reflecting the interests of the subsystems of consumer and producer of building materials and constructions. The optimization procedure is proposed to be carried out on the basis of the development of technical task. In the presented model describing a set of alternatives using the proposed algorithms search for the optimal control of the production of building materials in the solution of multicriteria optimization problems is the search for an alternative with the maximum comprehensive assessment is carried out.

1. Introduction

Today during constructing of projects of real estate the choice of building materials, which are used for manufacture of concrete building structures is carried out according to regulatory requirements $\sigma_{regul.}$. These requirements are developed according to the principle of unification (uniformity of technical characteristics).

$$\sigma_{regul.} = \bigcap_{m=1}^{M} \sigma_{regul.}^{m} \tag{1}$$

where $\sigma_{regul.}^{m}$, $m \in \overline{1,M}$ are many options for managing the characteristics of building materials, in accordance with regulatory requirements (Figure 1).

The field of regulatory requirements includes a limited number of recipes of the full range of options for the manufacture of building materials. It is expediently to counteract regulatory requirements with the optimization of building structures. It will allow to reduce growth of costs of resources of construction industry. It is natural that alternatives with optimum sets of values of characteristics for specific conditions of operation and functional purpose can be outside the field of

regulatory requirements. At the same time the principle of unification is shown in the form of more economic assortment approach. In this research, unit of the assortment of building constructions is an enough exact compliance of characteristics of building materials to the set conditions of their operation and to functional purpose in real estate objects [1, 2].
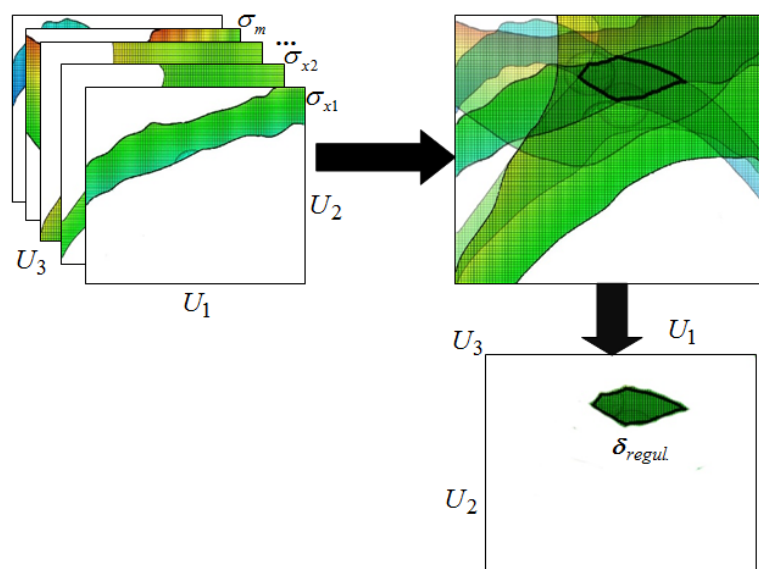

Figure 1. Formation of field of compliance to regulatory requirements of full set of characteristics of building material.

It has been developed the concept of optimization of release of the assortment of building materials for account and the description of features of assortment approach by the system analysis and the subject focused management methods. [3]. The concept includes design of model of the description of a set of feasible controls of production of construction materials, a stage of drawing up the technical specification and the optimization procedure.

2. The model of the description of a set of admissible controls by assortment of building materials

For creation of model of the description of managements of the assortment of concrete building materials were chosen following control's factors: U_1 – the water cement relation (W/c); U_2 – a ratio between large and small filler, sand and crushed stone the maximum fineness of 20 mm (r); U_3 – the content of the superplasticizing PFM-NLK additive increasing frost resistance, % of the mass of cement. The chosen factors, their codes and values of the top, average and lower level are given in Table 1

Table 1. Chosen factors, their codes and values of the top, average and lower level.

Code	Value	Researching factors		
		U_1 (W/c)	U_2 (r)	U_3 (D)
Top level	+1	0.7	0.8	0.6
Average level	0	0.6	0.65	0.5
Lower level	-1	0.5	0.5	0.4

The regression equations for such characteristics (2)–(6) as x_1 – durability at compression, x_2 – frost resistance, x_3 – watertightness, x_4 – density, x_5 – concrete workability have been received as a result of carrying out an orthogonal experiment [4] and processing of the obtained data, including checks of reproducibility of experiences and assessment of the significance of coefficients.

$$x_1 = 133.54 + 71.03U_1 - 272.5U_2 - 110.122U_3 - 133.93U_1^2 + 197.19U_2^2 + 106.33U_3^2 + 12.74U_1U_2 + 62.06U_1U_3 - 18.72U_2U_3 \tag{2}$$

$$x_2 = 33.86 - 618.65U_1 - 63.19U_2 + 1764.12U_3 + 1127.57U_1^2 + 855.9U_2^2 - 10219.91U_3^2 - 1171.61U_1U_2 - 1334.26U_1U_3 - 388.89U_2U_3 \tag{3}$$

$$x_3 = 47.23 - 92.72U_1 - 19.31U_2 - 0.36U_3 + 60.66U_1^2 + 5.1U_2^2 + 5.9U_3^2 + 14.07U_1U_2 - 5.19U_1U_3 + 0.83U_2U_3 \tag{4}$$

$$x_4 = 2679.66 + 1053.08U_1 - 1093.6U_2 - 22.5U_3 - 1188.48U_1^2 + 962.14U_2^2 + 10.65U_3^2 - 740.74U_1U_2 + 19.44U_1U_3 - 21.29U_2U_3 \tag{5}$$

$$x_5 = 7.93 - 23.99U_1 + 7.5U_2 + 1.62U_3 + 11.44U_1^2 - 11.52U_2^2 - 1.9U_3^2 + 7.53U_1U_2 + 1.57U_1U_3 + 3.89U_2U_3 \tag{6}$$

The list of characteristics of materials is considered by consumer. The main characteristics of materials for producer are costs of primary components at a mixing process and production costs. These characteristics depend on a ratio of primary components and are defined at the enterprise depending on technological process.

Two sets of matrixes-arrays are composed on base on the regression equations obtained using the software product Decon BM (Figure.2)
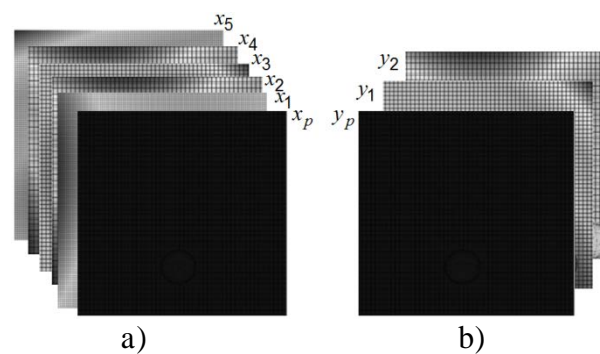

a)   b)

Figure 2. Matrixes-arrays of characteristic of finished products from concrete, considered from the position of the consumer (a) and the producer (b).

Material's characteristics in matrixes-arrays of producer and consumer have differences in dimension in arguments. This difference is an important obstacle in complex estimation of variants of manufacturing of building materials. Using subject-oriented management for solving this problem is required bringing material's characteristics to one universal qualitative scale, where the abscissa axis is the physical values of the finished product's quality, the ordinate axis is the qualimetric scale (Figure 3).
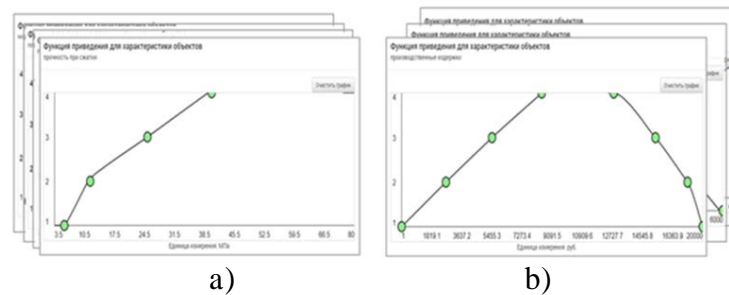
a)   b)

Figure 3. The reduced functions of the characteristics of the finished
product, constructed on the basis of the preferences of the subsystems
of the consumer (a) and the producer (b).

One of the most significant characteristics for both subjects of management the assortment of building materials and structures is their selling price [5]. To determine the price, it is necessary to develop a mechanism for subject-oriented pricing based on modeling of preferences of stakeholders in relation to the expected rate of return of the producer and product quality indicators by the consumer [6].

Pricing for variants of building material's production can be presented as a composition of models of stakeholders' preference, that reproduces the process of functioning of market mechanism and it has a goal to establish the demand and supply functions, also the contract price in equilibrium point (Figure 4). Modeling preferences is offered to realize in accordance with dimension of phase space F.

In the framework of the offered approach it is required to change interpretation of functions of supply and demand from "quantity of the acquired (made) product" to "satisfaction degree" from the chosen variant of material's production by the producer and consumer. The required result of the "fair" not manipulated pricing of an alternative of building material is determined by parameters of an equilibrium condition of the market that is formed in intersection point of curves of supply and demand in a subspace where satisfaction degrees from the transaction get the most equal values.
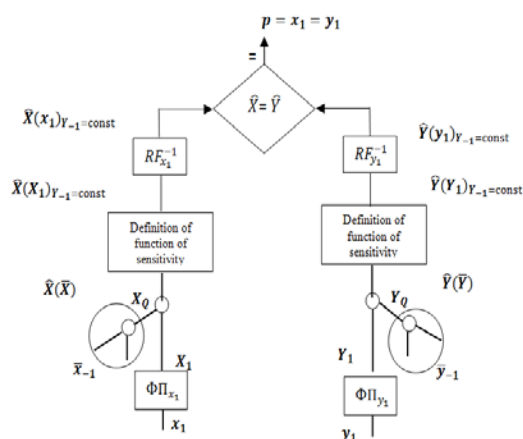

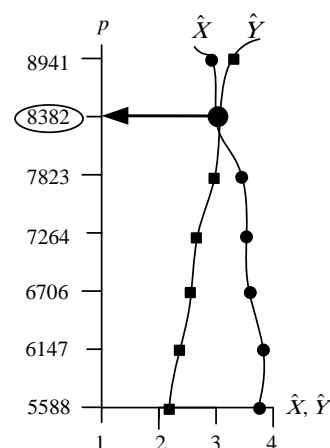**Figure 4.** The mechanism of subject-oriented pricing.

Figure 5. Determination of the agreed price.

The procedure of pricing is connected with using the phase (price P) and qualimetric (levels $\hat{X}$, $\hat{Y}$ of satisfaction of stakeholders) scales of the model of option of production building materials for fixed quality levels $X_{Q_x}^*$, $Y_{Q_y}^*$ and ends with occurrence of an event $\hat{X}(p^*)=\hat{Y}(p^*)$ with the result in the

form of an agreed price p^* for the alternative (Figure 5). With increasing validity of pricing's models within the framework of this mechanism, it is advisable to use the procedures for finding agreed solutions that are based on the development of the principles of active non-manipulative expertise and the generalized median.

The pricing process is held by experts one by one in the whole of set of alternatives of building material's production. At the end we have the model of description of set of feasible alternatives of release of building materials, which we will use for optimization in accordance with technical specification on production of assortment of building materials.

3. Technical specification for the production of assortment units of building constructions

As an example, consider the technical specification for the assortment of concrete slabs. On the basis of the information about the functional purpose and conditions of operation of the real estate object coming from the external environment, the designer representing the consumer's interests carries out the procedure for formalizing the requirements for the constructions [7], which can be presented in the following form (Table 2):

Table 2. Operational requirements for building structures.

№	Operational impacts	The unit of measurement	
Assortment unit №1			
1	Static and dynamic loads	16.7	kN/cm^2
2	Noises and sounds (percussion and air)	<49	Decibel
3	Temperature drops	$\geq$ F200	cycles
Assortment unit №2			
1	Static and dynamic loads	14.8	kN/cm^2
2	Noises and sounds (percussion and air)	<32	Decibel
3	Temperature drops	$\geq$ F130	cycles

After the procedure of formalizing the requirements for the characteristics of finished products it is carried out the procedure of transfer of requirements for the characteristics of building materials and setting multicriteria optimization tasks of building materials [8].

Table 3. Requirements for the technical characteristics of building materials.

x №	Strength, megapascal	Density, kg/m^3	Frost resistance, cycle	Watertightness
Assortment unit №1				
1	$x_1 \to \max$ $x_1 \geq 30$	$x_2 \to \min$ $x_2 < 2400$	-	$x_4 \to \max$ $x_4 > 2$
2	$x_1 \to \max$ $x_1 > 10$	$x_2 \to \min$ $x_2 < 2400$	-	$x_4 \to \max$ $x_4 > 4$
3	$x_1 \to \max$ $x_1 > 10$	$x_2 \to \min$ $x_2 < 2400$	$x_3 \to \max$ $x_3 > 200$	$x_4 \to \max$ $x_4 \geq 4$

Requirements for the characteristics of materials	$x_1^{\max} \geq 30$	$x_2 < 2400$	$x_3 > 200$	$x_4^{\max} \geq 4;$

<div align="center">Assortment unit № 2</div>

1	$x_1 \to \max$ $x_1 \geq 25$	$x_2 \to \min$ $x_2 \langle 2400$	-	$x_4 \to \min$ $x_4 \leq 6$
2	$x_1 \to \max$ $x_1 > 10$	$x_2 \to \min$ $x_2 < 2400$	-	$x4 \to \min$ $x_4 \leq 6$
3	$x_1 \to \max$ $x_1 > 10$	$x_2 \to \min$ $x_2 < 2400$	$x_3 \to \max$ $x_3 > 130$	$x_4 \to \min$ $x_4 \leq 6$
Requirements for the characteristics of materials	$x_1^{\max} \geq 25$	$x_2 < 2400$	$x_3 > 130$	$x_4^{\max} \leq 6$

The problem of optimization of the most significant characteristics of building materials, according to the reviewed example, is presented the next formula:

$$\hat{X}_{1,4} = (K_1 X_1 + K_2 X_4 + K_3 X_p) \to \max \tag{7}$$

Where X_1, X_4 – technical characteristics of building materials; X_p – price per unit of product, rub.;

K_1, K_2, K_3 – weighted coefficients of building material's characteristics.

The number of assortment units of building structures is determined by the number of setting of multicriteria tasks of optimization of characteristics of building materials.

4. Algorithms of search of optimal variants of production of assortment units of concrete building material

The development of this algorithm is based on the tool of complex estimation based on hierarchical linear bundles - "Jobs-Decon" [9].

The work of the algorithm begins with the identification of system limitations to the characteristics of the material (Figure 6). Using standard programs, a cyclic procedure for truncating all infeasible regions of matrix- arrays is performed, corresponding to the number of given limitations and creating a new array with feasible alternatives to realization. After that, a model of consumer preferences is determined through a phased implementation of procedures including the construction of reduced function, weighted coefficients, ranking of priority material characteristics and calculation of integrated assessment for all feasible alternatives. As a result of applying the algorithm, we obtain one or a set of several alternatives having maximal complex estimation. In the case of obtaining several alternatives having the same complex estimation, the incorrect choice is eliminated by involving the manufacturer in the solution of the problem and choosing the most economically and technically advantageous variant of manufacturing the building material, or, the choice problem is solved without taking into account the manufacturer's preferences, the best result is assigned automatically on the basis of maximizing or minimizing the addressing of cells.

As part of the choice of assortment of slabs, we obtain the following model of consumer's preferences (8)

$$\hat{X} = 0.43 * X_1 + 0.18 * X_2 + 0.38 * X_p \tag{8}$$

where X_1 – compressive strength, MPa, X_2 – water resistance, coefficient; X_p – price per unit of output, rubles; $K_1 = 0.43$, $K_2 = 0.18$, $K_3 = 0.38$ – values of weighted coefficients of material characteristics.
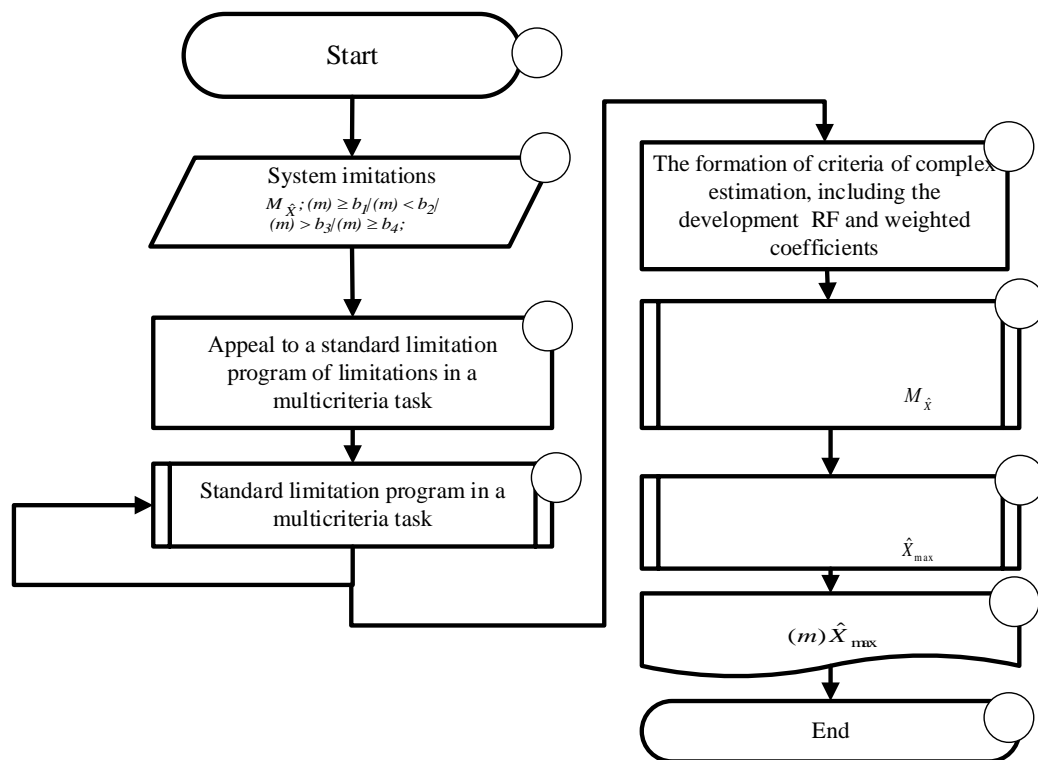
Figure 6. The flowchart of an algorithm of search of optimal controls of release of building materials in the context of solving the multicriteria optimization problem.

On the basis of this model of preferences, a procedure of complex estimation of feasible alternatives of building materials was carried out, among which the most complex estimation of has an alternative under No. 3 (Figure 7). Since we have a single alternative with the maximum value of a complex estimation it is not necessary to involve the manufacturer in the solution of the problem of choice. Otherwise, it is necessary to build a model of the manufacturer's preferences and to implement the repeated complex estimation with feasible alternatives.
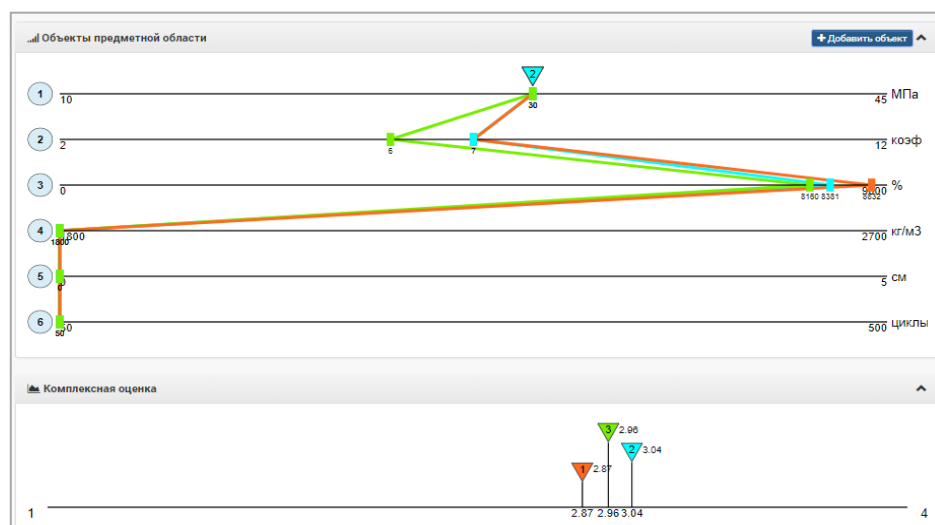

Figure. 7. Complex estimation of alternatives by the consumer.

The final stage is the procedure for selecting assortment units for all the tasks of multicriteria optimization of the release of building materials.

There was an efficiency evaluation of selected alternatives of the release of building materials at the end of the optimization procedure. It is proved that in the conducted experiment the proposed algorithms ensured the obtaining of optimal concrete compositions, intended for the production of two assortment units of slabs, that allowed to obtain on average an economic benefit of 453 rubles per unit of production in the processes of justifying the optimal properties of building materials.

5. Conclusion

As a result of the presented assortment approach, it becomes a possibility to take into account the functional purpose and operating conditions of structural elements in the real estate object, which contributes to the rational use of the primary components and the achievement of the optimal set of operational characteristics of building structures in buildings.

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