MULTI-CRITERIA OPTIMIZATION OF UP-TO-DATE CONSTRUCTION TECHNOLOGY

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ABSTRACT: The article analyzes the methods of multi-criteria alternative technological solution evaluation in construction environment. Methodology, which is used, allows to complexically evaluate the efficiency of construction designed decisions at the stage of preparation phase. There has been done a practical technological modeling of installation process of concrete floor as well as there have been determined optimal solutions. In order to achieve the results mentioned, a method of proximity to an ideal point was used.

KEYWORDS: multi-criteria optimization, method of proximity to an ideal point, rational trusses.

1. INTRODUCTION

At the very moment in Lithuania and other countries various construction and projection firms offer to use all kinds of new technologies and its systems, structural decisions, proper materials used as well as work implementation methods, without paying any attention to the factors, effecting the choice of selecting the most effective technology of construction process. Having in mind that funds should be realized rationally, it is the matter of vital importance to measure the practical adaptability of technologies being used either they are new or have been used for many years to achieve the best technological decisions. In order to achieve the efficiency of the funds invested and diminishing construction duration as well as increasing its quality, various construction process technologies are developed and improved by using modern technical and informational tools, which are integrated into the stages of projection and construction. The prospective technological processes' decisions and operations, their efficiency and competitiveness are programmed at the stage of construction objects' projection. In order to achieve the efficiency of construction technology it is advisable to use the achievements of fundamentals and applied science to solve the main tasks in various spheres of construction decision modeling and optimization.

While modeling and projecting construction technologies, it is advisable to perform the multi-criteria analysis of technological processes and decisions on the grounds to fully coordinate the goals of the interested parties (customer, projector, and contractor). That is why major principles and methods of construction decision technology multi-criteria optimization as well as questions associated with alternative decision technologies and mathematical modeling are analyzed in this paper. As for example, which provides the practical technological modeling of installation process of concrete floor and determining the optimal decisions based on the method of proximity to an ideal point.

2. MAJOR PRINCIPLES OF CONSTRUCTION TECHNOLOGICAL DECISION OPTIMIZATION

Applicable technological and other project decision optimization methods used in projection and construction processes could be divided into two major groups: applied mathematics and systemic-technical analysis methods. A great deal of construction organization tasks could be solved by using mathematic statistics (correlation and regression analysis), theory of chances, mathematic programming, 'gambling' theory, multi-criteria optimization and other methods. The selection of optimization method depends on the task character which is solved, the possessed source information and frequently it requires local interpretation. While solving practical construction optimization tasks, most frequently only one (the most important) of several economic criteria is chosen (ex.: total construction price, object construction or separate pieces of construction per one solid meter ($1m^3$) price, the revenue received, the greatest turnover, etc.). The significance of the criterion selected is very important. It shows that one of the criterions mentioned (for example, revenue received), which is selected by the interested party, is much more important than the other one, for example, total construction price. So to be concrete it shows the significance of one criterion to the interested party in comparison to the rest, which are left as less significant or insignificant. The significance of the criterion could be determined by employing statistical, expert opinion based methods, even comparison, and entropy methods. These methods help to determine various theoretical, subjective, and complex values of great significance that are further used in the decision optimization counting processes. By counting values it is meant that the interested party could choose the criterion (they think) of the greatest significance. Moreover, the client is frequently much more interested not in the price, but in other criteria like construction duration, aesthetics, harmfulness to the health of the materials used, longevity, convenience to exploit, comfortability, etc. So any construction technological decisions could be described and optimized according to the following system of criteria evaluation, where the criteria could be expressed by the indices of technological economy (TCI) and quality characteristics (QC). For this purpose methods of multi-criteria decisions are used [1, 2].

We can definitely state that each of the decision optimization method mentioned has got its own advantages and disadvantages. Moreover, each of them could be used to solve the tasks of specific constructions groups. They help to create various optimization models of theoretical objects, technological or work processes like technological net models (alternative decisions, resources, dynamic, duration), mathematic models (shape of matrices, equation systems, various probability models), expert level systems, decision support systems and many others models.

Researches of modeling and optimization were founded on the basis of applied mathematics method, economics, system theory, cybernetics, and in the sphere of counting technological science and its integration. While optimizing technological construction processes, it is advisable to apply the theoretical principles of system methodology on the grounds that in nowadays the technological projection methods which are used do not correspond to the requirements of effective decision making. It could be noted that one of the major disadvantages are the decisions are accepted synonimically, without any preliminary examination and evaluation of the model of construction process technology and many the like multi-criteria evaluation [3]. While solving the any technological decision optimization problem, it is necessary to perform 3 major steps of construction process systemic examination (Figure 1). While modeling the construction composite process technological decisions, it is advisable to accept these main preconditions [4, 5]:

- All possible variations of complex process technologic decisions have to be constructed. Moreover, technological connections and partial variants of the processes (partial alternative decisions) have to be established.
- While forming the net model, consisting of partial process technological variants, it is necessary to take a precondition that only one of many other partial process technological variants will be implemented.
- Every partial process has got its individual time duration, which is either technologically based or depends on the work expenditure.

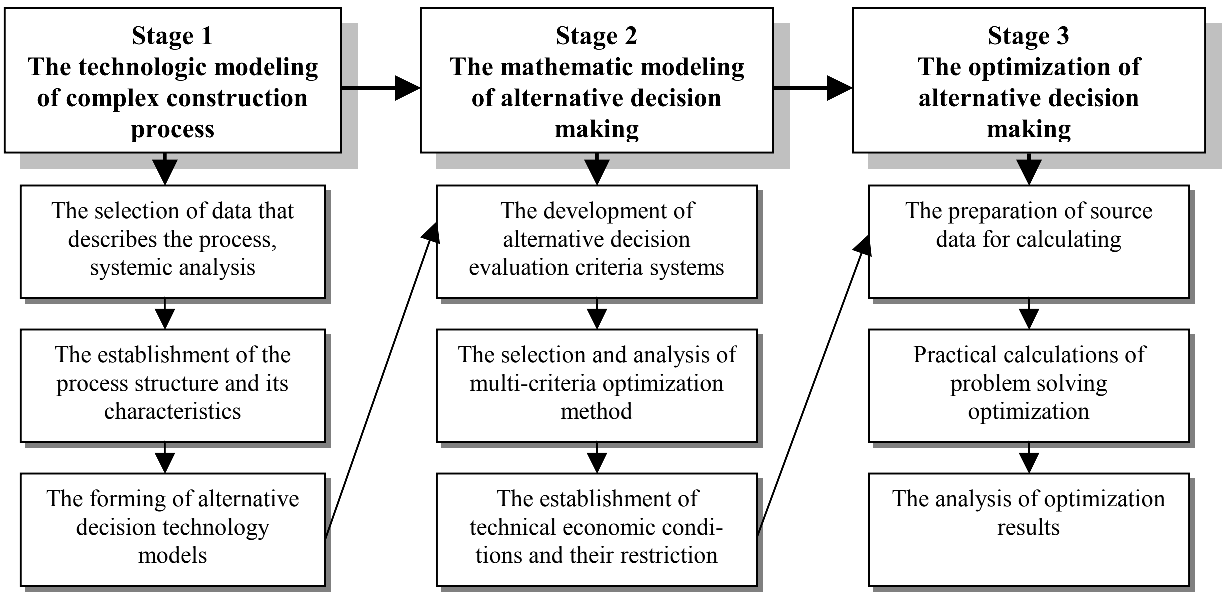

Figure 1. The steps of construction composite process systemic examination

So while creating the mathematical model of alternative technological decision making, it is advisable to define the set of the compared alternative decisions and their evaluation criteria. In that case, the source data matrix P, presented in Table 1, is prepared.

Table 1. The source data matrix P

Alternative decisions	Evaluation criteria			
	K_1	K_2	…	K_n
a_1	X_{11}	X_{12}	…	X_{1n}
a_2	X_{21}	X_{22}	…	X_{2n}
…	…	…	…	…
a_m	X_{ml}	X_{m2}	…	X_{mn}

The source data matrix P most often consists of different units of measurement. That is why the matrix should be normalized, i.e. it has to be transformed into the anti-dimensioned unit or sizes. Knowing the aims of the solution as well as applying the methods of normalization various normalized values of indices are obtained, which play the key role in other stages of solution multi-criteria optimization.

3. THE MAJOR RUDIMENTS OF APPLYING THE METHOD OF PROXIMITY TO AN IDEAL POINT, USED TO EVALUATE THE TECHNOLOGY

The main essence of the multi-criteria evaluation method is formation of generalized composed criterion. It is based on the comparison deviation of the criteria from so called the ideal criteria, consisting of the best variant criteria being analyzed. By applying the method and K_{bit} criteria, it is advisable to take into account that each variant of the task problem solving utility function has got the tendency to monotonously increase or monotonously decrease i.e. the larger value of any indices, the better it is or worse for less of the same index value. It depends on the fact whether the utility function increases or decreases. Indices have to be either cardinal or ordinal. If we have got the ordinal (qualitative) indices, they should be quantified. Besides, significance values should be determined, otherwise, they all are accepted as being equals. The application algorithm of the method of proximity to an ideal point, estimating the significance of the criteria, is presented in Figure 2.

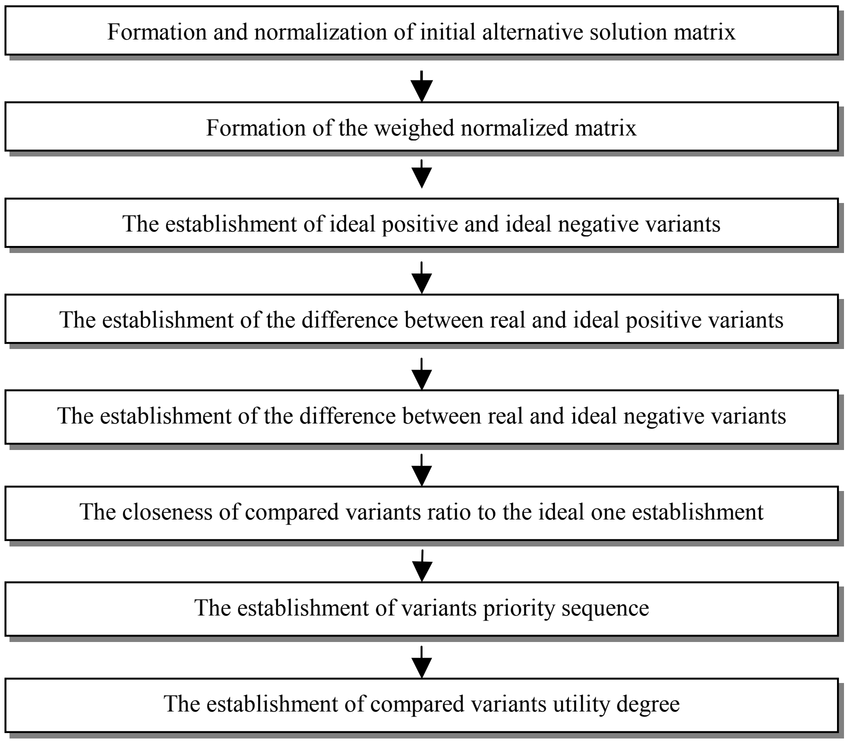

Figure 2. Application algorithm of the method of proximity to an ideal point

The matrix P of alternative architectural decisions is created. There could also be criteria either grouped or ungrouped. The matrix normalization is being dome according to the formula:

$$\overline{x_{ij}} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \text{ kur } i = \overline{1,m};\ j = \overline{1,n} \qquad (1)$$

If the significance of the subjective or theoretical ($\overline{q}$ or q_t) criteria is known, then the vector column multiplied by the normalized matrix corresponding column.

We get weighed matrix $\overline{P^*} = \left[\overline{P}\right] \cdot \left[q\right]$ (2)

If there are no values of significance, then $\overline{P} = \overline{P^*}$ ($\overline{P}$ matrix is compared to the weighed matrix), i.e. we take the precondition that entire alternative solution criteria are equally important. The ideal positive variant is being established:

$$a^+ = \left\{ \left[\left(\max_i f_{ij} \;/\; j \in I \right), \left(\min_j f_{ij} \;/\; j \in I' \right) \right] / \, i = \overline{1, m} \right\} = \\ = \left\{ f_1^+, f_2^+, \ldots, f_n^+ \right\} \tag{3}$$

where I – indices of ratio (maximizing), which possess the highest values.

The ideal negative variant is being established:

$$a^- = \left\{ \left[\left(\min_i f_{ij} \;/\; j \in I \right), \left(\max_j f_{ij} \;/\; j \in I' \right) \right] / \, i = \overline{1, m} \right\} = \\ = \left\{ f_1^-, f_2^-, \ldots, f_n^- \right\} \tag{4}$$

The difference (distance) between real and ideal positive variant is being found:

$$L_i^+ = \sqrt{\sum_{j=1}^{n} \left(f_{ij} - f_j^+ \right)^2} \tag{5}$$

where a_i – real variant; a^+ - ideal positive variant; L_i^+ - positive distance.

The difference between real and ideal negative variant is being found:

$$L_i^- = \sqrt{\sum_{j=1}^{n} \left(f_{ij} - f_j^- \right)^2} \tag{6}$$

$K_{bit,\,i}$ calculation of values (each alternative value is found):

$$K_{bit,i} = \frac{L_i^-}{L_i^+ + L_i^-}, \text{ when } \forall_i ; i = \overline{1, m} \tag{7}$$

$0 \le K_{bit} \le 1$, besides,

$$K_{bit,i} = \begin{Bmatrix} 1, jei & a_i = a^+ \\ 0, jei & a_i = a^- \end{Bmatrix} \tag{8}$$

The best (the most rational) architectural solution will become the one, which K_{bit} value will be max ($K_{bit,i}$=max). Using the values we form the priority sequence. Utility degree establishment. We compare the value of the variant examined with the value of ideal variant.

$$N_i = \frac{K_{bit,i}}{K_{bit,\max}} \cdot 100\% \tag{9}$$

4. THE ESTABLISHMENT OF THE OPTIMAL FLOOR COVER EQUIPMENT TECHNOLOGY, APPLYING THE METHOD OF PROXIMITY TO AN IDEAL POINT

The change appeared in technological systems affect not only the rest systems parts or elements, but also the expected final result. That is why it is the matter of vital importance to deliver systemic structuralization of the construction technological processes.

The installation of the floor cover is only a partial installation process, which could be analyzed in the complex manner. The complex process of the floor cover equipment maximally can form 7 partial processes. Each partial process has got its own conventional sign, for example: P – preparation of cover; I – the establishment of the ironed coat; G – surface priming; D_1 – installation of first cover coat; D_2 – installation of the second cover coat; S – slushing of juncture; L – cover varnishment.

All possible combinations of cover floor are created (Figure 3).

Each partial process possesses the original structure, which is distinctive from the rest (Table 2). Besides, the processes of floor installation can differ in the performance of separate operations. They could be either mechanized or hand-held. Moreover, there could be difference in the manner of separate operation performance, equipment used to perform the process of installation, preparation for the work, the supply of materials and manufactured products, methods of quality control.

Technological floor cover installation model is established in the following stage, where the combination of complex processes are reflected as well as combinations of all possible partial processes and correlation between them. The best model, which is suited for the case is net model.

While establishing the combinations of partial processes, the technological combination sequence of partial processes is found. It is important to establish the combinations of technological connections among the separate partial processes, because it could happen so that the variant of the partial process does not possess the connectivity with the other variant of the partial process, i.e. one of them could have no technological connection with another.

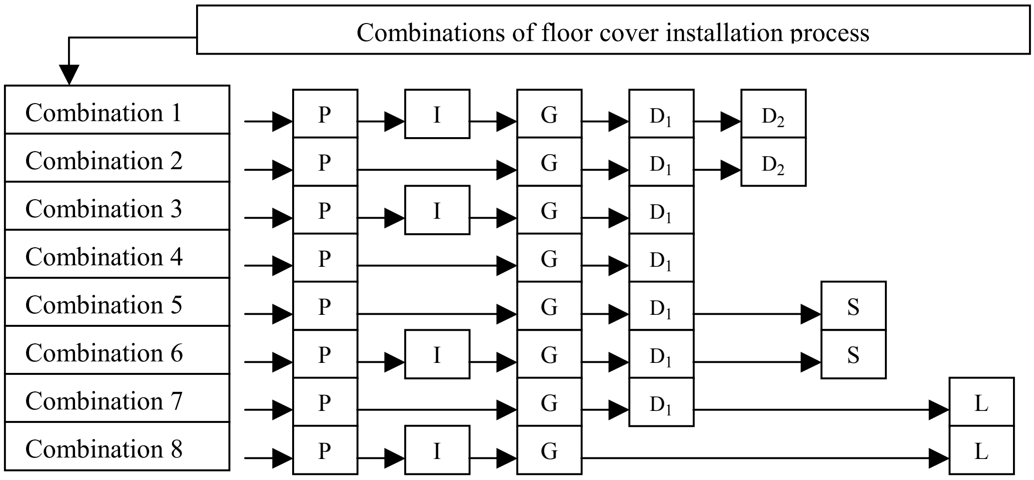

Figure 3. Combinational schemes of floor cover installation complex process

Table 2: Combinations of floor cover equipment partial processes

The code of partial process variant	The name of the floor cover equipment partial process; combinations of partial process (short description)
P	Surface preparation: - the take off of the cement pellicle, dust removal form the surface, corners making rounded, all arrangements
I1 I2	- the installation of the ironed cover from the cement grout - the installation of the ironed cover from the getting smooth grout (simple)
G G1	- carrying up of the primer, rubbing, surface thickening - carrying up of the primer for the basis of cement surface
$D_1$1 $D_1$2 $D_1$3 $D_1$4 $D_1$5	- the installation of one-layer primer from the mastic composition - the installation of two-layer primer from the mastic - the installation of primer layer while painting - the installation of the upper primer layer from tiles - installation of the upper primer layer from the grout on the basis of cement
$D_2$1	- the installation of the upper primer layer from mastic
S1 S2	- slushing of juncture among the tiles - slushing of cement surface
L	- priming of cover and varnishing (twice)

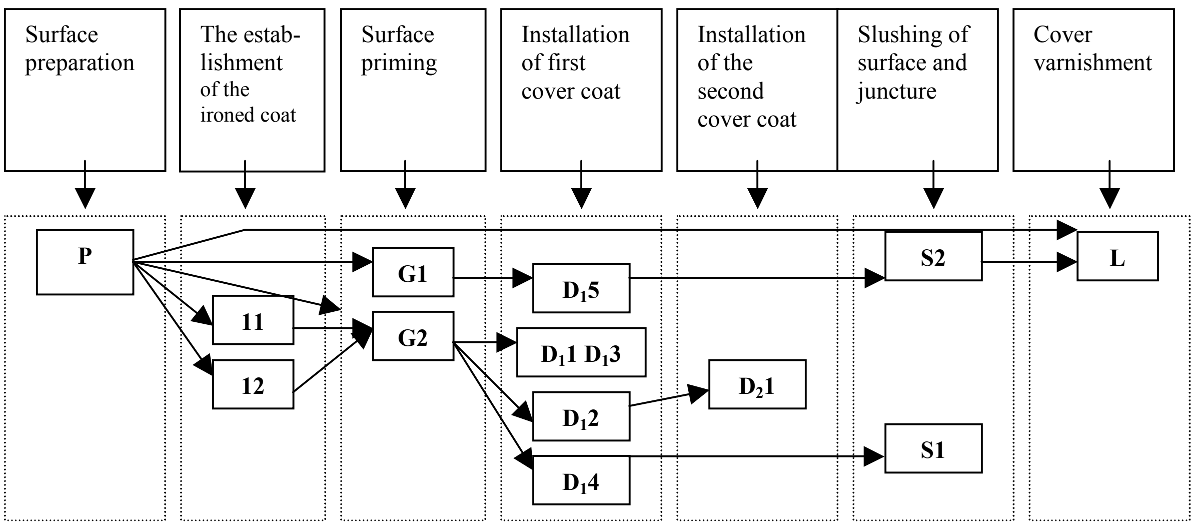

Figure 4. The scheme of variant technological connections between the separate partial processes

According to the data presented in Table 2 and Figure 4 as well as the construction methodology of net model, the net model of floor cover installation process technology is formed. The net model of floor cover installation process technology is the major scheme on which variants of the complex processes are selected and furthermore the continuous calculations of the variant values are performed. All possible ways from the beginning till the end are in search. Each possible way of the technologic net model possesses a different composition of partial processes. Entire possible ways of technologic model are presented in Table 3.

Table 3. Variants of floor installation complex process

Variant	Variant of complex process, defining	
	The way of technologic way model	Combination of partial processes variants
1	1→2→6→8→10→12	P→G→$D_1$1
2	1→2→6→8→10→13 →17→20	P→G→$D_1$2→ $D_2$1
…		
14	1→2→3→5→6→8 →10→15→18→21	P→12→G→$D_1$4→ S1

In order to select the most suitable variant of floor cover installation the evaluation system is formed (Table 4).

Table 4.Evaluation criteria system

No.	The name of criterion	The description of criteria
1	The price of floor installation variant	It is the summed price of materials, mechanisms and work costs, meeting $1m^2$ of the floor's cover
2	Work costs	It shows the workforce working time per hour, needed for the installment of $1m^2$ of the floor
3	The level of work mechanization in percentage (%)	It shows the relative accumulated workforces' mechanized work costs, expressed in percentage
4	The floors' resistance to wear and tear	The index shows how many grams are polished within $1cm^2$, while performing tests according to Taber, who directly evaluates the longitude of the cover
5	Chemical resistance of the floor cover (in points)	The resistance of the floor cover is tested in various aggressive conditions
6	The beginning of using the floor cover, in days	It estimates the duration of cover installation, which allows then the maximum loading of mechanism as well as chemical (work costs plus technological intervals / breaks)
7	Ecology conditions, in points	They reveal the harmfulness of the floor cover materials to the environment
8	Comfortability, in points	The index shows the satisfaction of working force while using the cover
9	Hygiene, in points	The index evaluates the hygiene characteristics of the cover while using it
10	Aesthetic view, in points	The index evaluates the appearance of the cover

Table 5. The calculation of criteria significance determination by the even comparison method

Criteria of matrix A

Criteria	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	ΣA_k	q	%
K1		2	2	1	0	1	1	1	1	1	10	0,11	11
K2	0		1	0	0	1	1	1	2	2	8	0,09	9
K3	0	1		0	0	1	0	1	1	1	5	0,05	5
K4	1	2	2		1	2	1	1	1	2	13	0,14	14
K5	2	2	2	1		2	2	1	2	1	15	0,17	17
K6	1	1	1	0	0		1	0	1	1	6	0,07	7
K7	1	1	2	1	0	1		1	1	1	9	0,10	10
K8	1	1	1	1	1	2	1		0	1	9	0,10	10
K9	1	0	1	1	0	1	1	2		1	8	0,09	9
K10	1	0	1	0	1	1	1	1	1		7	0,08	8
										Σ	90	1,00	100

The one of the major clients of floor cover projection, cover installation and exploitation processes is the customer. So while selecting the proper system of criteria evaluation, we first of all, should find out what needs and wants possesses the customer. The needs and wants lately are expressed by the criteria of evaluation. The investigation of customers' needs and wants is done. Biographical particulars were used to

perform the investigation. Some of the criteria are highly important to the contractor, who executes the whole work, as well as designers, who project floor cover for exploitation in some definite environment. Although not all of the criteria are equally important. That is why it is advisable to establish their significance.
Subjective criteria significance $\overline{q}$ is chosen in this paper, which was determined by the even comparison method (Table 5).

While performing the calculation of criteria significance on the basis of even comparison method, we received the significance of subjective criteria. The source matrix is formed in the following stage.
While performing the normalization of the matrix, and evaluating the significance of the criteria, as well as forming weighed normalized matrix, we received calculation results.

5. CONCLUSIONS

At the very moment in Lithuania and other countries various construction and projection firms offer to use all kinds of new technological projecting systems as well as work execution technologies, without paying any attention to the circumstances, affecting the choice of selecting the most effective technology of construction process.
In order to rationally employ the technological process of the funds, it is advisable to perform the modeling and multi-criteria evaluation of the alternative solution technology.
To perform the selection of the most suitable floor cover installation variant, the algorithm of solution optimization was formed a well as the criteria evaluation system, which describes the goals of interested parties striking for the aim in projection, work execution and exploitation processes.
While performing the investigated modeling and evaluation of concrete floor cover system alternative solution technology, was established that among all cover systems (epoxy, acrylic paint, tiles, cover on the cement basis) it is advisable to install the UREDUR 2000 covers in the aggressive environment.

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