ON THE SUBJECT OF ASSESSING THE COMPOSITION OF IT SERVICES ENTERPRISE INFORMATION SYSTEMS VIA FUZZY SETS THEORY

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One of the factors for the success of any enterprise on the modern market of production and services makes the targeted use of mathematical and software computers, complexes and computer networks as part of information systems (IS) of enterprises, as the basic principles of the Digital Economy of the Russian Federation program states. This assumption is based on the fact that "the effective development of markets and industries (fields of activity) in the digital economy is possible only if there are developed platforms, technologies, institutional and infrastructural environments" [1]. Currently, the growing dependence of business processes on the quality and reliability of the supporting information systems requires a systematic approach to automation, which is closely linked to the issues of setting up both the enterprise IT architecture and the business architecture as a whole. That allows us to consider the transition to service-oriented architecture (SOA). Such a method of building up an IP complex is applied, then the support of the necessary business processes is carried out by various combinations of IT services, which under this circumstance, in its turn, leads to the need of creating diverse methods to evaluate and choose IT services (hereinafter, services) in conditions of SOA [2].

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Studies have shown that the process of determining the necessary selection of services is reduced to solving a multicriteria task of forming the composition of services according to specified indicators, depending on their functional purpose [3]. In addition, usually the process of forming such a composition adds a stage of the human-machine procedure for specifying preferences, which at the same time would give sufficient flexibility in changing preferences when choosing services and display understandable information about the causes and consequences of establishing certain preferences, the so-called select [4].

At the same time, the choice of one or another composition of services necessary for the functioning of an IP is significantly affected by various kinds of uncertainties that may be caused by:

1. Lack of information, with occasionally inaccuracy about alternative options for technical, economic and other reasons.
2. Impossibility of conducting a large amount of research and evaluating the characteristics of IP, which does not allow to establish a probabilistic model adequate to the chosen situation.
3. Various degree of expert confidence in assessing certain parameters of the considered information systems, etc.

Such uncertainties significantly reduce the possibility of using deterministic or probabilistic models. In this case, to evaluate the quantitative and qualitative characteristics of alternatives, it is proposed to use the mathematical apparatus of fuzzy sets when choosing services. With the proposed method of solving the above problem, the option of using linguistic scales based on trapezoidal fuzzy numbers can provide advantages as follows:

1. Ability to take into account unclear requirements for the maintenance of business processes.
2. The use of fuzzy sets allows decision makers and experts to conduct a flexible assessment of quantitative characteristics in case of uncertainty considering errors or inaccuracies in the assessment process.
3. The ability to reduce qualitative expert assessments to quantitative (fuzzy) making it possible to simultaneously take into account quantitative and qualitative assessments in a single model.
4. The use of a fuzzy linguistic approach, when the assessment is conducted in linguistic terms, for example, "low quality", "acceptable quality", "high quality", etc., which are generally accepted and more understandable by the decision maker

The basis for modeling the task of choosing IT services in the framework of the SOA for IP is proposed to consider building a tuple in the form of:

$$<X, Z, Y, G, P, R, W, K>, \quad (1)$$

where $X = \{x_i\}, i = \overline{1,n}$, – set of business processes selected in the framework of an enterprise strategy for automation using IP;

$Z = \{z_k\}, k = \overline{1,s}$, - set of software tools in the software (software) of the selected IP, considered in the selection process as alternatives that implement the required functionality to automate and support business processes X;

$Y = \{y_j\}, j = \overline{1,m}$, - set of services provided by various information systems Z, according to the service-oriented approach;

G – set of criteria for assessing the quality of alternatives considered in the problem of choosing services;

P – fuzzy estimates of IT services Y on a variety of criteria G;

R - set of rules defining the principles of comparing and ranking assessments of services Y based on their assessments P;

W – restrictions reflecting the goals and preferences of decision makers in the task of automating business processes X;

K – optimal decision criterion, which determines the rules for choosing services based on their P estimates, subject to constraints W.

The formal formulation of the problem of choosing services under SOA conditions consists in finding such a set of IT services $Y^* = \{y_{j1}, y_{j2}, \ldots, y_{jm}\}$, which will provide the necessary support for business processes

$X = \{x_i\}, i = \overline{1,n}$ in accordance with the rules of comparison and selection of alternatives R taking into account the determining optimality criterion K.

In this case, the problem of modeling the choice of IT services in the formulation (1) using the theory of fuzzy sets can be formulated as follows - based on fuzzy requirements for the maintenance of business processes X and fuzzy information about the parameters of IT services Y it is necessary to develop fuzzy models for assessing the quality of IT services based on the accepted criteria structure G and forming a model for choosing IT services based on the optimality criterion K.

When solving the problem of assessing the quality of services as an integral part of IP, quality should be understood as the completeness of properties and characteristics that provide the ability to meet the stated or implied needs of the enterprise (business functions).

Using the the structure of criteria for assessing the quality of information systems in accordance with the standard "GOST R ISO / IEC 9126-93" is proposed [5]. This is where the integrated assessment is based on six quality factors: functionality, reliability, usability, efficiency, maintainability, portability (or mobility). Each of the six factors is defined in more detail by using separate criteria and subcriteria that form the hierarchical structure of the quality criteria. At the lowest level of the given criteria structure there are metrics by which the subcriteria of the lowest level are measured..

To calculate the integral value of the quality criterion based on the values, it is proposed to use the hierarchy analysis method proposed by T. Saati, which allows you to calculate the evaluation of the higher criterion $g^j = \sum_{l=1}^{l_j} g_l^j p_l^j$, as convolution of subordinate subcriteria g_l^j, $l=\{1, 2, \ldots l_j\}$ and their weights p_l^j, calculated by pairwise comparison of the significance (weight) of each of the subcriteria [6].

At the same time, the proposed fuzzy model of quality assessment does not take into account the fact that experts may not be sure which of the fuzzy values of the linguistic scale can accept estimates of alternatives according to individual criteria, which we define as confidence factors. In this case, as factors of confidence, we can consider the characteristics of utility, significance, availability, performance, integration with other applications, fault tolerance, etc.

The most important feature of the problem under consideration is that if there is a certainty factor g, for each alternative $\mathbf{z_k}$ there are several ratings for this criterion $u^t(z_k, s_t), t = \{1, 2, \ldots t_g\}$, under different conditions of the external environment or various external factors – s_t. Thus, the choice of an alternative does not lead to an unambiguous result in the process of evaluating.

To evaluate alternatives based on confidence factor the method of calculating the generalized value of the alternative estimate z_k on the confidence factor g is applied:

$$u^{gen}(z_k) = \alpha \sum_{t=1}^{t_g} \hat{p}_t^{\,k} u^t(z_k, s_t) + (1-\alpha) \min_t \{u^t(z_k, s_t)\}, \quad (2)$$

where,

$\alpha \in [0;1]$ – coefficient reflecting the level of pessimism-optimism of the decision maker regarding the development of the situation. When $\alpha = 0$ (pessimistic variant) the external environment behaves in an antagonistic manner, and the criterion takes the minimum possible value in the rating scale; case $\alpha = 1$ (optimistic variant) the point estimate of the generalized criterion is made on the basis of the Bayes optimality criterion; when $\alpha \in (0;1)$ estimated intermediate between fully optimistic and completely pessimistic variant;

$\min_t \{u^t(z_k, s_t)\}$ – - the minimum value in the rating scale by criterion g;

$u^t(z_k, s_t)$ – possible values of the fuzzy scale of assessment of the confidence factor g, depending on the state of the external environment s_t,

$\hat{p}_t^{\,k}$ – point a priori estimates of the "probability" that the evaluation of an alternative z_k will take value $u^t(z_k, s_t)$ on a criterion rating scale g.

To calculate the coefficient $\hat{p}_t^{\,k}$ the method of constructing the weight coefficients of Fishburn from the theory of utility is used. To reach this, on the basis of expert estimates, it is

necessary to streamline the values of the criterion assessment scale $\boldsymbol{g}$ according to which of the values is more likely when each alternative is evaluated $\boldsymbol{z_k}$. Point estimates of prior probabilities are defined as follows:

$$\widehat{\boldsymbol{p}}_{\boldsymbol{t}}^{\,\boldsymbol{k}} = \frac{\boldsymbol{r_t^k}}{\sum_{\boldsymbol{t=1}}^{\boldsymbol{t_g}} \boldsymbol{r_t^k}}\,, \tag{3}$$

where

$$\boldsymbol{r_{t-1}^k} = \begin{cases} \boldsymbol{r_t^k}\,, & \boldsymbol{i}\text{f } \boldsymbol{s_{t-1}} \approx \boldsymbol{s_t} \\ \boldsymbol{r_t^k + 1}, & \boldsymbol{i}\text{f } \boldsymbol{s_{t-1}} \succ \boldsymbol{s_t} \end{cases}, \boldsymbol{r_{t_g} = 1, t = t_g, (t_g - 1), \ldots, 2}. \tag{4}$$

Attitude $\boldsymbol{s_{t-1} \succ s_t}$ means that, according to experts, the probability of an event $\boldsymbol{s_{t-1}}$ higher $\boldsymbol{s_t}$. Attitude $\boldsymbol{s_{t-1} \approx s_t}$ means that, according to experts, events $\boldsymbol{s_{t-1}}$ and $\boldsymbol{s_t}$ equally likely.

Considering the optimality criterion $\boldsymbol{K}$ for building up a model of IT services, it is assume that when making a decision on the choice of services, the decision maker is guided by the cost parameters of the presented set of services. In this case, as an option, for solving the problem of estimating the total cost of IT services, it is advisable to use the total cost of ownership model using fuzzy estimates, since it most fully describes the cost structure associated with the acquisition and operation of IT services in the enterprise [7]. In this case, as an option, for solving the problem of estimating the total cost of IT services, it is advisable to use the total cost of ownership model using fuzzy estimates, since it most fully describes the cost structure associated with the acquisition and operation of IT services in the enterprise:

$$\boldsymbol{TotCost(y_j) = STCO(z_k) + \sum_{y_j \in Y^k} TCO(y_j)} \tag{5}$$

where,

$\boldsymbol{STCO(z_k)}$ – total cost of ownership of basic IP $\boldsymbol{z_k}$, which includes IT services;

$\boldsymbol{TCO(y_j)}$ – incremental costs related to IT service $\boldsymbol{y_j}$.

Then, an algorithm based on the calculation of the extended Lee-Wong parameter is used to compare and rank fuzzy trapezoidal estimates of the total costs of IT services. When determining the Lee-Wong parameter for a set of fuzzy numbers $\boldsymbol{A_1, A_2, \ldots, A_n}$ common carrier is determined $\boldsymbol{sup(A)}$, so that $\forall \boldsymbol{A_i}: \boldsymbol{supp(A_i) \subseteq supp\,(A) = \{\min_{i=1\div n}(a_{1i})\,;\, \max_{i=1\div n}(a_{4i})\}}$. The base is defined on this carrier - fuzzy number $\boldsymbol{V}$, with continuous convex membership function $\boldsymbol{\mu_V(x)}$. Next for each $\boldsymbol{A_i}$ according to the formula (7) Lee-Wong parameter determined $\boldsymbol{LW(A_i > V)}$, based on which the ordering of fuzzy numbers:

$$\boldsymbol{LW(A_i > V)} = \frac{\int_{-\infty}^{+\infty} \int_{-\infty}^{y} \mu_{A_i}(x)\mu_V(y)\boldsymbol{dxdy}}{\int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \mu_{A_i}(x)\mu_V(y)\boldsymbol{dxdy}} \tag{6}$$

Choosing a fuzzy number $\boldsymbol{V}$ when calculating the Li-Wong parameter suggests various scenarios for the behavior of the external environment depending on a priori awareness of decision makers.

In order to take into account a priori awareness of decision makers about the possible behavior of the external environment during a fuzzy estimate of costs, the generalized Lee-Wong criterion should be applied [8]

$$\boldsymbol{LW^{gen}(A_i) = \alpha LW(A_i > V_{opt}) + (1 - \alpha) LW(A_i > V_{pes})}, \tag{7}$$

where,

$\boldsymbol{LW(A_i > V_{opt})}$ and $\boldsymbol{LW(A_i > V_{pes})}$ Lee-Wong coefficients for optimistic and pessimistic estimates of fuzzy numbers $\boldsymbol{A_i}$, respectively;

$\boldsymbol{\alpha}$ – coefficient reflecting the level of pessimism-optimism of the decision maker regarding the development of the situation. When $\boldsymbol{\alpha = 0}$ estimated pessimistic option, in case $\boldsymbol{\alpha = 1}$ the optimistic option is estimated, and in the case of $\boldsymbol{\alpha \in (0; 1)}$ estimated intermediate between fully optimistic and completely pessimistic options.

The presented models for assessing the quality and total costs of IT services make it possible to specify the task of forming the composition of services as follows.

As to statement (1) it is necessary to determine:

- a set of business processes $\boldsymbol{X} = \{\boldsymbol{x_i}\}, \boldsymbol{i} = \overline{\boldsymbol{1,n}}$, which should be automated as part of the implementation of the IT strategy of the enterprise;

- a set of information systems $\boldsymbol{Z} = \{\boldsymbol{z_k}\}, \boldsymbol{k} = \overline{\boldsymbol{1,s}}$, considered in the selection process;

- a set of IT services $\boldsymbol{Y} = \{\boldsymbol{y_j}\}, \boldsymbol{j} = \overline{\boldsymbol{1,m}}$, provided by information systems $\boldsymbol{Z}$;

- a set of fuzzy requirements for the quality of the implementation of business processes $\boldsymbol{W} = \{\boldsymbol{w_i}\}, \boldsymbol{i} = \overline{\boldsymbol{1,n}}$.

As a result, it is necessary to form such a set of IT services $\boldsymbol{Y^*}$ and information systems $\boldsymbol{Z^*}$, within which these IT services will be implemented so as to provide the necessary level of quality support for all business processes $\boldsymbol{X}$, and also, that this set should have a minimum estimate of the total cost of ownership of the selected IT services. It should be noted that the formulation of the problem of choosing IT services leads to the construction of the display of many business processes $\boldsymbol{X = \{x_i\}}$ to a variety of information systems under consideration $\boldsymbol{Z = \{z_k\}}$.

Thus, considering the uncertainties arising in the process of evaluating and selecting IT services for the use of the mathematical apparatus of fuzzy numbers makes it possible to:

Build up a fuzzy model for assessing the quality of IT services, taking into account the preferences and a priori awareness of the decision maker of the possible behavior of the external environment, when assessing the factors of confidence. The model is per standard "GOST R ISO / IEC 9126-93" alongside with the hierarchy analysis method.

Develop a fuzzy model for estimating the total cost of IT services, taking into account the incremental costs of acquiring individual services. The use of this model in conjunction with the developed algorithm for comparing and ranking fuzzy numbers allows for a more flexible and accurate selection of IT services with minimal total cost, considering decision makers' preferences.

Create a model for choosing IT services in terms of a service-oriented architecture, which, based on fuzzy assessments of the quality of IT services and the total costs of their acquisition and operation, allows you to define a set of IT services that meets the required quality levels of business process support with minimum total cost estimate.

An example of the practical implementation of the research can serve as measures for the selection and justification of IT services in the construction of the IP complex a number of logistics companies. This process is based on a methodology consisting of the steps as follows:

Stage 1 – formation of a list of alternatives to the task of choosing IT services and determining the structure of criteria for assessing the quality of IT services.

Stage 2 – fuzzy assessment of the integral quality provided by IT service providers. A fuzzy assessment is made by an expert method based on the linguistic scale.

Stage 3 – definition of cost items and the calculation of the total cost of IT services, according to (5).

Stage 4 – set of IT services that meets the required levels of business process support with a minimum estimate of total costs.

Thus, the use of the considered models and tools allows to create a set of IT services meeting the required levels of quality support for business processes with minimum estimate of total costs of those IT services for various cost items (purchase of equipment, software licenses, cost of software development, implementation and integration of software, staff training, updating and maintenance of equipment and its software versions, training new employees, etc.). The result is presented in the form of software developed for practical use for computers, complexes and as well as computer networks used by the transport logistics system.

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