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METHOD OF CHOICE OF A TECHNICAL SYSTEM FOR PROJECT IMPLEMENTATION BASING UPON SITUATIONAL EFFICIENCY CRITERION

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Abstract

This work demonstrates correlation between technical system efficiency criterion and complex system efficiency criterion in which the said technical system operates. Furthermore, the said correlation may be expressed by means of a set of separate particular criteria of a complex system. Methodology of choosing the technical system for project implementation within the framework of project-oriented organization of a complex sociotechnical system is also proposed. The offered method provides for a basis algorithm for calculations of situational efficiency criterion for technical system supposed to be applied within the project. The criterion in question indicates the extent to which the technical system is suitable for implementing its objective under specific conditions arising at various stages of the project implementation.

Keywords: project management, project, technical system, sociotechnical system, situational efficiency criterion.

Introduction

Recently, researches aimed towards developing a general theory of efficiency are more and more common in a number of works ([1] through [6]). As shown by practical experience, this process is not spontaneous. Results, obtained in these works laid a substantial cornerstone for developing applicable methodologies in a number of directions, including operating efficiency for complex social and technical systems with rigid demands from such factors, as time (terms of implementation), resources (financial, at the first turn), and quality. Complicated interactions within such systems, in a number of cases, make it impossible to determine for sure efficiency criterion for a particular subsystem, both from the points of view of quantity and quality, which, consequently affects negatively precision of definitions and formulations and, finally, prevents most achieved results from practical application.

Such a situation leads to lack of confidence in analysis methodologies available by now and classifying them as subjective and prejudiced evaluation of project results, manufacturing activities or entire organization in general. At the same time, it is notable to mention that most technical systems' efficiency is described well enough from the methodological point of view. As an example, such collective works as [1] and [2] may be mentioned. Situation is slightly heavier with procedural description of mathematical models dealing with social systems' efficiency. Here works enlisted as [5] and [6] should be noted containing general evaluation of the most essential criteria affecting objectivity.

As the analysis below shows, as well, as that of a number of other works, neither of them offers any solution in technical system efficiency determination within the framework of project management for sociotechnical systems' operation.

Demand for such determination increases to vital in cases when a technical system is an integral part of a project being implemented. Replacement of such a technical system or a few of other systems involved into the project implementation leads, normally, to substantial expenditures, or, in a number of cases to, so to say, "reformatting" of the relevant project.

At the initial stage of considering such a problem, complex of social system's purpose-oriented actions is an apparent object or researching, whereas its apparent subject are regularities connecting the efficiency of such a project with the technical system functional quality, conditions and techniques of its application to the processes in question.

The above statement provides certain grounds to suppose, that it is a social component which is a cornerstone of the efficiency determination defining the value of the efficiency criterion for a technical system being the technical aid of achieving the aim.

Striving advance of projecting technologies demands from scientists to accelerate their work in developing applicable methods for determining efficiency in operation of entire complexes involved into projects as well, as those of validation of choice of either technical system providing both quantitative and quality evaluation of result of technical system application with the project under consideration. The statement of this problem found its reflection, though in a very rough outline, in works indexed below as [8] and [9].

It goes without saying, that changes in a project implementation conditions being, at the first glance, not essential or not affecting the outcome may cause radical alterations in parameters of intended technical system or, in some cases, require new vision of ways of either system application. Researches being carried on show obvious impossibility to apply cut-and-dried solutions of available technical systems efficiency determination techniques within the framework of project management approach to complex sociotechnical systems' activity.

In view of the above, the **objective of proposed research** consists in *developing applicable method enabling to choose technical system for a project implementation basing upon situational efficiency criterion.*

Some illustrative examples of sociotechnical systems to form certain definitions base and to give a clear idea of forthcoming reasoning and their project-oriented directions dealing with their life cycle processes management are stated below.

As the first example a shipping company operating a small number of ships involved in heavyweight and oversize service. Each shipment with such company is unique in essence and is dealt with in a form of a project involving a complex technical system represented by a ship along with direct participants and crew. Technical condition, reliability and a great number of other, not less significant, factors affect successful outcome of the project. Furthermore, as mentioned before, after the project starts, changing or replacement of technical system for such project would mean total failure of the project.

A construction corporation involved in building of large objects with construction sites being remote from raw materials source may be proposed as the second example. The situation with such corporation requires involvement of highly specialized technical aids, such as cranes of high capacity, drilling machinery, mobile plants producing concrete, etc. each and any of the above systems requires, as in the former case, to consider not only key criteria, but also faultless efficiency evaluation for particular technical units, especially if there are any options available.

As it is illustrated in the two above examples, complex sociotechnical systems (CSTS) activity processes are directly connected with technical systems (TS) operation as base-forming components. Consequently, the projects implementation efficiency within such activities depends on efficient application of technical systems.

1. Technical System Choosing Model

There are two approaches to technical system choice for a project implementation. The first approach provides selection of technical system from a number of those available within a sociotechnical system with efficiency criterion being the highest for a particular project. In the second case, technical system probable application originating from external medium should be analyzed taking into account both project efficiency and general sociotechnical system operation efficiency in total. Such an approach requires efficiency quantitative evaluation for a number of probable technical system application options.

Fig. 1 below demonstrates the technical system choosing model for a project implementation within the framework of project-oriented organization of a complex sociotechnical system.

Sociotechnical system plays a part of a projects generator in the above model. Necessity in organizational and technical activities rises from continuously arising demands of external medium and may be implemented within a framework of a certain project. As it was previously mentioned, projects highly sensitive to technical system, or systems, are concerned. Implementation of such projects requires complex technical systems. Under such circumstances, the system should be evaluated as complying with formal characteristics meeting a number of parameters provided for in the project. If there is a lack of suitable technical system the choice should be made from those proposed by external medium.

After a group of technical systems is compiled as meeting formal features dictated by project implementation conditions, criteria characterizing technical system operation in various possible situations, i.e. situational fields, should be indentified. After this the efficiency criterion should be calculated, being, in its turn, predictable potential efficiency criterion, or situational efficiency criterion. The solution of technical system should be adopted basing upon the obtained results. Referring to statistical data of adopted solutions, it is notable that about 20% fall upon technical systems which had never been involved into specific types of projects. In this view, substantial increase of risks should be noted impairing the efficiency characteristics.

Furthermore, even with high values of predictable efficiency characteristics, it is a fact that the quality of complex technical system displays in full only in the course of action, i.e. according to prescribed purposes. Therefore, the most impartial system quality evaluation may only be obtained basing upon its purposed application.

The further stage represents the project implementation. After the project is implemented, two efficiency criteria are calculated – project management efficiency and that of technical system activity within the project framework. All the data relevant to obtained results should be stored in sociotechnical system database and should be used as an accumulated experience for application in other projects.

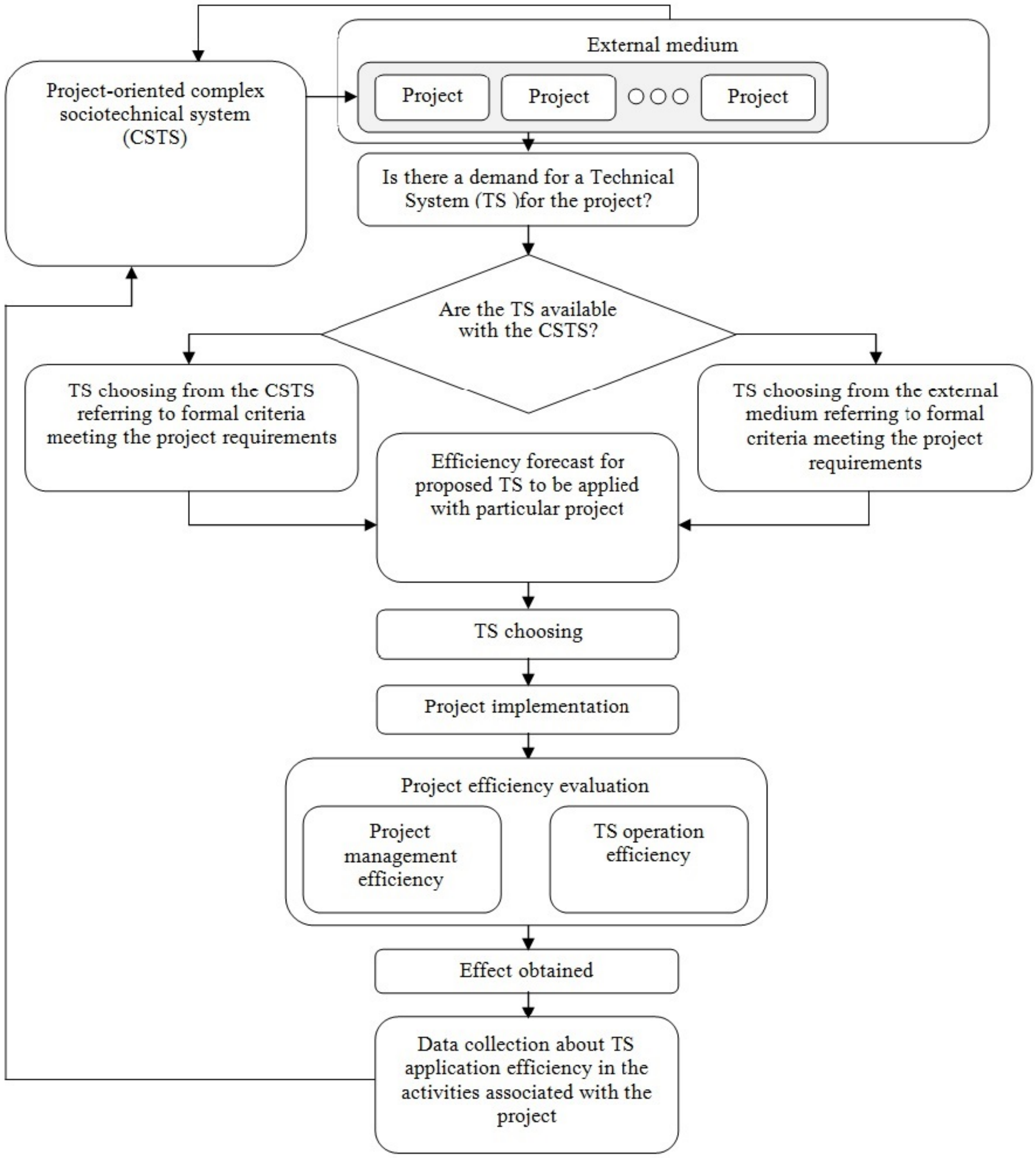

Figure 1 Model of choosing technical system to implement a project within the framework of complex sociotechnical system project oriented organization

As it is shown in the above model, the efficiency is estimated in two stages with the predictable efficiency criterion calculated at the first stage and the resulting efficiency criterion at the second stage. Furthermore, the calculations at the second stage are made simultaneously in two directions. As a result of the first direction, we should obtain project management efficiency characteristic and as a result of the second direction technical system application efficiency for the particular project. The calculation procedure for the technical system application efficiency for the specific project is described in the Section 2, below.

2. Technical System Application Efficiency Calculation Procedure

Here a multi-step definition method is applied for additive efficiency function based on vector criterion [2]. Nowadays two methods are the most common, the composite scaling method and half division method. Basing on the principle put into the composite scaling method, the proposed procedure is demonstrated for choosing technical system for project implementation applying the situational efficiency characteristic.

Supposing, that oversized units shipment project implementation initiated by a certain sociotechnical system requires a technical system with application criteria being money and time, i.e. transportation costs and terms within which the shipment in question may be performed. The project determines limits for the said criteria as US$ 125.000 ($K_1^{TR} \le 125$) as the total funds assigned for shipment implementation within terms not exceeding 45 days ($K_2^{TR} \le 45$). In view of the both criteria it is obvious that they are subject to minimization, i.e. a technical system with aggregated criteria character is minimum is the most favourable.

Researches have been carried on for a situation, when own technical system with suitable particulars is unavailable with sociotechnical system, and three options were represented with parameters, as below:

$$K_1 = \begin{pmatrix} 105 & 110 & 117 & 122 \\ 100 & 110 & 120 & 125 \\ 100 & 105 & 110 & 120 \end{pmatrix} \qquad K_2 = \begin{pmatrix} 42 & 40 & 39 & 38 \\ 45 & 42 & 40 & 39 \\ 43 & 42 & 41 & 40 \end{pmatrix}$$

where:

K_1 –the first criterion data matrix;

K_2 – the second criterion data matrix;

K_j^{is} – data vector for j-th criterion of i-th technical system for s-th situaton.

The project conditions require to identify a technical system with the highest possible potential efficiency characteristic, i.e. the most suitable option.

Since the proposed criteria are not measured in the same units, they should be brought previously to a unified dimensionless scale. The formula below is applicable for their transformation:

$$\overline{K} = \frac{K}{K^{TR}}$$

where:

K – sociotechnical system criterion;

K^{TR} –external medium demands to the criterion.

Now proceeding with calculations:

$$\overline{K_1} = \begin{pmatrix} 0{,}84 & 0{,}88 & 0{,}94 & 0{,}98 \\ 0{,}80 & 0{,}88 & 0{,}96 & 1{,}00 \\ 0{,}80 & 0{,}84 & 0{,}88 & 0{,}96 \end{pmatrix}, \qquad \overline{K_2} = \begin{pmatrix} 0{,}93 & 0{,}89 & 0{,}87 & 0{,}84 \\ 1{,}00 & 0{,}93 & 0{,}89 & 0{,}87 \\ 0{,}96 & 0{,}93 & 0{,}89 & 0{,}87 \end{pmatrix}.$$

Next stage supposes finding average of two criteria for each technical system and graphing the criterion flow characteristic depending on simulated system:

$$\overline{K^i} = \frac{\sum_{j=1}^{n} K_j^i}{n}$$

As a result, numerical values are obtained, as follows:

$$\overline{K} = \begin{pmatrix} 0,8866 & 0,8844 & 0,9013 & 0,8657 \\ 0,8800 & 0,9146 & 0,8688 & 0,8555 \\ 0,8777 & 0,8835 & 0,8853 & 0,8800 \end{pmatrix}$$

Functions graph are, as follows:

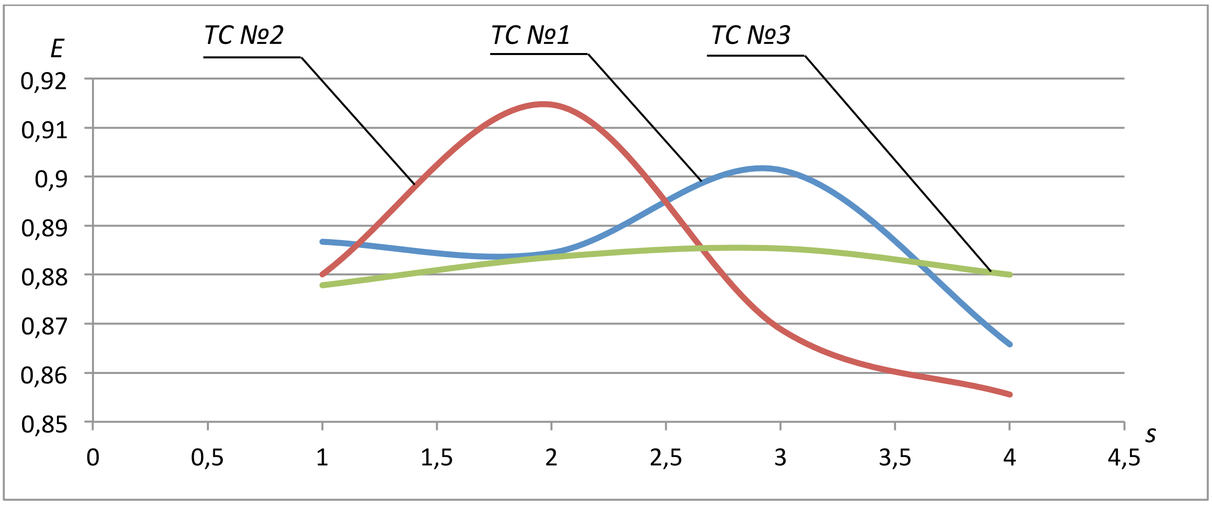

Figure 2 Average standardized criteria for each technical system for four consistently simulated situations

Since the criteria in question play different parts, weight factors should be applied to evaluate their influence. In the most of cases weight factors are determined by means of expertise applying certain algorithms of comparing the factors with each other [7]. Wight factors for system components may be obtained by means of several calculation techniques. Most of methods being currently applicable are based on interviewing experts with further mathematical processing of their judgments. Direct alignment method has been chosen as applicable for this particular case, i.e. factors for each criterion may be placed randomly, provided, as below:

$$\sum_{i=1}^{n} a_i = 1,$$

where:

a_i being a weight factor for the i-th criterion.

Weight factors for each of the criterion are, as below:

$$a_1 = 0,7$$

$$a_2 = 0,3$$

With reference to the above judgments, efficiency function is proposed to be calculated as alteration of its criteria for different simulated situations, i.e. its behavior in situational fields. For a problem with criteria subject to maximization:

$$E_i^s = \frac{\sum_{j=1}^{n} a_j K_j^{is}}{n\sum_{j=1}^{n} a_j}$$

For criteria subject to minimization:

$$E_i^s = \frac{\sum_{j=1}^{m} a_j \frac{1}{2}\left(\sum_{j=1}^{m} K_j^{is} - K_j^{is}\right)}{m\sum_{j=1}^{m} a_j}.$$

If there are criteria subject to both categories the two values should be summarized:

$$E_i^s = \frac{1}{2}\left(\frac{\sum_{j=1}^{n} a_{j\max} K_{j\max}^{is}}{n\sum_{j=1}^{n} a_{j\max}} + \frac{\sum_{j=1}^{m} a_{j\min} \frac{1}{2}\left(\sum_{j=1}^{m} K_{j\min}^{is} - K_{j\min}^{is}\right)}{m\sum_{j=1}^{m} a_{j\min}}\right)$$

where:
E_i^s – value of efficiency function for i-th technical system in the s-th situation.

Calculations carried on under proposed technical systems enable to produce following results:

$$E = \begin{pmatrix} 0{,}8393 & 0{,}8899 & 0{,}8991 & 0{,}9127 \\ 0{,}8573 & 0{,}8776 & 0{,}9040 & 0{,}9109 \\ 0{,}8500 & 0{,}8949 & 0{,}9103 & 0{,}9116 \end{pmatrix} \qquad \sum E = \begin{pmatrix} 0{,}885233 \\ 0{,}887467 \\ 0{,}8917 \end{pmatrix}$$

The obtained efficiency values for individual situations allow to interpolate all the rest values to construct a graph of efficiency for proposed technical systems:

$$E_i = f_i(s)$$

The proposed graph shows that in the most cases, or situations, the efficiency characteristic prevails with the third technical system. However, as described in details in [10], the system resting in a particular situation or situational field is stochastic value. In this view, this value should be taken into utmost consideration at the stage of summarizing situational efficiency characteristic.

$$\sum_s p_s E_i^s \to \max$$

where:
p_s – chance that the s-th situation occurs.

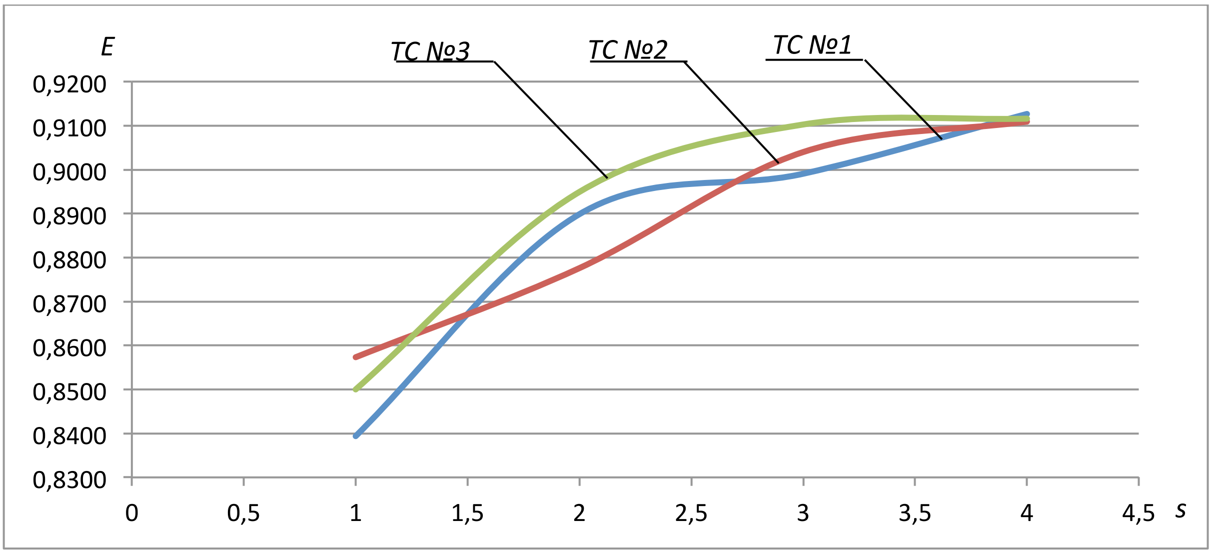

Figure 3 Graph of efficiency function for each of the three technical systems for four consistently simulated situations.

Thus, the solution is adopted on the basis of forecast of efficiency characteristic depending on sociotechnical system probable staying within different situational fields.

Supposing, that the probability that the system stays within each of described situation is equal, the graph represented as Figure 3 will construe the final representation for situational efficiency of proposed technical systems. Thus, the results of above calculations enable to conclude, that the third technical system TS 3 is the most preferable option.

The passage below describes the procedure of technical system choice basing upon situational efficiency characteristic. In the course of technical system analysis to choose the most efficient one for implementation of a particular project at the primary stage criteria should be identified which describe quantitative evaluation of specific behavior for each technical system. The obtained criteria should be classified into two groups with the first group including criteria which efficiency is expressed in their minimization, whereas the second group including criteria, efficiency of which is expressed in their maximization. Vectors of efficiency characteristic should be determined for each group separately for separately identified situations according to proposed aggregation methodology. After this the efficiency function should be formatted and graph constructed. Situational efficiency characteristic should be calculated according to probability of each event's occurrence. the solution should be adopted basing on the obtained results.

Conclusions

As it is described in this work, the technical system efficiency is directly related with complex system efficiency, within which the former technical system operates, and may be expressed in the form of a set of its particular characteristics, such as criteria describing specific aspects of the system's activity and characterizing, both directly and implicitly, quality of achieving its targeted function. Such an approach to the efficiency evaluation applying identified criteria in view of their interaction may be used for preliminary analysis end evaluation of probable acceptable optional technical systems.

Since the efficiency, similar to any other feature of a system possesses a certain intensity of its indications, the method enabling to obtain situational efficiency characteristic is proposed in this work as a measure of intensity display under various circumstances / situations.

Situational efficiency characteristic may form one of factors contributing to adopting a particular decision to apply a certain technical system in a particular project and indicate extent of its fitness to meet a certain targeted function under actual conditions of the project implementation.

Methodology representing graphical interpretation of efficiency determination for a complex technical system under conditions of project activities referring to its criteria complex may be developed on the basis of above efficiency function graph.

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METODA WYBORU SYSTEMU TECHNICZNEGO DO REALIZACJI PROJEKTU W OPARCIU O SYTUACYJNE KRYTERIUM EFEKTYWNOŚCI

Streszczenie

W pracy omówiono korelację między kryterium efektywności systemu technicznego i kryterium efektywności złożonego systemu, w którym wspomniany układ techniczny działa. Ponadto, wspomniany związek może być wyrażony za pomocą szeregu odrębnie określonych kryteriów złożonego systemu. W artykule zaproponowanio także metodologię wyboru systemu technicznego dla realizacji projektu w ramach projektowo zorientowanej organizacji, złożonego systemu socjotechnicznego. Sugerowana metoda przedstawia algorytm będący podstawą do obliczenia sytuacyjnego kryterium efektywności systemu technicznego, który miałby być stosowany w ramach projektu. Kryterium, o którym mowa, wskazuje w jakim stopniu system techniczny jest odpowiedni do realizacji swojego celu w określonych warunkach pojawiających się na różnych etapach realizacji projektu.

Keywords: zarządzanie projektem, projekt, system techniczny, system socjotechniczny, sytuacyjne kryterium efektywności.

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