The main purpose of modern information systems (IS) is to support the procedures of controlling many business processes (BP) of an enterprise. At the same time, due to a weak formalization of BP, processes of development, reengineering of various service-oriented IS and IT services are a complex problem.

To address this problem, the task to improve the method for choosing IT services that meet an assigned set of functional and non-functional limitations was stated. The specific features of the original method for choosing IT services were analyzed, its main shortcomings were identified. The model of the BP precedent was modified to establish the relationship between descriptions of the precedent, functional requirements, and the used IT services. The method for selecting IT services for the IS was improved by adding the functions of requirements analysis and searching for descriptions of IT services that partially meet the stated functional requirements. In the method, the adaptive linear associator of the mADALIN neuron was used to quantify the degree of match of the functional requirement and the description of the function of the IT service. These proposals were the basis for the improved method for selecting the IT service that best fits the set of constraints that are formed.

Based on the result of the conducted research, an experimental test of the improved method for selecting an IT service to solve the problem of automation of the activities of sale force of the electronic policy OSAGO was carried out. The information technology implementing the original method for choosing IT services was compared to the improved method. It was shown that the improved method makes it possible to identify situations of a match of functional requirements of a customer and the descriptions of IT services. This makes it possible to select those IT services that match the functional requirements to a degree above the assigned minimum limit

Keywords: information technology, selection of services, functional requirement, precedent, adaptive linear associator

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IMPROVING A METHOD FOR SELECTING INFORMATION TECHNOLOGY SERVICES

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1. Introduction

The vast majority of modern information systems (IS) of control of business processes (BP) of an enterprise are based on the service-oriented architecture (SOA). The main advantage of the IS with the SOA is the weak connectivity of distributed replaceable IS elements (IT services) that interact with each other according to the standardized protocol. This and a number of other advantages enable the IS with the SOA to effectively automate flexible business processes (BP) of enterprises. Flexible BP here refer to the processes that can change in a relatively short time or, to some extent, have a large number of different execution scenarios. A detailed description of the benefits of the IS and the SOA-based IT for business automation is given, in particular, in paper [1].

However, the introduction and operation of the IS with SOA rather quickly revealed a large number of difficulties and challenges that greatly offset the benefits and reduce the overall efficiency of such systems. That is why publications that cover both the benefits, and the problems of the SOA began to appear almost immediately. The positive and negative experience of implementation and operation of the IS with SOA continues to be under study nowadays. In fact, scientific and applied research in the area of creation, implementation, and operation of the IS with SOA is at the stage of accumulating and generalizing the positive and negative experience of a wide variety of tasks.

One of these tasks is to select IT services that could best meet the requirements of users of the IS with SOA that arise from the operation of such a system. The difficulty of this task is primarily related to the fact that existing IT services of the operated IS are oriented to meeting the requirements that appear in the course of designing this IS. However, there is a problem of meeting the requirements of users of the IS with the SOA when new requirements arise in the form of requests to modify the operated IS with the SOA and its separate IT services. This problem is solved in the following way:

a) by minimizing the consumption of finance and time to modify and implement separate IS services that can best meet the requests for a change that are put forward;

b) by ensuring the most complete possible meeting by new or modified IT services the terms of agreements about the service levels that are made between developers and users of the IS with the SOA.

At the same time, there are no well-established common solutions to such a problem. Admittedly, current research

in this area tends to focus, as a rule, on the development, implementation, and operation of the IS with the SOA at specific enterprises. For example, paper [1] contains descriptions of recommendations on the SOA application based on the experience of the IBM corporation. Application of such recommendations to small and medium-sized enterprises requires special scientific and applied research into the adaptation of these recommendations to new conditions. That is why research in the area of solving the problems of choosing IT services for the IS of the management of BP of small and medium-sized enterprises should be considered relevant.

2. Literature review and problem statement

Current research in the area of design and operation of the IS with the SOA can be conventionally divided into two main areas. The first of these areas include the numerous attempts to generalize positive and negative experiences in the form of a list of recommendations. Examples of the studies of separate authors within this area include the papers that have already been mentioned [2, 3]. In paper [2], the focus is on highlighting the pros and cons of the SOA, conditions for starting the SOA-based projects, as well as revealing mistakes that are made in such projects. However, the recommendations in paper [2] are unnecessarily general in nature and do not take into consideration the specifics of separate enterprises and the IS. It is not possible to quantify the costs for the implementation of an SOA-based project on the recommendations given in paper [2]. The issues arising from the operation of the IS with the SOA almost were not tackled.

It is noted in research [3] that modern business is required to consider carefully the strategic plans for the development of its companies, to competently assess the architecture of a company and the BP flowing in it. It is also recognized that the actual positive effect and saving from the SOA implementation is a matter of prospects. In paper [3], the focus is on describing the reasons for the failures of the SOA-based projects. In addition, the requirements that lead to the success of SOA projects are highlighted in paper [3]. However, there are no specific recommendations and rules that allow formalization of the process of deciding on whether it is appropriate to choose the SOA as the IS architecture of an enterprise.

The studies in this area summarize the experience not only of separate researchers but also of large organizations. Examples of this generalization are papers [4, 5]. Research [4] generalizes the experience of solving the problem of selecting a provider of manageable IT services in IBM corporation. In [5], a similar experience is summarized from the perspective of an individual researcher. The essence of such papers boils down to publishing a set of recommendations, the implementation of which should help solve the problem of choice (for papers [4, 5] – selection of a provider of manageable IT services). However, such works initially contain a number of drawbacks. The maximum generalization of the recommendations cited in such studies should be considered the main drawback. At best, such recommendations can be seen as needs or conceptual models of technical and economic constraints of the problem of selection. A significant amount of research is required in order to move from them to formalized descriptions of the objective and limitation functions that enable automation of the solution of the selection problem. The standard [6], which contains the basic requirements for the IT services management system, has a similar drawback.

Another drawback, particularly in the recommendations in article [4] is their focus on the experience of a particular corporation. A significant amount of research is also required to move from these recommendations even to similar recommendations for smaller IT companies. That is why though the studies in this direction are of some scientific value, they can not be the objects to further analysis.

Another direction includes less common scientific research based on the fundamentals of the formal decision-making theory. A classic example of such research is found in article [7]. In particular, it considers the solution of such problems of selecting IT services as:

a) a problem of dynamic choice (in the process of system operation) of IT services to perform a specific role in the system;

b) a problem of identifying all IT services, meeting functional and non-functional requirements, on the set of available IT services;

c) a problem of choosing from a set of IT services, which are identical in functionality, a subset of IT services that satisfy the customer's preferences for the non-functional attributes of these services;

d) a problem of identifying a set of IT services that meet a specified set of functional and non-functional limitations;

e) a problem of deciding whether to use an IT service to meet the current need (based on non-functional features and composite context);

f) a problem of identifying all IT services that meet functional and non-functional requirements.

For the operated IS, the most relevant of these tasks is to decide whether to use an IT service to meet a current need (based on non-functional features and compositional context). The formal solution to this problem in paper [7] seems to be a combination of the following elements:

– a general and expandable model of non-functional features;

– the method of ranking IT services (based on the method of logical evaluation of preferences);

– a step-by-step reverse algorithm for selecting IT services in composition scenarios.

Another challenge that arises from the operation of the IS with the SOA is to determine a set of IT services that meet a set of functional and non-functional limitations. The request for a change, which can be functional, non-functional, or combined, is usually considered as a set for operated IS. This problem appears in the following situations:

a) an employee of an enterprise-developer of the IS with the SOA tries to detect reusable IT services that meet an assigned set of requirements in the maximum degree;

b) the IS with the SOA finally formulates a set of requirements in the course of the operation and tries to determine, which IT service or a software module in the immediate access best matches this set (the problem of the automatic composition of IT services);

c) a user of the IS with the SOA is independently looking for the IT service to solve a specific problem.

To solve this problem, the model of quality of IT services, which has the following features, was developed in paper [7]:

– ability to express both technical and business aspects of quality;

– taking into consideration the views of a programmer and an end-user.

Based on this model, a common approach to solving this problem was developed in paper [7].

However, the description of the solution to the problem of determining a set of IT services that meet a given set of functional and non-functional limitations, proposed in paper [7], has a number of shortcomings. Among these shortcomings, it is necessary to underline the assumption, formulated by the authors, according to which many functionally equivalent IT services were determined before the solution of this problem started. The practical experience of modifying and developing small and medium-sized IS of companies' management shows that this assumption is not true in most cases.

A similar drawback is inherent in a series of modern studies in this direction. Thus, article [8] outlines the option of solving the problem of the automated composition of web services taking into consideration user restrictions. While solving this problem [8], the procedure of selecting IT services, which would make it possible to form in an automated way a composition that meets the following conditions:

a) full functionality (including full performance);

b) optimal by non-functional criteria of service quality;

c) meeting the main limitations of the quality of services.

To carry out such a procedure, it is proposed in article [8] to use graph models of composition variants and the harmony search algorithm enabling selection of the IT services that are most suitable for these models. However, the need to meet the condition of full functionality makes the proposed solution impossible to apply in cases of modification of an existing IT service or creation of a new one.

Another drawback of most models and methods for solving different variants of the problem of choosing IT services is the lack of unification of the list of elements of a set of non-functional attributes describing the IT service. In addition, it was found that the importance of each non-functional attribute is subjective and varies in different contexts of the application of the same IT service. The complexity of solving this problem is increased due to dynamic changes in the course of interaction between the flows of the IT service in real-time. That is why it is proposed in article [9] to solve the problem of choosing IT services as a multi-critical decision-making problem in real-time. To solve this problem, article [9] proposed to use the formal Service Workflow Specification language and the hierarchy analysis process. However, this way of solving the problem of choosing IT services does not take into consideration the need for the chosen IT service to meet the functional requirements of a customer.

Modern research into the discussed above variants of the problem of the choice of IT services is mostly focused on finding the most appropriate methods and ways to solve this problem. Thus, paper [10] proposes the variant of solving the multi-critical problem of choosing the optimal IT service during their composition, which involves the use of:

– the methods of evolutionary computing to find local maxima in the estimation of the IT services;

– the methods for solving the clustering problem to form local sub-sets of descriptions of IT services to choose from;

– a distribution model that is formed based on the results of solving the problem of clustering locally optimal IT services.

This way of solving the choice problem makes it possible to find the IT services, optimal both by the criteria of functional quality and by the criteria of non-functional quality. However, the practical implementation of the solution to the choice problem proposed in paper [10] requires large computational costs. That is why it is very difficult to apply this option of a solution to operated small and medium-sized IS with the SOA.

At present, the knowledge-oriented approach, the application of which was explored in [11], is considered as one of the options for solving the problem of choosing IT services. In accordance with this approach, during the solution of the problem of the composition of IT services, they are chosen using the Formal Concept Analysis method. The source data for this method according to paper [11] are formal descriptions of functional and non-functional requirements. At the same time, in [11], the BPMN notation is supposed to be used for formal description of functional requirements. However, this approach does not take into consideration the possibility of changing the significance of separate non-functional requirements during the operation of IP with SOA. In addition, the exclusive use of the BPMN notation for formal description of functional requirements imposes additional restrictions on the application of the approach proposed in paper [11].

In this case, the use of the knowledge-oriented approaches to solving the problem of the composition of IT services and the related problem of the optimal choice of IT services should be regarded as promising from the practical point of view as well. Thus, research [12] contains the results of comparison of the knowledge-oriented solution to the problem of the composition of IT services based on the algorithm of distributed evaluation, which was developed by the authors, with the traditional solution of this problem. According to these results, the formation of compositions from selected IT services surpasses in quality the traditional solutions due to the effective use of knowledge [11, 12]. In accordance with this approach, the IT services during the solution of the problem of IT-service composition are chosen using the Formal Concept Analysis method. The source data for this method, according to [11], are formal descriptions of functional and non-functional requirements. At the same time, in research [12], it is proposed to use the BPMN notation for a formal description of functional requirements. However, this approach does not take into consideration the possibility of changing the significance of separate non-functional requirements during the operation of the IS with the SOA. In addition, the exclusive use of BPMN notation for formal description of functional requirements imposes additional restrictions on the application of the approach proposed in [12].

At the same time, the use of knowledge-oriented approaches to solving the problem of the composition of IT services and the related task of the optimal choice of IT services should be considered promising from the practical point of view as well. Thus, paper [13] contains the results of comparing the knowledge-oriented solution of the problem of the composition of IT services based on the algorithm of distributed evaluation with the traditional solution of this problem. According to these results, the formation of compositions from selected IT services surpasses in quality the traditional solutions due to the effective use of knowledge.

It is necessary to highlight modern research aimed at solving the problems of search, selection, and composition of services in a cloud environment. Thus, for example, article [14] proposed the new fuzzy methodology for selecting services in the cloud environment. This methodology takes into consideration product characteristics and functionality,

customer support and rating, safety parameters, and other factors. However, the solution proposed in [14] makes it possible to substantiate the choice only of a cloud platform as a whole rather than of separate services. Most of the research focuses on solving the problem of choosing the services in the cloud environment solely based on non-functional requirements and quality characteristics. Thus, in [15], the scheme of choosing cloud services, based on a multi-purpose model of task planning by their cost and calculation time, was proposed. A multi-critical model for selecting cloud services taking into consideration their quality indicators, the values of which are determined from different sources, was developed in study [16]. A similar problem, but for conventional corporate networks, was considered in research [17]. In general, it should be recognized that the problems of selecting services, explored in [15–17], are based on the assumption that the functional requirements of users of these services are met as fully as possible. The validity of this assumption in [15–17] is not verified.

Research into the problems of the search, selection, and composition of services for different options of online technologies continues today. Thus, in [18], it is proposed to use an improved version of the algorithm of optimization of colonies of flying ants to solve the problem of selecting services according to their quality indicators. A special algorithm of global optimization and dynamic redevelopment is proposed in [19] to solve the problem of choosing the optimal plan for performing a function on a set of services with different quality indicators. However, in paper [19], there is no analysis of completeness of performing the function by various services.

It should be expected that the use of the decentralized data-processing methods to solve the problems of search, selection, and composition of services will not produce the desired result. It is argued in paper [20] that using this method to solve the problem of choosing the function in the networks of The Internet of Things does not give a serious advantage over the method of centralized data processing. However, this statement needs to be verified for the cloud technologies, as well as for corporate networks of today's enterprises.

The results of analysis of publications in the field of solving the problem of choosing IT services make it possible to draw the following conclusions:

a) according to established ideas, the problem of selecting IT services is a generalization concept, which includes six options of this problem discussed above;

b) special attention is paid to the problem of choosing IT services in connection with solving a more complex problem of automation of making compositions of performed IT services;

c) at the formal level, all options of the choice problem are particular cases of the problem of multi-critical optimization, the solutions of which are Pareto-optimal;

d) at choosing IT services, an important role is played by both functional and non-functional requirements for selected services, as well as by possible changes to these requirements, either because of changes in the context of the IT service application or over time;

e) the use of traditional and Data Mining models and methods for choosing IT services leads to high computational costs, which is typical of complex IS;

f) the use of knowledge-oriented models and methods to solve the problems of choosing IT services is promising, but the relatively new and not fully researched line of research.

These findings determine the need for research aimed at improvement of the existing methods for solving such a choice problem as the problem of determining a set of IT services that meet an assigned set of functional and non-functional restrictions. At the same time, it is recommended that the focus should be made on the situation, in which an employee of an enterprise-developer of the IS with the SOA tries to detect IT services available for reuse. Such IT services are presented as precedents of automated business processes. The precedent describes the obtained experience in the form of data and knowledge, which ensures its subsequent processing with specialized IS. This situation is currently most typical of the IT companies, which develop and accompany small and medium-sized IS with the SOA under conditions of modeling business processes, partial or complete outsourcing. Such methods enable solving the problem of searching and selecting IT services in an automated way, taking into consideration the limited computing capabilities of these IT companies.

3. The aim and objectives of the study

The aim of this study is to improve the model of automated business processes and the method for choosing IT services that meet an assigned set of functional and non-functional limitations. As a result of the proposed improvement, the method should identify the IT services available to developers that would best meet functional and non-functional requests for changing the operated IS. This makes it possible to formalize the execution of works on analyzing requests for changes in functions and in separate IT services of the operated IS and localization of the IT services, the modification of which will make it possible to fulfill these requests.

To achieve the goal, the following tasks were set:

– to improve the model of the precedent of the automated business process by adding a description of the requirements for a functional task and descriptions of IT services, the running of which supports the processes of its solutions;

– to improve the method for selecting IT services for the operated IS to identify such IT services that would best meet both functional and non-functional requests for IS change;

– to check the possibility of assessing the degree of matching IT services and the formulated request for a change to generate the set of the best-considered alternatives.

4. Materials, the method, and criteria to study the improvement of the method for selecting the services of information technology

4. 1. Materials to study the improvement of the method for selecting the services of information technology

The results of analysis of the materials of previous studies made it possible to establish that the choice of IT service is significantly influenced by uncertainties that can be caused by:

– lack or absence of information on alternatives in the market;

– impossibility to conduct a large number of studies and evaluations of the characteristic of IT services due to the high cost of such studies;

– fundamentally contrary opinions of experts when assessing certain parameters of the IT services under consideration.

In this regard, within the framework of this study, we stated the problem of choosing the IT service for small and medium-sized IS with the SOA as the search for such IT

service ITs_j, which will ensure the implementation of the required functional problems $FZ=\{fz_j\}$, $j=1,...,n$ in accordance with the rules of comparison and selection of alternatives $R=\{fz_j\}$, $j=1,...,n$. Though such representation can somewhat worsen the accuracy of solving the problem of choosing the IT service, it leads to a significant reduction of the computational complexity of the ways of solving the problem due to using the methods of expert evaluation that are simpler to implement.

To describe the requirements for functional problems in the operated IS with the SOA, it was proposed to consider requests for a change. It was assumed that each request for a change in *RFC* was generally a set of functional and non-functional requirements that uniquely determine a set of functional *FZ* problems. Then, the choice of the IT service ITs_j that satisfies *RFC* implies the search for such an IT service, the functions, properties, and characteristics of which will best satisfy the maximum number of the requirements, forming *RFC*.

4. 2. Results of analysis of the method for choosing a set of services of information technology

Based on the previous representation of the problem of selecting IT services, the method for selecting a set of IT services for the IS with the SOA was developed. It was a sequence of the following stages [12].

Stage 1. Determining the list of functional problems {*FZ*}, which should be implemented by the IT service based on analysis of a request for a change *RFC*.

Stage 2. Determining IT-services *ITs*, matching the list of functional problems {*FZ*}.

Stage 3. Determining restrictions {*W*} for the set of IT-services *ITs*.

Stage 4. Formation of the list of IT-services IT_s^*, meeting restrictions {*W*}.

Stage 5. Introduction of a set of criteria to assess IT-services IT_s^*. At this stage, it is necessary to add criteria G^*, by which IT-services IT_s^* will be assessed and compared.

Stage 6. Determining the rules of comparison {*R*}. At this stage, experts determine the set of rules {*R*}, according to which IT-services IT_s^* will be assessed and compared.

Stage 7. Assessment of IT-services IT_s^* by experts. At this stage, in an expert way, the set of estimates {*P*} by the chosen criteria G^* are formed based on the set of rules {*R*} for a set of IT-services IT_s^*.

Stage 8. Introduction of the set of estimates{*P*} into the system.

Stage 9. Comparison of expert assessments. At this stage, the method of pair-wise comparisons of alternatives is used to compare and rank IT services based on expert assessments. Completion of the method.

4. 3. Criteria for assessing the quality of the information system

To assess the quality of the IS, in accordance with the ISO/IES 1926 1:2001 standard, it was proposed to use a group of criteria based on six quality factors: functionality, reliability, practicality, effectiveness, maintainability, and mobility.

Each of these factors is determined in more detail by the criteria of different levels, forming a hierarchical structure of quality criteria [12].

– functionality: suitability, correctness, ability to interact, consistency, security, ease of implementation;

– reliability: stability, ability to restore;

– practicality: clarity, ease of use;

– effectiveness: the nature of changing over time, the nature of resource changes;

– maintainability: the ability to be analyzed, variability, sustainability, ability to be tested;

– mobility: adaptability, compliance, interchangeability.

At the lowest level of this structure of criteria, there are the metrics, by which the lower-level criteria are compared.

Set {*ALT*} is formed by IT analysts who are competent in terms of the functionality of various software. The management imposes some restrictions {*W*} on the generated set of software {*W*}, and if alt_j meets these limitations $z_i\{W\}$, it becomes one of the elements of the set of considered alternatives $\{ALT^*\}$.

Set of ratings{*P*}for the set of alternatives $\{ALT^*\}$ is formed by experts based on a set of rules {*R*}, which is the totality of knowledge, skills, experience, and qualification of experts because it is possible to compare the considered alternatives $\{ALT^*\}$only in an expert way. It is necessary to obtain an appropriate set of ratings {*R*}.

The considered method involves the division of the problem of choosing the IT service into two consecutively solvable parts:

a) the search on the set of IT services *ITs* of the subset of IT services IT_s^* that meet the customer's functional requirements;

b) the choice from the found subset of IT services IT_s^* of the IT service, for which experts' ratings of the values of quality criteria would be the best.

However, these methods and criteria leave open the issue of linking the chosen IT service to the context of the automated BP. In addition, from the description of the method, it is unclear whether this method is applicable in case of an incomplete match of each IT service from set *ITs* and the set of functional requirements for the chosen service stated by the customer. This situation quite often arises during outsourcing accompaniment by IT companies of the developed small and medium-sized IS with the SOA in the BP of customer enterprises. That is why the subsequent study on the improvement of the considered method is divided into two parts:

– the theoretic and applied research into the possibility of improving the method to solve the problem of determining a set of IT services that partially meet the assigned set of functional and non-functional restrictions;

– applied validation of the possibility of implementation in the method of assessment of the degree of IT service matching the formulated request for a change in order to form the set of the best-considered alternatives.

5. Results of the improvement of the method for selecting a set of services of information technology for the information system

5. 1. Results of the improvement of the model of precedent of automated business process

One of the challenges of the development of information technology is the need to establish formalized links between the emerging requirements of users and the IT services that implement them. The application of the classical mathematical methods for its solving is difficult because of the difficulty in establishing the links of their elements. That is why in order to make the context link of the selected IT services to the requirements of automated BP, we use its formal representation in the form of the precedent model, proposed in [21].

According to [14], the precedent implies a structured representation of gained experience in the form of data and knowledge, which ensures its subsequent processing using specialized IS. This model is generally a tuple in the following form:

$$Mp =< Np,\ D,\ T,\ St,\ Rt >, \quad (1)$$

where Np is the unique, content name of the precedent;

D is the description of the domain, in which the application of the precedent is considered; this description in fact sets restrictions on the possible solutions of the problem;

T is the description of the problem or of the functional task, for the solution of which the precedent was developed;

St is the set of descriptions of the processes of solving problem T, which can be applied to realize a similar problem in future;

Rt is the obtained result of solving a problem (a form of the output document).

The processes of forming, selecting, comparing, and adjusting a precedent determine the content of the information technology, for the support of which, an improved method and an appropriate precedent model will be developed.

In accordance with the problem of selecting IT services that meet the new requirements of users of the IS with the SOA, it is proposed to correct the model (1) by introducing the following elements in it:

a) sub-set $ITacm \in T$ of descriptions of requirements for the functions of the problem or a functional problem, for the solution of which the precedent was developed;

b) sub-set $IT_s^{BP} \in St$ of descriptions of IT services, the operation of which provides for the process of solving problem T.

In general, the elements of subset $ITacm$ are meaningful words from the text description of the functional requirement for a problem or task. These meaningful words determine the essences of the domain and the relationship between them that determine the structures of input and output data in IT services.

The elements of subset T_s^{BP} are tuples in the following form:

$$IT_s^{BP} = \left\{\left\langle N_s, S_s \right\rangle\right\}, \quad (2)$$

where N_s is the unique name of the IT service; S_s is the description of the structures of input and output data of the IT service. A detailed formal description of the element of tuple S_s was considered in [22].

We will also introduce set ITs_{IS} of IT services, which are at the disposal of the IT-company developer of the operated IS with the SOA. These services are supposed to be the primary candidates for reuse to meet the customer's functional requirements for a new precedent or a new problem-solving process. The description of the set of ITs_{IS} will take the following form:

$$ITs_{IS} = \left\{\left\langle N_{IS}, REC_s, S_{IS} \right\rangle\right\}, \quad (3)$$

where N_{IS} is the unique name of the IT-server at disposal of a developer; REC_s is the description of functional requirements implemented by IT-service N_{IS}, S_s is the description of the structures of input and output data of the IT service. Sub-set REC_s is by its composition similar to subset $ITacm$. The detailed description of the element of tuple S_{IS} is similar to the description of S_s.

Then, to determine the degree of satisfaction of the assigned set of functional restrictions by the desired IT service, it is proposed to use the function of adaptive linear associator of mADALINE neuron proposed in [23]. This function describes a comparison of two requirements for the same function and takes the following form:

$$Profit\left(ITacm_j\right) = \frac{S\left(ITacm_j\right)}{W\left(ITacm_j\right)} \to 2, \quad (4)$$

where $Profit$ is the designation of the function of adaptive linear associator;

$ITacm_j$ is the description of the automated IT service as functional requirements stated by a customer, implemented by a developer;

$S(ITacm_j)$ is the number of all elements of set $ITacm_j$; $W(ITacm_j)$ is the number of unique elements of set $ITacm_j$.

As it follows from [16], the value of function (4) will aim to 2 if the description of the functional requirements implemented by the reusable IT service perfectly matches the description of the functional requirements for the process or the problem set by a customer.

5. 2. Results of the improvement of the method for selecting a set of services of information technology for an information system

The additionally introduced elements of model (1), set (3), and function (4) make it possible to improve the considered above method for selecting a set of IT services for the IS with the SOA. The essence of the improvement lies in formalizing the works on analyzing functional requirements and searching for descriptions of the IT services that partially meet the stated functional requirements.

Then the improved method will be presented by a sequence of such stages and steps.

Stage 1. Formation of functional requirements for a process or a problem of the precedent, for the solution of which it is necessary to choose the IT service.

Step 1. 1. Choose the unique name of precedent $n_j \in Np$ from set Np.

Step 1. 2. In accordance with the unique name of precedent n_j chosen at Step 1. 1., form set T of the given precedent.

Step 1. 3. Formulate a list of functional requirements describing the new or modified IT service of precedent n_j.

Step 1. 4. Based on the formulated list of functional requirements, formulate element $ITacm_j \in ITacm$, describing a new or a modified IT-service of precedent n_j.

Stage 2. Selection from the set of IT services ITs_{IS} the sub-set of IT-services IT_s^*, meeting the functional requirements n_j of a customer.

Step 2. 1. Form set ITs_{IS} of the IT-services, that are available in the IT-company developer of the operated IS with the SOA.

Step 2. 2. Set value ε as the minimum permissible degree of a match of the description of functional requirements of the customer $ITacm_j$ and the descriptions of functional requirements with REC_s, implemented by IT-services.

Step 2. 3. For each s-th element of the set of IT services perform operation $ITacm_j \cup REC_s$ and calculate the value of function $Profit$ from expression (4) for the obtained result of the operation.

Step 2. 4. If the performance of Step 2. 3 resulted in detection of only one IT service, for which condition $Profit=2$ is satisfied, derive the information about this IT service and complete application of this method.

Step 2. 5. If the performance of Step 2. 3 resulted in detection of some IT services, for which condition $Profit=2$ is

satisfied, form sub-set IT_s^* from these IT services and complete the application of this method.

Step 2. 6. If the performance of Step 2. 3 resulted in detection of the IT services, for which condition $2>Profit\geq\varepsilon$ is satisfied, then:

a) form sub-set IT_s^* from these IT services;

b) add as an additional alternative the name of the IT service created "from scratch" that completely meets the functional requirements stated by a customer;

c) complete application of this method.

Step 2. 7. If Step 2. 3 resulted in detection of the IT services, for which condition $Profit<\varepsilon$ is satisfied, report the lack of reusable IT services and complete application of this method.

Stage 3. Specification of the set of criteria for assessing IT services.

Step 3. 1. Form the initial set of criteria G taking into account their hierarchy (section 4 of this article).

Step 3. 2. Propose to take the initial set of criteria G as the foundation of finite set G^* when assessing the indicators of quality of IT services of sub-set IT_s^*. If a user agrees – accept $G^*=G$.

Step 3. 3. Form the specified set of criteria G^* by adding, correcting and/or removing separate criteria or groups of criteria from initial set G.

Stage 4. Selection by experts of the set of rules of comparison R, based on which the search of the IT-service from sub-set IT_s^*, that best satisfies the assigned set of non-functional restrictions will be performed.

Step 4. 1. Formation of the initial set of rules for comparison $\{R\}$, from which experts choose the applicable rules for comparison.

Step 4. 2. Choice by an agreed opinion of experts of the set of rules of comparison R, by which the search for the IT-service from sub-set IT_s^*.

Stage 5. Assessment by experts of IT services from sub-set IT_s^* according to the accepted sub-set of rules R.

Step 5. 1. Formation by experts of the set of rating St of values of the chosen criteria from the specified set of criteria G^*.

Step 5. 2. Process the set of ratings of solutions St in accordance with the sub-set of rules of comparison R chosen at Step 4. 2.

Step 6. Formation of the results of the selection of IT service that partially satisfies the assigned set of functional and non-functional restrictions. Completion of the method.

It should be noted that Stage 4–6 are outlined in less detail because their implementation depends on the choice by company analysts of specific methods for comparing the ratings of the values of criteria from set G^*. Thus, in papers [12, 24], the application of the rules that form the hierarchy analysis method was considered to pass these stages. It is expected that in the course of the program implementation of the improved method, specific methods for processing expert ratings will be implemented as a totality of separate services connected by the results of the selection of a particular method.

The application of the improved method will make it possible during the solution of the problem of choosing an IT service to identify situations of the partial match of functional requirements of a customer and descriptions of IT services. As a result of detection of such situations, the method allows, in the absence of a complete match, to separate for further analysis those IT services, the degree of matching of which with functional requirements of a customer is not lower than the assigned minimum limit.

The implementation of the improved method during the solution of the problem of choosing an IT service is carried out by the adjusted information technology (IT) of providing IT services, presented in Fig. 1 [12].

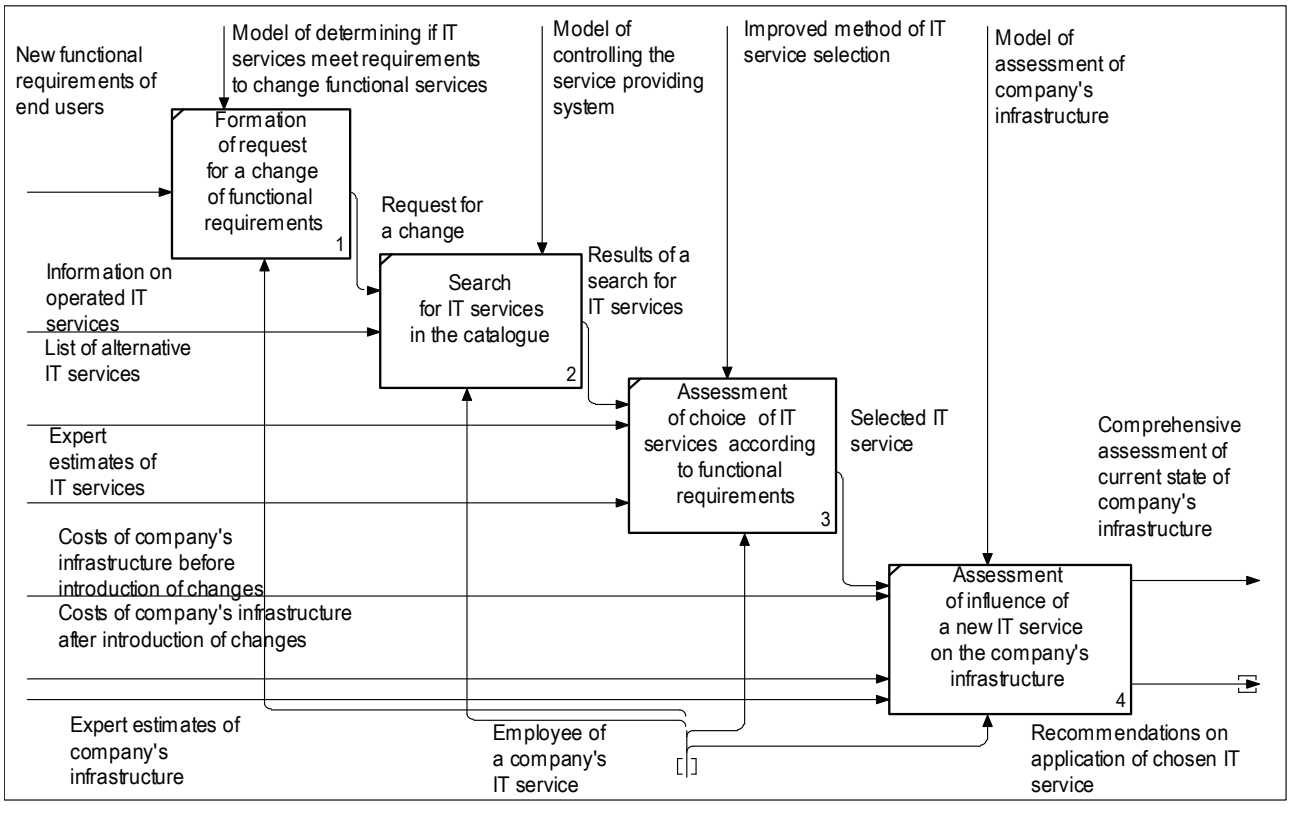

Fig. 1. Information technology to provide IT services

The information technology of providing IT services includes four stages:

– stage 1. Formation of request for a change of functional requirements;

– stage 2. Search for IT services in the catalog;

– stage 3. Assessment of choice of IT services according to functional requirements;

– stage 4. Assessment of the influence of a new IT service on the company's infrastructure.

IT automates the process of finding the match between requests for change and IT services. This is necessary in order to evaluate the use of an IT service and make an appropriate management decision.

5. 3. Checking the possibility to implement an assessment of the degree of match of the information technology services and the formulated request for a change in requirements

The pilot test of the possibility to implement an assessment of the degree of matching the services of information technology and the formulated request for a change of requirements was carried out on the example of the information system "Comprehensive System of Automation of the Insurance Company" (IS "CSAIC") for the precedent "E-policy".

The basic version of the "Comprehensive System of Automation of the Insurance Company" consists of the following basic functional modules: "Insurance Calculator", "Accounting of Agreements", "Data List Import", "Underwriting", "Accounting of Forms", "Commissions", and "Finance".

With the introduction of the feature of the e-policy sale, there appeared the problem of the development and implementation of IT services, which led to an expansion of the list of functions of the operated information system.

In paper [12], the information technology implementing the original method for choosing IT services was considered. In this technology, the human operator implemented Stages 1–4 of the original method, comparing text descriptions of the functional requirements and descriptions of the functionality of services.

Consider how Stages 1 and 2 are applied to the same example. Since there was no such precedent in the activities of insurance companies before, in the course of passing Step 1. 1. a model of a new precedent was created. For this model, the name of the main document of this precedent "Electronic policy" was chosen as a unique name of preceden $n_j \in Np$.

In the course of passing Step 1. 2 of the method, it was found that set T for the precedent "Electronic Policy" was not determined yet. That is why this set was created with one element, which also received the unique name "Electronic policy". The way Step 1. 2 is passed implies that the created functional task will automate the implementation of the basic BP scenario on the formation and sale of the OSAGO electronic policies.

In the course of passing Step 1. 3, the following list of functional requirements was obtained from the request for a change describing the new IT service for the automation of the main scenario performing the BP "Electronic Policy":

a) "filling in an electronic policy";

b) "checking an electronic policy";

c) "drawing up e-policy";

d) "selling an electronic policy";

e) "print-out an electronic policy";

f) "checking the validity of an electronic policy";

g) "payment of an e-policy";

h) "calculation of e-policy commission";

i) "authorization via SMS".

In the course of passing Step 1. 4, element $ITacm_1$, describing a new IT service for precedent "Electronic Policy", was formulated. This element is a set of nine elements formed from the functional requirements obtained at Step 1. 3 using the Porter stemming method, followed by the removal of "stop-words". Results of Step 1. 4 are given in Table 1.

Table 1

Description of the results of passing Step 1.4 of the improved method

No. of element of set $ITacm_1$	Original description of the functional requirement for this element	Content of the element of set $Itacm_1$ after using Porter stemming and removing «stop-words»
1	filling in an electronic policy	e-policy is filled in
2	checking an electronic policy	e-policy is checked
3	drawing up e-policy	e-policy is drawn up
4	selling an electronic policy	selling of e-policy
5	print-out an electronic policy	print-out of e-policy
6	checking the validity of an electronic policy	check of the validity of e-policy
7	payment of an e-policy	Payment of e-policy
8	calculation of e-policy commission	calculation of e-policy commission
9	authorization via SMS	SMS authorization

During Step 2. 1 of the method, we formed set ITs_{IS} of IT services, which were included in the operated versions of the IS "CSAIC" before the appearance of the precedent "Electronic policy". The list of the elements of this set is shown in Table 2.

Table 2

Description of elements of set ITs_{IS}

No. of element	Name of element N_{IS}
1	insurance calculators
2	accounting of agreements
3	data list import
4	underwriting
5	accounting of forms
6	commissions
7	finance
8	settlement
9	DMS
10	reporting
11	administration
12	CRM
13	re-insuring
14	internet shop

Each of the services, included in Table 2, implements a set of functional requirements. That is why the description

of each element of the set of ITs_{IS}, in accordance with (3), was supplemented with descriptions of the functionality of the relevant service, forming set REC_s. Full descriptions of the functionality can be found on the website of the IT company "Prof-ITsoft" [25]. An example of this description for the element "insurance calculators" is shown in Table 3.

While passing Step 2. 2, the value of the minimum allowable degree of match ε=1.25 was accepted. This value will enable detecting all IT services, the functionality of which can match the sub-set $ITacm_1$ separated at Step 1. 4, at least by 25 % (similar to [16]).

While passing Step 2. 3, for each element in Table 2 by each element of set REC_s, the values of function Profit were calculated. Before performing operation $ITacm_j \cup REC_s$, the names of services N_{is} and descriptions of functionalities from set REC_s were also pre-processed by the Porter stemming method, followed by the removal of "stop words". To determine the total value of the function Profit for each IT service on the whole, the obtained values of functions Profit were averaged.

An example of passing Step 2. 3 for the first element $ITacm_1$ "filling in an electronic policy" and the functionality of the IT service "insurance calculators" of set many ITs_{IS} is given in Table 4.

While passing Step 2. 4 and Step 2. 5, it was found that the values of function *Profit*=2 based on the results of passing Step 2. 3 were not obtained.

While passing Step 2. 6, the subset of functions of IT services, which meet condition $2>Profit2>>Profit\geq\varepsilon=2.5$, was found. This subset is given in Table 5.

The obtained results of using the improved method and the results of the previous method [12] were compared when passing Step 2. 6 on the example of a subset of services IT_s^* of CSAIC.

Results of passing Step 2. 6 in the form of a subset of services IT_s^* and service "Electronic policy" created from scratch and added as an alternative are shown in Table 6.

It should be noted that as a result of applying the original method as a subset of services IT_s^*, services of CSAIC, shown in Table 7, were proposed [13].

Table 3

Description of elements of set REC_s for element "insurance calculators" of set ITs_{IS}

No of element of set REC_s	Name of the element of set REC_s
1	calculation of the insurance rate and insurance premium based on the data entered by a user, taking into consideration the settings chosen in the tariff plan calculation
2	printing out documents in PDF or XLS format (insurance application, policy on the form of strict reporting, agreement, invoice, etc.)
3	use of different tariff plans with different values of base payments and ratios, payment options, contract expiration dates, etc.
4	setting up the availability of tariff plans, sale channels, form numbers, and setting commission for specific units of the sale network up to individual agents
5	possibility of issuing duplicates, reissuing, and prolonging contracts
6	online use of inspection rules to monitor the existence of non-standard contract terms and operative underwriting
7	control of possibility of using the number specified at the conclusion of the contract (or a form of strict reporting) – check on its availability to the user and permissible status (not used before, not lost, not spoiled, etc.)
8	control of the limits of liability for the contract as a whole or for each insured object, specified in the proxy chosen to make an agreement
9	automatic commission calculation depending on the shareholder and the contract manager, the possibility to change the commission in the contract within the permitted limits

Table 4

Results of passing Step 2. 3 for element $ITacm_1$ "filling in an electronic policy" and functionality of IT service "insurance calculators" of set ITs_{IS}

Result of operation $ITacm_1 \cup REC_s$	Value S $(ITacm_1 \cup REC_s)$	Value W $(ITacm_1 \cup REC_s)$	Value of function *Profit*
filled in electronic policy calculation insurance rate premium outcome entered by user given accounting of settings of the chosen tariff plan	16	16	1
filled in electronic policy print-out document format pdf xls declared insured policy form of strict reporting contract invoice	16	15	1.0(6)
filled in electronic policy use of different tariff plan different values basic payment ratio the payment option validity of contract	17	16	1.0625
filled in electronic policy setting available tariff plan sales channel form number settings commission specific units of chain sales separate agent	19	18	1.0(5)
filled in electronic policy possible issuing duplicate reissued prolongation contract	9	9	1
filled in electronic policy used cash control check non-standard conditions contract operational underwriting regime online	15	15	1
filled in electronic policy control possibility use specified concluded contract number form of strict report check availability to user permissible status used lost spoiled	24	24	1
filled in electronic policy control specified chosen concluded contract proxy liability limit contract as a whole each insured object	16	15	1.0(6)
filled in electronic policy automatic calculation commission dependent stakeholder manager contract possible change commission agreement allowed limit	17	16	1.0625

Table 5

Subset of functions of IT services that meet condition $2 > Profit2 > Profit \geq \varepsilon = 2.5$

No. of element of set $ITacm_1$	No. of element of set ITs_{IS}	No. of element of set REC_s	Value of function *Profit*
8	1	9	1.2(6)
8	2	6	1.2(6)
1	5	1	1.25
2	5	1	1.25
3	5	1	1.25
4	5	1	1.25
5	5	1	1.25
7	5	1	1.25
1	6	3	1.(296)
2	6	3	1.(296)
3	6	3	1.(296)
4	6	3	1.(296)
5	6	3	1.(296)
6	6	3	1.276
7	6	3	1.(296)
8	6	3	1.609
9	6	3	1.308
1	8	2	1.25
2	8	2	1.25
3	8	2	1.25
4	8	2	1.25
5	8	2	1.25
7	8	2	1.25
9	8	2	1.(27)

Table 6

Description of elements of set IT_s^* of the improved method

No. of element	Name of element N_{IS}
1	Insurance calculator
2	accounting of agreements
5	accounting of forms
6	commission
8	settlement
15	electronic policy

Table 7

Description of elements of set IT_s^* of the original method

No. of element	Number of element N_{IS}
2	accounting of agreements
4	Underwriting
6	Commission
14	internet shop
15	electronic policy

The results of comparing selected sets IT_s^* of the original and the improved methods make it possible to draw the following conclusions.

Firstly, the improved method makes it possible, due to the automated execution of steps of Stage 2, to eliminate errors made in the formation of the set IT_s^* by a human operator. This applies to the inclusion of services "Underwriting" and "Internet-shop" in the set IT_s^* in the course of applying the original method. As a result of the quantitative assessment of the degree of duplication of functional requirements by the functions of these services, it was found:

a) for service "Underwriting", the maximum value of function *Profit*=1.(153846) (degree of match of functions of the service and the separated set of functional requirements is a little more than 15 %);

b) for service "Internet-shop", the maximum value of function *Profit*=1.1(6) (degree of match of functions of the service and the separated set of functional requirements is a little less than 17 %).

Secondly, services "Electronic policy" and "Accounting of agreements" were included in the set IT_s^* as a result of the application of the improved method. It is these services that were recognized as the best solutions for automation of the activity on selling the OSAGO electronic policy [12], according to the results of passing the stages of evaluation of the non-functional characteristics of the original method. That is why the results of passing Stages 1 and 2 of the improved method should be considered reliable.

6. Discussion of the results of the study on improving the method for choosing the services of information technology

The original method involved searching for IT services *Its* that matched the list of functional problems {*FZ*} by a simple comparison of the descriptions of these services and tasks. At the same time, the neuron proposed in [23] does not take into consideration the use of the functions of separately operated services in the existing BP. That is why two main areas of improvement of the original method were proposed:

a) separation of specific BPs and precedents, for which a set of functional requirements for the sought-for IT services is formed;

b) automation of operations to quantify functional requirements and descriptions of the functions of separate IT services.

The first direction was implemented in the improved method in the form of steps of Stage 1. The proposed solution in the future will make it possible to form sets of services for the automation of separate BP of enterprises not based on the results of analysis of a large number of separate functional requirements, but rather on the results of analysis of descriptions of precedents. Comparison of the business needs of an enterprise and existing precedent descriptions based on (1) is expected to result in the detection of reusable precedents. In this case, it is necessary to identify only those functional requirements that determine the difference in the scenario implementation of the precedent at the enterprise-customer of the IS. This could lead to a significant reduction in the time spent on the formation and analysis of functional requirements for the IS.

The second direction was implemented in the improved method in the form of steps of Stage 2. The proposed solution will allow the elimination of errors that may occur during the comparison of functional requirements and descriptions of IT services directly by a human operator. In addition, the proposed solution excludes the subjective perception by a human operator of the meaning of separate words. However, the application of the proposed solution requires some increase in the number of computational operations compared to the original method. This is a definite drawback of the improved method.

Assessment of the effectiveness of the developed improved method depends on many factors, primarily on the exact compliance with the specifications of functional requirements and descriptions of IT services, as well as availability and support in the relevant database of analog precedents. That is why the function of the adaptive linear associator of the mADALINE neuron, proposed in [23], is used to quantify the effectiveness at this stage.

The improved method was tested during the selection of an IT service to solve the problem of automation of the activity on selling the OSAGO electronic policy. As a result, it was found that the improved method was more effective than the original method proposed in [12]. This was made possible due to the use of function *Profit,* forming a quantitative assessment, to evaluate the degree of a match of functional requirements and descriptions of IT services.

The main feature that makes it difficult to apply the improved method is the need to create and maintain in the relevant state a database of precedents analogs that have in their composition the necessary IT services. This requires additional works to form such a database and, as a result, to increase the funds and time spent on the creation of the IS. However, such costs can be offset by reusing previously developed solutions to the problem in accordance with the formulated requirements for the IS.

Another difficulty with the application of the improved method is the need to ensure that the specifications of functional requirements and descriptions of the IT services are as accurate as possible. To address this issue, it is necessary to develop special unified descriptions of functional requirements and functions of IT services as a result of additional theoretical research and practical tests.

7. Conclusions

1. The model of the precedent was improved by introducing in it the descriptions of the requirements for the functions of a problem or a functional problem, for the solution of which a precedent was developed, and descriptions of IT services, the operation of which provides for the processes of problem-solving. Such a model makes it possible to establish a direct match of descriptions of business precedent, functional requirements for IT services, and functions of separate IT services.

2. The method for selecting IT services for the operated IS was improved. As a result of the improvements, the method makes it possible to establish a match between the descriptions of the precedents of the implementation of the BP and functional requirements for the necessary IT service. In addition, the improved method makes it possible to automate the execution of works on the search for IT services, which at least partially meet the functional requirements that were put forward. The essence of the proposed improvement is to develop a formal description of the automated BP. The function of the adaptive linear associator of the mADALINE neuron was used to quantify the degree of a match of functional requirement and the description of the function of the IT service, which are the elements of the improved model of the precedent. As a result, in the absence of a complete match, the IT services, which match the functional requirements of a customer to the degree that is not lower than the assigned minimum limit, are separated.

3. The improved method was tested. The possibility of solving the problem of automating the activity on selling the OSAGO electronic policy was tested on the example of a change in the functional requirements for the IS "CSAIC" of IT company "ProfITsoft". For comparison, the minimum allowable degree of coincidence ε=1.25 was accepted. This value will make it possible to detect all IT services, the functionality of which can meet the separated set of functional requirements at least by 25 %. The results of testing suggest that the improved method makes it possible to search for the necessary IT service that best meets the set of functional requirements and non-functional restrictions.

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