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COMPARISON OF THE PRODUCTION AUTOMATION SYSTEMS EFFICIENCY ON THE BASIS OF THE CHARACTERICTICS

The efficiency indices of the built-in automation systems, which can be used for the assessment of the efficiency of different variants of the system construction are given in the paper. Methods of multicriterial comparison of the efficiency of different variants of production automation systems construction, presented by numerous quality indices are considered. The drawbacks of the known methods, based on the application of the resulting efficiency index, obtained by the summation of the weighted quality indices are described. The process of the optimal decision search is proposed to perform in two stages: determination of the set of the forward looking engineering solutions, selection of the optimal decision from previously determined set of the perspective decisions. At the second stage it is necessary to use the additive function for the convolution of the efficiency indices. Comparison of the efficiency of various forward looking variants of automation systems construction is carried out by the resulting efficiency indices. Final results, obtained in such a way, is more reliable as compared with the using of the additive function for the convolution of the efficiency indices without the preliminary search of the advanced systems, because the additive function is used only for the preliminary constricted set of variants of system realization. Analytical procedure of the search of the advanced engineering variants of automation system construction is developed.

Key words: *automation system, system efficiency, quality indices, vector comparative systems, analytical procedure.*

Introduction. Renovation of the production capacities of the enterprise can be carried out by means of buying modern equipment or by the modernization of the available equipment. Modern technological equipment contains the built-in automation systems (BAS), enabling to increase its productivity and considerably improve the production quality.

Decrease of the expenses for the production renovation can be achieved by means the preliminary assessment of the efficiency of different renovation variants to order to choose the optimal decision. The following indices of BAS efficiency are used: purchase cost; duration of the work for the dismounting of the available and installation of the new BAS; cost of the installation and commissioning work; surface for the location of the built-in automation systems (BAS); cost of maintenance and repair; consumed power; warranty operation life; trouble – free time; average renovation time; range of operation temperatures; increase of the final output yield from the same amount of the raw material; necessary quantity of the technological staff; return on the capital employed; reduction of the environmental pollution level as a result of new equipment usage, etc.

Thus, when comparing different variants of BAS construction it is necessary to use multicriterial analysis, as it enables to perform the selection of the best (optimal) decision.

For quantitative assessment of the characteristics of the complex system the notion «efficiency» is used[1, 2], it implies the degree of the system adaptation to perform the tasks put forward. Quantitative assessment of the efficiency is carried out by means of the criteria, consisting of the efficiency indices, each of which is a characteristic of one of the system properties.

Any complex system or its part is characterized by the set (vector) of the efficiency indices:

$$K = \langle q_1, q_2, \dots q_m \rangle, \tag{1}$$

where $\{q_i\},\ i = \overline{1, m}$ – are separate efficiency indices.

Optimization methods, based on the reduction of the vector optimization to the scalar one, for instance, the method, suggested in [3] are widely used. Such methods provide the introduction of the resulting (generalized) efficiency index K_r , it is determined by the following functional:

$$K_r = \Phi\left(k_1, k_2, \ \dots \ k_m;\ \gamma_1, \gamma_2 \ \dots \ \gamma_m\right), \tag{2}$$

where Φ – functional, that provides the convolution of the set of the separate efficiency indices to the resulting index; $\{k_i\}$, $i = \overline{1, m}$ – set of the estimates of the separate indices; γ_i – weight coefficients of the separate indices.

But the generalized efficiency indices may fail to meet the requirements as they have a drawback: fault in one index can be compensated at the expense of another index.

In many cases it is impossible to determine the analytical form of the dependence (2). For the solution of the optimization problem, analytical form of the functional (2) is form, using the method of the expert assessments. Optimal solution, obtained in such a way, will be characterized by the element of subjectivism. Among the methods of vector optimization the Poreto principle got wide application, it enables to narrow the area of optimal solutions search.

The essence of the given method is that vectors $K(S^1)$ and $K(S^2)$, which show the efficiency of the systems S^1 and S^2 are compared, i. e., the condition is verified:

$$K(S^2) \leq K(S^1). \tag{3}$$

If the condition (3) is realized, then the preference is given to the system S^2. If the vectors are incomparable, then the systems S^1 and S^2 are referred to the perspective variants (Poreto area). For the selection of the solution from the narrowed area of solutions, the methods, based on the resulting efficiency index are applied.

The division of the optimization process into two stages – the stage of Poreto area determination and the following stage the selection from this area (the only best system) on the base of the resulting efficiency index enables to minimize the worsening of the optimal search results

For the search of the perspective solutions in the area of the possible solutions, the method of working characteristics was suggested in the monograph [4], the given method, using the monotonicity property, enables to find in the space of the possible solutions the working surface, which is the boundary of the perspective solutions area. In the same monograph the analytical procedure of the search of the perspective solutions area is suggested. However, this procedure must be applied only in case, when the number of the specific efficiency indices does not exceed two ($m = 2$).

Aim of the research. Develop the efficient analytical procedure of the perspective solutions search in m – dimensional area of the possible solutions.

Problem set up. Formally the task of the optimal system search is formulated in the following manner. At the first stage it is necessary to find the area of the perspective solutions $\Omega \subseteq W$ by the set efficiency vectors K (1) in the area of possible solutions W. At the second stage in the area Ω it is necessary to find the best variant of the system $S_{opt} \in \Omega$, that provides minimal functional of the resulting efficiency index K_r:

$$K_r(S_{opt}) = \min_{S \in \Omega} K_r(S), \quad \Omega \subseteq W. \tag{4}$$

For ease of comparison of vector K (1) values, that correspond to different variants of the system, all quality indices k_i are reduced to the standard form:

$$k_i \geq 0, \quad (i = \overline{1,m}). \tag{5}$$

The smaller the value of k_i, more efficient the system is.

Systems S^1 and S^2 can be compared by the quality vector $K = K(S)$, if one of the following conditions is met:

$$1) \text{ or } K(S^2) \leq K(S^1), \quad \Bigg\}$$

$$2)\ \text{or}\ K(S^2) \geq K(S^1), \tag{6}$$

$$3)\ \text{or}\ K(S^2) = K(S^1).$$

If any of these conditions is not met, then the systems S^1 and S^2 area incomparable by the vector K. The essence of the vector inequalities is the following (6):

1. Each of quality indices $k_i(S), (i = \overline{1,m})$ in the system S^2 is not greater (not worse), than in the system S^1, of which , at least, one of these indices is smaller (better), than in the system S^1. In this case it is stated that the system S^2 is better than the system S^1.

2. All the quality indices $k_i(S), (i = \overline{1,m})$ in the system S^2 are not better (not smaller) than in the S^1, of which, at least, one of these indices is greater (worse). It is stated that the system S^2 is less efficient than the system S^1.

3. The equality when $k_i(S^2) = k_i(S^1), (i = \overline{1,m})$, thus, the systems S^1 and S^2 have the same quality, i. e., belong to the same class of systems.

For vector-comparison systems the notion of absolute advantage criterion is introduced, it is formulated in the following way: if the vector inequality $K(S^2) \leq K(S^1)$, is performed, i. e., $k_i(S^2) \leq k_i(S^1)$ for all $i = \overline{1,m}$, of which at least for one i the inequality is performed strictly (i. e. $k_i(S^2) < k_i(S^1)$), then the system S^2 is absolutely better than S^1.

Analytical procedure. The following notions are used in the process of development of the analytical procedure of the perspective systems search in the m-dimensional area of the possible solutions:

– *basic system* – the system, considered at the current step of the procedure as the initial;
– *current system* – the system, compared with the basic system at the current step of the procedure.

The 8-step analytical procedure of the perspective variants of the system search is presented below.

Step 1. All the variants of the system and values of their quality indices are written in the Table 1.

Table 1

Variants of the systems

Variant of the system	Quality indices					Result
	k_1	k_2	k_3	…	k_m	

Step 2. The first system, written down in the Table is taken as the basic system, the second system is selected as the current system, afterwords the transition to step 3 is made.

Step 3. Quality indices of the basic and current systems are compared.

Step 4. If the in the process of comparison absolutely worse current system is revealed (relatively the basic system), then in the column «Result» the system is marked by the sign «-». As the current system, the next system, not marked by «+» or «-» that does not coincide with the basic system is selected, afterwords the transition to step 3 is made. If the Table is looked through up to the end, then the transition to step 8 is made.

Step 5. If in the process of comparison absolutely better current system is revealed (relatively the basic system), then in the column «Result» the basic system is marked by «-». As the basic system absolutely better found system is taken, as the current system – the next system, not marked by «+» or «-», that does not coincide with the basic system, is taken, afterwords the transition to step 3 is made. If the Table is looked through up to the end, then the transition to step 8 is made.

Step 6. If in the process of comparison the revealed current system is vector incomparable with the basic system, then as the current system the next system, not marked by «+» or «-» is selected, it does not coincide with the basic system, afterwords step 3 is performed . If the Table is looked through up to the end, the transition to step 7 is made .

Step 7. The basic system is marked by the sign «+» in the column «Result». As the basic system the first system not marked by signs «+» or «-» is assumed. If the Table is looked through up to the end, then the transition to the step 8 is made. Otherwise as the current system the next system not marked by the sign «+» or «-» is selected and the transition to the step 3 is made.

Step 8. If only one system not marked by the sign «+» or «-» remains in the Table, then in the column «Result» it is marked by the sign «+» and the procedure is completed. If more than one system not marked by the sign «+» or «-» remains in the Table, then as the current system the next system not marked by the sign «+» or «-», which does not coincide with the basic system is selected, and the transition to the step 3 is made.

The example of the application of analytical procedure, with the revealing of the absolutely better system is shown in Table 2. The abstract system which can have 5 different variants of the realization is considered. Each variant is evaluated by five quality indices. The number of the realization variants and the number of quality indices may be random. The values of the quality indices can be obtained by any known method, for instance, by means of Delhi procedure.

In Table 2, single absolutely better system is marked by the sign «+», and absolutely worse systems are marked by the sign «-».

Table 2

Variant of the system	Quality indices					Result
	k_1	k_2	k_3	k_4	k_5	
S_1	2.5	4.2	2.5	3.7	4.2	-
S_2	7.2	6.3	7.2	5.2	4.7	-
S_3	3.1	4.2	3.1	4.3	4.4	-
S_4	4.2	5.3	4.2	4.8	4.3	-
S_5	2.4	3.6	2.5	3.6	4.0	+

On the base of the analytical procedure, described above, the program, enabling to perform automatically the process of the perspective systems search in the area of possible solutions, is developed.

Fig. 1 contains the result of the program operation.

System	k1	k2	k3	k4	k5	k6	k7	Result
S1	3,4	2,8	4,2	5,4	3,8	4,6	6,3	+
S2	3,5	3,2	4,4	5,7	4,2	4,9	6,4	-
S3	3,7	2,9	4,6	5,6	4,1	4,8	6,5	-
S4	3,7	3,0	4,8	5,9	4,0	4,7	6,6	-
S5	3,3	2,9	4,1	5,6	3,8	4,7	6,3	+
S6	3,6	3,0	4,5	5,8	4,3	5,0	6,5	-

Fig. 1. Result of the operation of the program of perspective systems search

It is seen in Fig. 1 that the systems S^1 and S^5 are vector incomparable, that is why, they are referred to the area of the perspective systems (marked by the sign "+").

In case, when several systems are perspective, i. e., for them the «Result» is characterized by the sign «+» (Fig. 1), the transition is made to the second stage of optimization, when for the termination of the search process the weighted sum of the quality indices is used, this sum is determined by the additive function. Value of the vector K is assumed to be better, if this value corresponds to the minimal value of the sum:

$$K_p = \sum_{i=1}^{m} c_i \cdot k_i \Rightarrow \min , \qquad (7)$$

where $\sum_{i=1}^{m} c_i = 1$, $c_i \ \left(i = \overline{1,m}\right)$ – certain weight coefficients, determined by Delhi procedure.

Final result, obtained in such a way is more valid, as compared with the application of the additive function for the convolution of the totality of the specific quality indices to the resulting index without the preliminary search of the perspective systems, because the additive function is used only for the preliminary narrowed area of search (the revealed set of the perspective variants of system realization).

Conclusions. Original analytical procedure of multicriterial selection of the perspective variants of the system from the set of the admissible variants is suggested in the paper. On the base of the procedure the program, that can be used for the analysis of different variants of technological equipment of the enterprise renovation in order to find optimal solution, is developed. The procedure can be applied for various systems, presented by numerous efficiency indices.

Further studies on the subject will be carried out for searching the analytical type of the functional (2), that decreases or excludes the possibility of compensation the drawback of one quality index at the expense of another.

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