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Cloud Services Selection on the Base of Decision Support System

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Abstract: Recently, enterprises are increasingly using cloud services for efficient work, including decision making. This paper proposes a non-classical version of the Decision Support System (DSS), which provides the choice of the best IT service when migrating an enterprise to a cloud environment. This should increase the efficiency of management decisions in the development of an enterprise's IT strategy. We have studied the problems of effective implementation of a cloud IT environment in an enterprise (organization), considering information security (IS) risks. At the same time, we have proposed modern approaches to the development of models for the migration of enterprises (organizations) to the cloud environment. Based on the DSS Cloud IT Service Implementation Model, we developed software to assess the suitability of an enterprise for cloud migration and determine the best IT service. The implemented software can be used by different customers, including IT engineers, IT enterprise managers, freelancers.

Keywords: DSS, JavaScript, IT strategy of the enterprise, cloud services, method of analysis of hierarchies

1 Introduction

In recent years, cloud technologies or cloud computing (Cloud computing) have gained effective application. Cloud computing is considered as a model of providing convenient access through a network to a common pool of computing resources subject to configuration (for example, to communication networks, servers, data storage facilities, application programs and services), which can be quickly provided with minimal operational costs or released from contacting the provider.

Cloud technologies are of interest to both large companies that are trying to optimize their costs for the IT infrastructure of the enterprise, and small companies that do not have the opportunity to immediately deploy their own infrastructure. Ordinary users are also interested, who can receive such services as data storage, use of programs, etc.

The growing interest in cloud computing technology is associated with the economic effect of their use. During their use, consumers can significantly reduce capital costs for the construction of data centers, the purchase of server and network equipment, hardware and software solutions. This can be accompanied by ensuring continuity and operational efficiency, as well as the time of construction and commissioning of large information technology infrastructure facilities.

All these issues under these conditions are transferred from users to cloud service providers, and the user only pays for the services provided. Also, cloud services provide their users with flexibility in setting such parameters as computing power, file storage volume, software composition, etc.

However, despite the obvious advantages, when using cloud technologies, it is necessary to solve several issues. The main ones are trust in the service provider, ensuring the confidentiality, integrity, authenticity and irrefutability of information at all stages of its existence, uninterrupted work, protection against unauthorized access (UA) and the

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preservation of personal data of users that are transferred and processed in the cloud. Therefore, for every enterprise (organization) the issue of choosing the best cloud technology that will ensure the effectiveness of management decisions considering information security risks is relevant.

Here we propose the development and analysis of software that is able to analyze and assess the suitability of an enterprise, including IT applications, for cloud migration from the planning stage. This can reduce the risks of losses when implementing cloud technologies and find the best IT service.

We have created a decision support model for the transition to the cloud based on the hierarchy analysis method, which allows us to evaluate the possibility of implementing IT applications in the cloud according to three group criteria: economic value, technological capability and IT level. These suggestions give the opportunities to receive recommendations for decision-making based on generalization matrices.

When performing the work, we are using the methods of system analysis, the method of analysis of hierarchies, the method of expert assessments, and the multi-criteria approach.

2 Analysis of literature sources

There are a lot of different sources that propose the cloud solutions with different benefits for the enterprises. We tried to analyze them in term of extracting the main criteria for the successful solutions and operational work in cloud.

In work [1] in the cloud, they propose the simple model stands in stark contrast to the traditional, capital-intensive model of corporate IT infrastructure. For instance, they suggest paying for only consumed resources that is similar to the work of the mobile operator models. If demand decreases and the power is no longer needed, the systems can be turned off and no more fees are charged.

In work [2], data processing centers (DPC), where servers for the organization of cloud services are located, are also initially designed for maximum efficiency and minimal impact on the environment.

In the papers [3], [4] the authors offer models and methods that provide the analysis of the subject area, evaluation and selection of the best alternatives for both the models of cloud IT services and cloud service providers. The authors claim that this model can create the successful cloud strategy and the subsequent introduction of cloud technologies at the enterprise.

The authors of the paper [5] proposed a system that allows adaptive adjustment of allocated resources in the conditions of cloud services. The system uses an online resource demand forecasting model to determine short-term resource needs. The proposed approach uses a special program inside each Decision making and support systems (DSS), that may not be acceptable for many systems and platforms of cloud services.

The authors of the paper [6] focus on the structure of the management hierarchy based on the requirements for the placement of programs and services. The proposed hierarchical structure automatically constructs and maintains the hierarchy, which can then be used by the control program. Thus, the proposed structure uses division into groups when managing child nodes defined by the hierarchy. The hierarchy of nodes is built and managed on top of the physical network of cloud services. As a result, the DSS places the user's application (or service) on the corresponding node or distributes the user's context to other nodes.

In the works [7], [8], [9] the authors discuss the efforts to develop methods, algorithms and DSS that provide cloud services. The researchers are mainly focused on the areas of provision, distribution, capacity planning, comparison and scaling of cloud services resources. At the same time, they describe many systems with software-defined technologies and software platforms for providing and monitoring resources, including accurate methods, load prediction mechanisms, etc. Most of the proposed approaches for managing resources in a cloud and virtualized data centers are based on the principle of resource consolidation of cloud services.

The work [10] proposes a concept for the creation of technologies for a global information exchange in the cloud and architecture, market-oriented for the distribution of resources in the clouds. These technologies are based on the need to converge competing IT paradigms. To enable the successful implementation of cloud computing, the authors presented different options for solving the problem to reveal the existing potential in practice. For example, they describe high-efficiency content delivery through ”cloud storage”.

In work [11] the authors propose an open cloud computing interface framework that supports resource allocation, monitoring, and automatic configuration for cloud resources to meet infrastructure-level application requirements. The framework includes a set of protocols and API of a vendor-agnostic platform that can solve various management tasks while meeting integration, portability, and interoperability requirements. The new architecture contains developed implementation of the JADE agent platform from Cloud Agency as a runtime environment. It supports agent communication through an agent-to-agent communication channel and a standard HTTP-based agent-to-agent communication language.

The migration of an enterprise to the cloud requires a well-defined strategy that would support all the capabilities and functionalities of cloud technologies. Its success depends on the presence of service-oriented architecture (SOA) at the level of the institution, which would provide the necessary infrastructure for the implementation of the cloud. Without SOA and BPM (business process management), the transition to cloud methods does not make any sense from a financial point of view, because it leads to high costs combined with re-engineering of existing systems. And, definitely, the strategy of introducing cloud architecture should correspond to the strategy of the enterprise.

3 Methods and models in DSS during the transition to cloud IT services

3.1 Stages for strategy of cloud migration

The purpose of the study is to develop methods and algorithms that would increase the effectiveness of management decisions in the development of the IT strategy of the enterprise (organization) by using the DSS for the selection of cloud IT services.

Having analyzed the results of the latest research related to the transition to the cloud model and the experience of enterprises in its use, we propose to divide the strategy of the transition to cloud technologies into several stages:

1. Development of a corporate database (DB) using a DBMS suitable for parallel processing;
2. Assessment of the current level of the enterprise in terms of IT needs, structure and use;
3. Carrying out experiments with the implementation of cloud methods in various structures of the enterprise;
4. Selection of optimal cloud methods;
5. Implementation and management of cloud technologies at the enterprise.

In order to realize the benefits and get the maximum return from their investments, enterprises must consider various problems and features of cloud IT implementation, unique for each specific situation [12].

In the process of making decisions about implementation at the enterprise, the primary task is the selection of services as candidates for implementation based on economic, technological and safety factors. When implementing cloud technologies, it is necessary to have a strategic plan that can help to correctly set goals and see their achievement, monitor and adjust the movement to achieve the result.

The task of creating the DSS is to develop a software tool capable of analyzing and evaluating the suitability of the enterprise, namely, its IT applications from the point of view of migration to the cloud even at the planning stage. This will reduce the risks of losses when implementing cloud technologies and find the best IT service.

3.2 Information System Development

The information system should be easy to use both for experts who will evaluate the enterprise, IT applications and IT services, and for the employees of the enterprise themselves, who will be able to observe all the proposed options. It should be emphasized that until now there is no consensus on the methods of assessing the suitability of cloud computing, but this is difficult to achieve, since there is no single, standard, structured platform in the industry that could help enterprises in evaluating and reducing the risks of ”cloud” computing [13].

Based on the DSS model on the implementation of cloud IT services, we develop the software (Information System) to assess the suitability of an enterprise for migrating to the cloud and determine the best IT service.

The information system is aimed at analyzing and processing heterogeneous data on enterprise migration to the cloud. The system must perform the following tasks:

– preservation of arrays of data on the assessment of the enterprise: economic, technological, safety assessment;
– creation of factors and criteria;
– gradation of factors and criteria;
– analysis of data and obtaining parameters for assessing the suitability of an enterprise for moving to the cloud and determining the best IT server at selected enterprises.

Figure 1 shows a diagram of use cases for the proposed system.

3.3 Method of DSS hierarchy analysis in the process of transition to cloud IT services

It is possible to build a general model for the transition of companies to cloud technologies. It consists of four stages: research, assessment of the effect of the transition, launch and implementation. Each of these stages is mandatory to achieve the goal of the transition (see Figure 2).

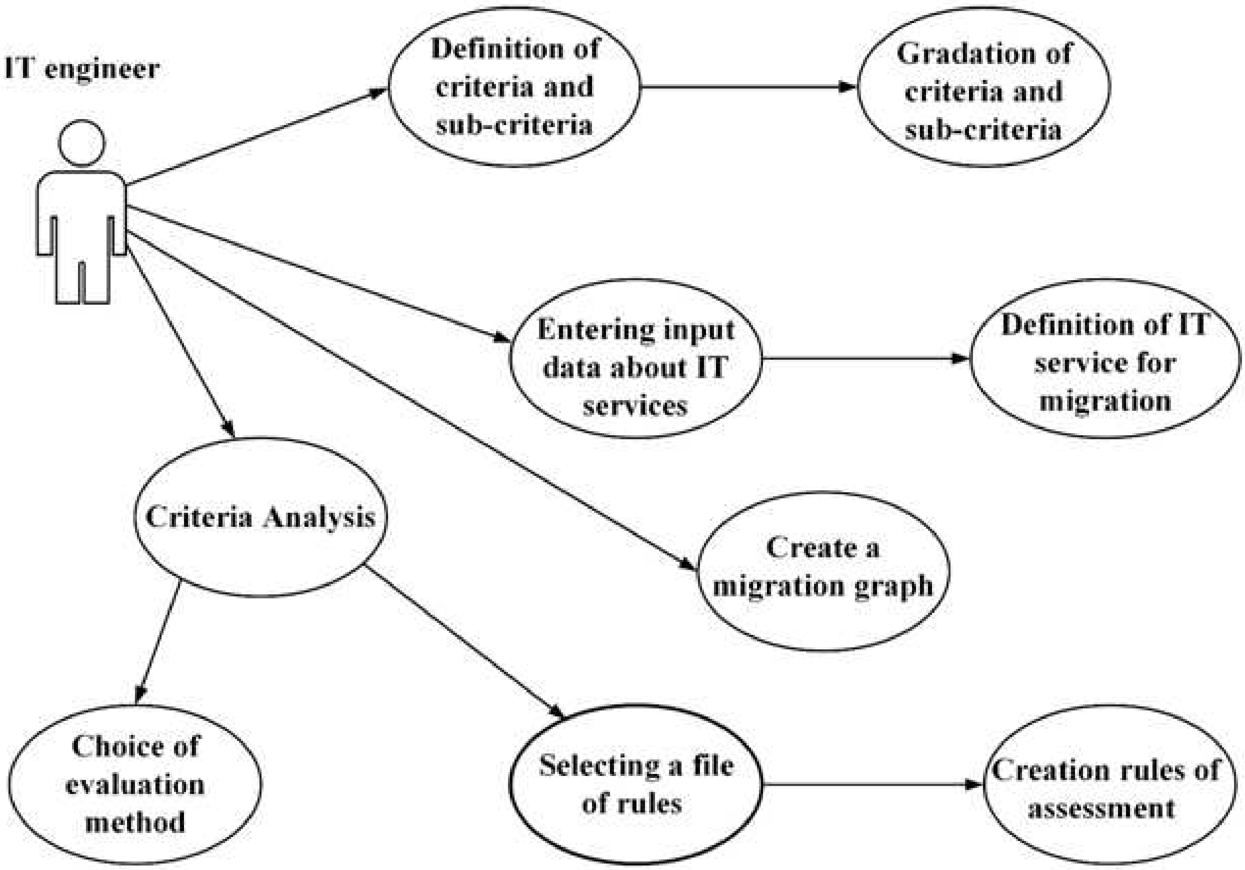

Fig. 1: Diagram of system use cases

At the research stage, the company conducts a full analysis of the range of cloud technology services, their features and benefits. Evaluation of the effect of the transition is the most important stage, where the issues of the feasibility of a full or partial transition to cloud technologies are resolved. Accordingly, the last two stages, launch and implementation, are performed in the case of a positive assessment of the effect of the transition.

At the final stage, developed system provides the most complete testing of the new infrastructure for fault tolerance, deployment of the cloud environment and direct work in the cloud.

To increase the validity of decisions made by an expert on the priorities of alternatives, the hierarchy analysis method (HAM), is often used in practice. This method allows reflecting the expert's qualitative assessments [14].

Let's consider the stages of constructing a relative value function on a complete set according to the HAM methodology.

Stage 1. When comparing arbitrary two elements x^i and x^j of this set, the decision-maker (DM) is faced with the question: to what extent (how many times) does one element prevail over the other? To determine the preference of objects, a scale of the relative importance of objects is used.

Stage 2. Based on the results of the research, we will compile a matrix of pairwise comparisons (PCM) $A = \| a_{ij} \|_{(m \times m)}$.

If the DM responses were consistent, $a_{ij} = \frac{w_i}{w_j}$ for all $i, j = \overline{(1,m)}$. Consistency means that:

1. $a_{ij} = 1, a_{ij} = \frac{1}{a_{ji}}$ for all $i, j = \overline{(1,m)}$, that is, if the object x^i preferable to x^j by $\alpha > 1$ times, then the value of the object x^j is $\frac{1}{\alpha}$ of the value of the object x^i.
2. in case of complete agreement $A = \begin{pmatrix} W_1 \\ \dots \\ W_m \end{pmatrix} = m \begin{pmatrix} W_1 \\ \dots \\ W_m \end{pmatrix}$.

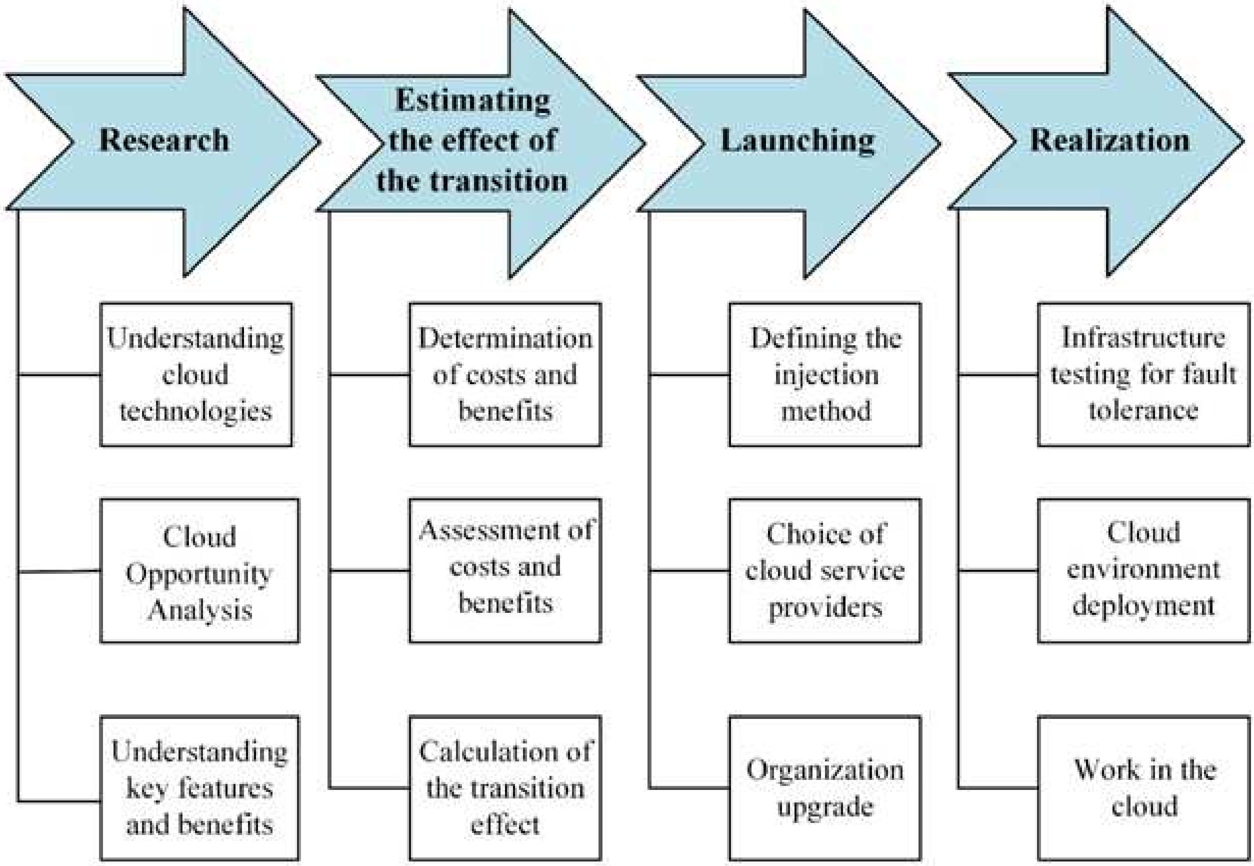

Fig. 2: Model of transition of companies to cloud technologies

This means that the vector of relative values $(w_1,...,w_m)^T$ is an eigenvector of the matrix A and corresponds to the number $\lambda = m$ of this matrix.

Properties 1) and 2) are used when DM responses will contain errors. That is, after constructing matrix A, such relative values of objects are searched for, for which $\lambda_{max} \to m$ (where m is the largest number of matrix A). The closer $\lambda_{max} \to m$, the better DM responses are consistent with each other.

Stage 3. Using the geometric mean method, we approximately calculate the vector of relative values $(w_1,...,w_m)^T$.

The calculation of indicators of the relative value of objects is carried out using the geometric mean element of each of the rows of matrix A:

$$W_i = \frac{\sqrt[m]{a_{11}...a_{im}}}{\sum_{i=1}^{m} \sqrt{a_{i1}...a_{im}}} \quad i = \overline{(1,m)} \tag{1}$$

Stage 4. Let us estimate the value of the eigenvalue to which the calculated vector of relative values corresponds. For this, we find the product $A \cdot w$.

Stage 5. To estimate the value of λ_{max}, we can divide the components of multiplication by components $A \cdot w$ on the components of the vector of relative values w. We will obtain a vector, after which we will choose the average arithmetic component of this vector for the approximate value of λ_{max}.

Stage 6. Next, we calculate the consistency index $J_p = \frac{\lambda_{max}}{m-1}$, the value of which is compared with the reference. If $J_p \leq 0,1J_e$, then the results of the DM poll are satisfactory.

The process of using the HAM to assess the possibility of working in the cloud consists of several components. The main steps of the hierarchy analysis method are:

1. Hierarchical representation of the problem.
2. Construction of a set of pairwise comparison matrices (PCM).
3. Definition of vectors of local and global values.

4. Checking the consistency of the obtained results.
5. Calculation of the overall HAM score.

Step 1. As a rule, the hierarchy is built from the top, the global goal in terms of solving the problem, through intermediate levels on which the goal depends, to the lowest level, which is usually a list of alternatives. Each of the presented criteria (economic value, technological capabilities and degree of IS) has several sub-criteria. They, in turn, can have several levels of sub criteria. Figure 3 presents a hierarchy for evaluating a set of IT services according to the criterion of economic value for working in the cloud with the use of HAM. The given criteria have sub-criteria, which together form a group of criteria [15].

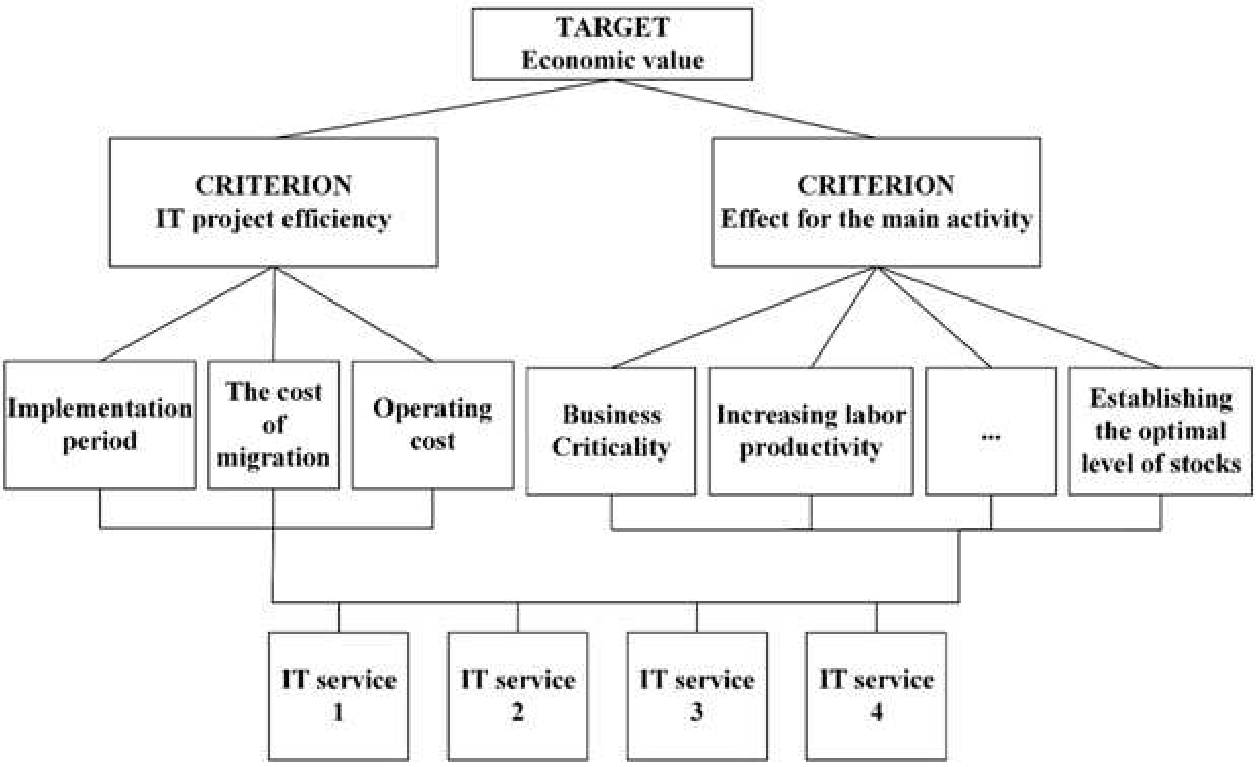

Fig. 3: Hierarchy for evaluating cloud services according to the economic-value criterion

Step 2. The expert should draw up a matrix of pairwise comparisons for the criteria of each level, expressing his opinion about the relative priorities of the criteria according to the HAM scale. At this step, the corporate program is evaluated according to quantitative and qualitative criteria.

Evaluation by quantitative criteria. When evaluating cloud IT services according to a quantitative criterion, they are compared with each other considering the quantitative value of the criterion (the score of the application according to the criterion that has a positive effect) is calculated by normalizing the values by one. For a series of numbers r_i, $i = 1...n$ the normalized value of r_{kn} is equal to (2):

$$r_{kn} = \frac{r_k}{\sum_{i=1}^{n} r_i}. \tag{2}$$

According to the criterion that has a negative effect, the relative score of the application is calculated by determining the inverse values and further normalizing them.

For a qualitative criterion the relative score of the application is calculated by pairwise comparison using the HAM scale (from 1 to 9). In our opinion, this method has qualitative advantages compared to all others, as it allows you to fully take into account all the criteria put forward before choosing the optimal project.

Step 3. On the basis of each of the constructed matrices of pairwise comparisons, sets of local priorities are formed, which reflect the relative priorities (value, importance, power of influence) of the compared elements in relation to another element. To do this, you need to calculate a set of eigenvectors for each matrix, and then normalize the result to unity, thereby obtaining a vector of priorities.

Sub-criteria have both local and global priority.

Step 4. When drawing up matrices of pairwise comparisons, expert judgments should not violate the axioms of order. In particular, if one element is better than another, and that, in turn, is better than the third, then the first must also be better than the third, and the strength of the superiority of the first element over the third must be greater than that of the first over the second and the second over the third. However, it is human nature to make mistakes. Therefore, matrices of pairwise comparisons based on subjective judgments may be inconsistent. The so-called consistency index (CI) is used to assess the degree of deviation from consistency.

Step 5. The total score for the IT service for each of the criteria is determined by the additive convolution formula (3):

$$R_x = \sum_{i=1}^{M}\sum_{j=1}^{N_i} W_i \cdot w_{ij} \cdot R_{ijx}, \tag{3}$$

where R_i is HAM score for the i cloud service; M – the number of groups of criteria; N_i – the number of elements in the i group of criteria; W_i– priority value of the i group of criteria; w_{ij}–the priority value of the j criterion belonging to the i group of criteria; R_{ijx} – expert score of comparison of the x-application according to the j criterion in the i group of criteria.

Next, the points for each IT server are compared in the decision vector $R_x = (R_{ec}, R_t, R_r)$, which will give a holistic view of the results of transferring various corporate applications to the cloud for various criteria and help in making a reasoned decision [16].

3.4 The algorithm for improving the HAM in DSS

The use of pairwise comparisons in the HAM makes it possible to correctly determine the weights of the indicators and to rank them only under the condition that the consistency index does not exceed 10% [17]. In the case of analysis of factors and criteria that have different numerical characteristics, the problem of consistency of comparisons is somewhat reduced and largely depends on expert assessments when comparing non-parametric criteria. In such cases, it may happen that the obtained vectors of relative values of alternatives or vectors of weights (both criteria in the indicators and of the indicators themselves) may have a significant degree of inconsistency compared to the ideal experiment.

In works [18], [19] , the authors have proposed to estimate the degree of inconsistency by comparing a completely consistent matrix and one obtained by expert methods. At the same time, a completely consistent matrix has rigidly connected elements, and for such a matrix the condition is fulfilled $\frac{a_{ij}}{a_{kj}} = const$ for all j.

Consider the matrix of pairwise comparisons $A^F = (a^F_{ij})$. The rows of this matrix can be interpreted as vectors $\mathbf{a} = (a_{i1}, a_{i2}, , ..., a_{in},)$. Then, for a completely consistent matrix, they must be parallel $\mathbf{a_i} \parallel \mathbf{a_j}$. Accordingly, the angle between the vectors, or rather the cosine of the angle between the vectors $cos(\angle \mathbf{a_i a_j}) = 1$. Therefore, in addition to the traditional index of consistency, the value $cos(\angle \mathbf{a_i a_j})$ can be used as a measure of the consistency of the matrix of pairwise comparisons, the value of which indicates the dependence between the elements of the matrix. Decreasing the dependence of elements leads to an increase in the angle between the matrix row vectors and, accordingly, to a decrease in the consistency index.

The cosine of the angle between the vectors is defined as (4):

$$cos\alpha = \frac{\mathbf{a_i} \cdot \mathbf{a_j}}{\|\mathbf{a_i}\| \cdot \|\mathbf{a_j}\|}, cos\alpha = \frac{\mathbf{a_i} \times \mathbf{a_j}}{\sqrt{(\mathbf{a_i} \times \mathbf{a_i}) \cdot (\mathbf{a_j} \times \mathbf{a_j})}} \tag{4}$$

where $\mathbf{a_i} \times \mathbf{a_j}$ – scalar product of vectors $\mathbf{a_i}$ and $\mathbf{a_j}$.

For the matrix of pairwise comparisons $A^F = (a^F_{ij})$, the consistency index, the cosine of the angle between the vectors, can be represented as (5):

$$CI = cos^F \alpha = \frac{\sum_{k=1}^{n} a_{ik} a_{jk}}{\sqrt{\sum_{k=1}^{n} a_{ik} \sum_{k=1}^{n} a_{jk}}}. \tag{5}$$

On its basis, for each pair of vectors of pairwise comparisons, we obtain a consistency matrix:

$$CI = \begin{pmatrix} 1 & ci_{12} & \dots & ci_{1n} \\ ci_{21} & 1 & \dots & ci_{2n} \\ \dots & \dots & \dots & \dots \\ ci_{n1} & ci_{n2} & \dots & 1 \end{pmatrix} \tag{6}$$

The elements of the consistency matrix lie within $0 \leq iy_{ij} \leq 1$ and show the degree of consistency of each pairwise comparison to the others. The intermediate result of the evaluation of the elements of the matrix (6) is the possibility of determining the minimum and maximum agreements, their ranking, establishing monotonic sequences, etc.

Thus, the implementation of the proposed method makes it possible, despite the sufficiently large size of the array of criteria within the given limits, to carry out correct pairwise comparisons with the achievement of the given level of consistency ($CI \leq 10\%$) and to determine the relative values of the sub criteria $w_1^i, w_2^i, \ldots, w_k^i$ that can be trusted. It is advisable to use a similar technique for the formation of an agreed matrix of pairwise comparisons of factors $A^F = (a_{ij}^F)$, based on the assessment of the degree of agreement, which determines the relative estimates of the values of the factors on the factor set $\{\Omega^1, \Omega^2, \ldots, \Omega^m\}$. Thus, a generalized vector $W(\Omega, w)$ is formed as a result.

To implement the given task, it is necessary to develop a module for ranking factors, criteria and sub-criteria for assessing the possibility of an enterprise transitioning to the cloud. For this purpose, a modification of it has been developed based on HAM, which makes it possible to rank the factors of migration opportunities to the cloud by increasing the level of consistency of expert assessments due to the correction of pairwise comparisons. The procedure for correcting pairwise comparisons to achieve an acceptable level of consistency can be carried out in automatic and iterative modes, as well as with the help of a repeated expert survey. The iterative adjustment condition corresponds to a situation where the inputs to the comparison of alternatives are reasonably consistent, but there are comparison judgments that differ significantly from others in both magnitude and validity. In all other cases, under conditions of significant inconsistency of the matrix of pairwise comparisons and in the presence of judgments that contradict each other, it is advisable to conduct a repeated expert assessment. The level of reliability of paired judgments and their comparison in terms of reliability is proposed to be determined based on statistical analysis of numerical values of pairwise comparisons of the matrix, where for a sample of $n(n-1)$ evaluations of pairwise comparisons (without diagonal elements) the average value of evaluations and the root mean square deviation σ(RMSD) are determined as a measure of the dispersion of the consistency of the comparisons. Schematically, the adaptive procedure for correcting pairwise comparisons to increase the level of consistency is presented in Fig. 4. The algorithm for selecting the matrix

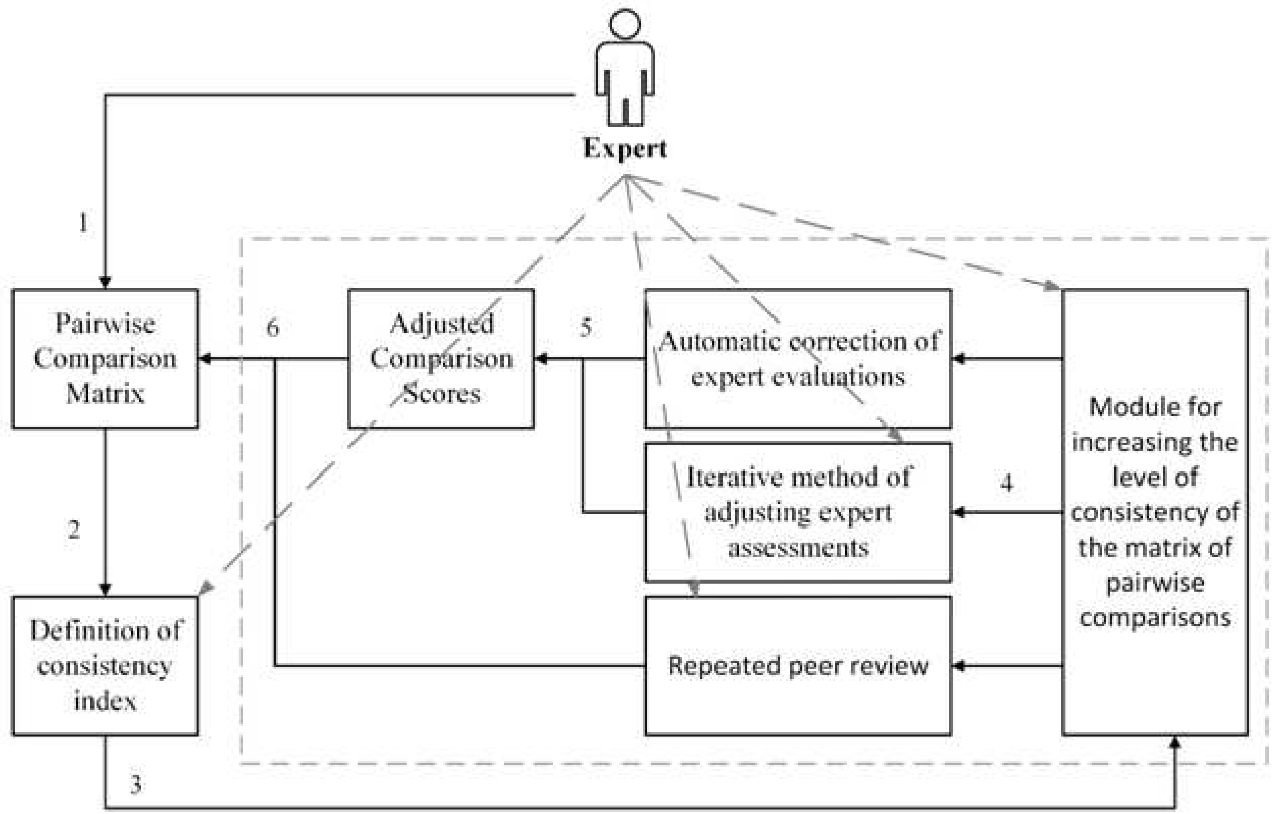

Fig. 4: Scheme of adaptive selection of numerical estimates in the matrix of pairwise comparisons (participation of the expert in the process of processing the matrix of pairwise comparisons is indicated by a dotted line)

correction method is shown in Fig. 5.

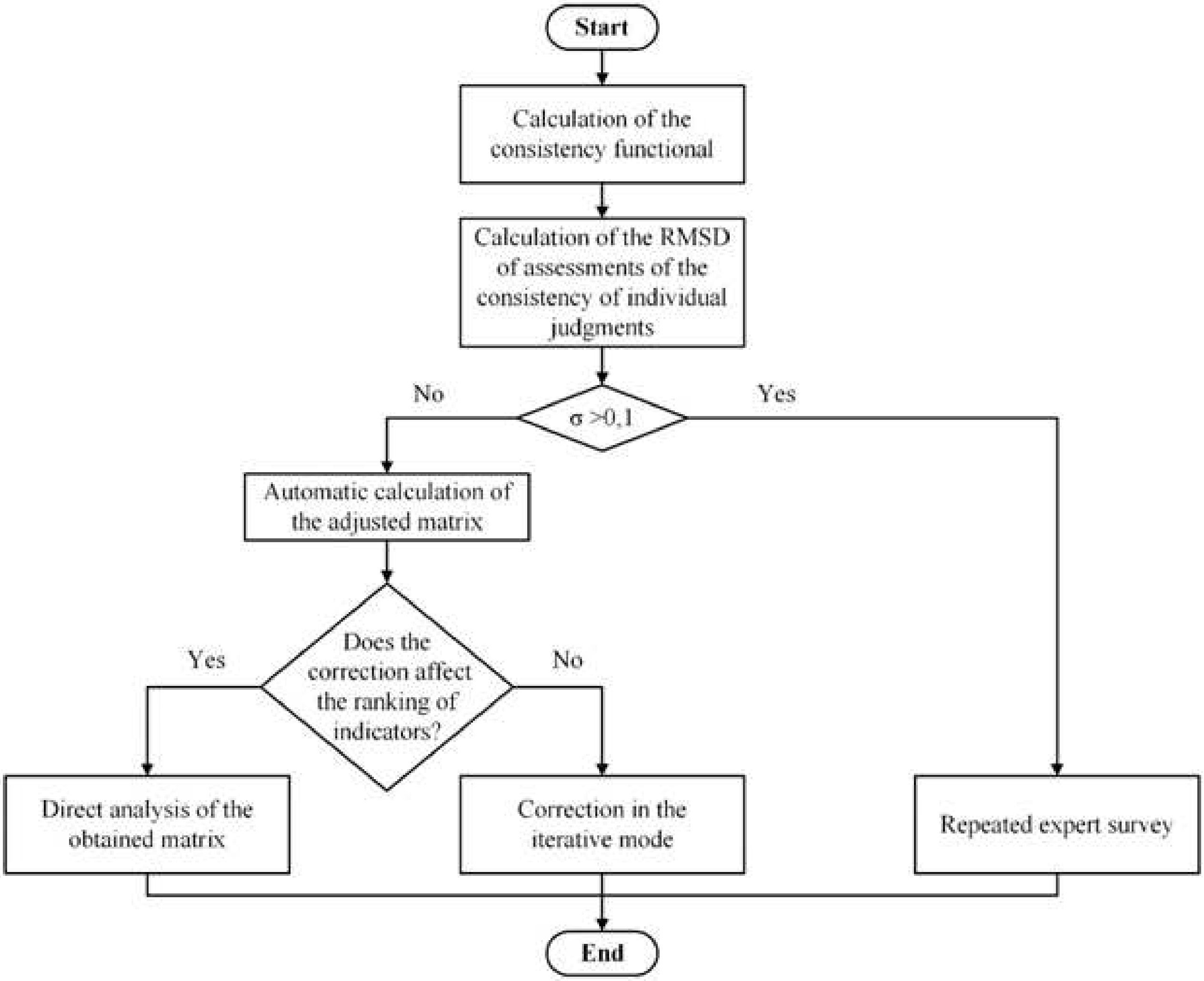

Fig. 5: Algorithm for choosing the correction method in the process of increasing the degree of consistency of pairwise comparisons

Automatic correction has certain limitations associated with situations where there is a low level of consistency and data analysis does not provide useful information [20]. The automatic adjustment process is carried out based on the comparison of the consistency functional (7):

$$\Phi(cos\alpha) = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}}{n^2} \tag{7}$$

calculated based on the cosine matrix. The automatic correction algorithm is shown in fig. 6 Iterative correction procedures are expedient to use under the conditions when there is sufficient consistency of pairwise comparisons in most positions of the matrix of pairwise comparisons, there is useful information about the weights of indicators. At the same time, the advantage of the iterative method is that the correction process is associated with one of the estimates – usually with the element of comparison, which has the lowest level of consistency, and all other adjusted estimates are based on the adjusted primary element [21]. The condition of automatic correction of the matrix of pairwise comparisons corresponds to the situation when the result of the ranking of indicators does not change when the consistency index is brought to an acceptable value. In [22], based on the analysis of the RMSD of the consistency index for matrices of different dimensions, it was found that the probability of rational adjustment of the matrix of pairwise comparisons is the greater,

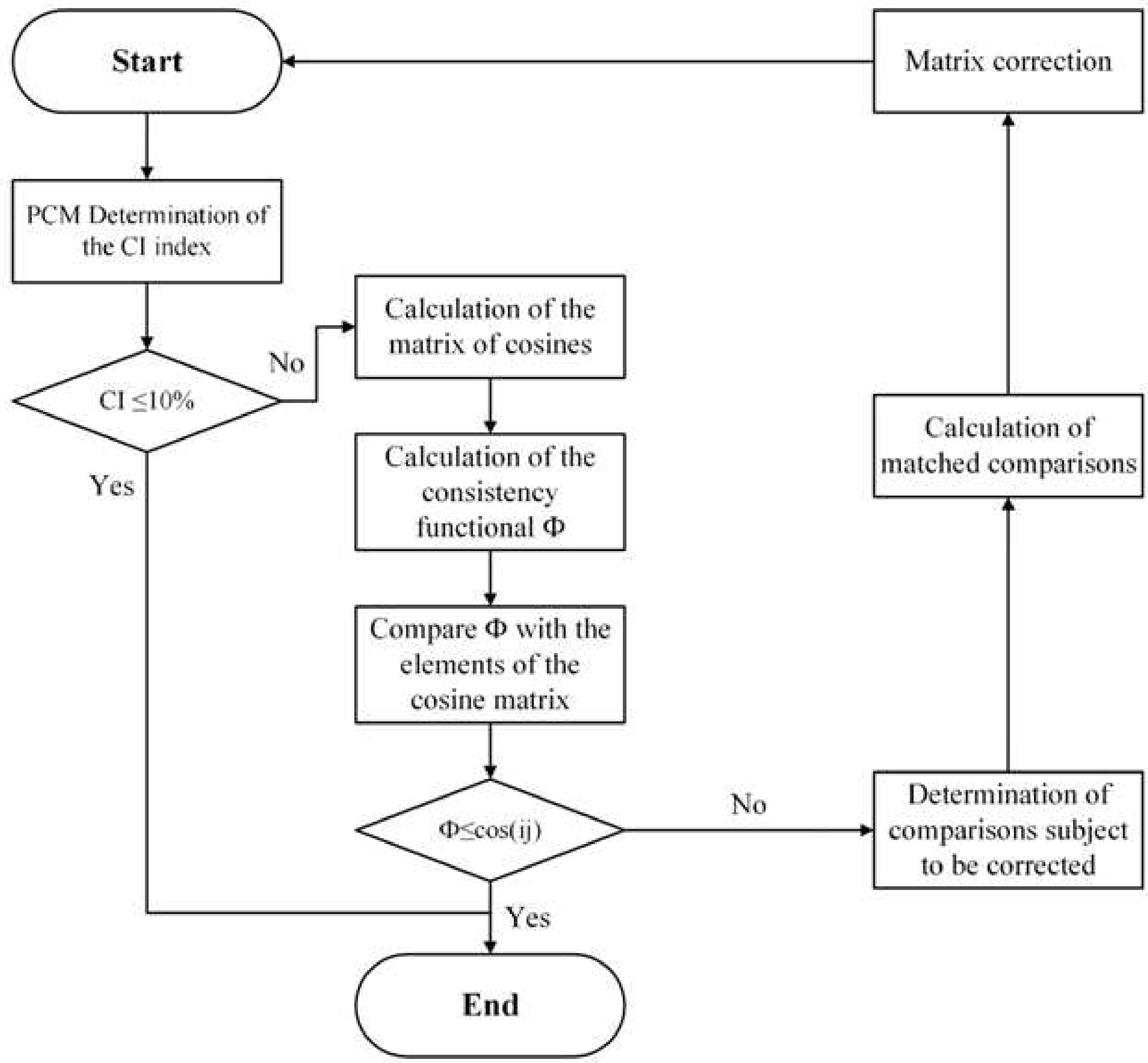

Fig. 6: Algorithm of automatic correction of the matrix of pairwise comparisons

the greater the dispersion of the consistency of judgments, because in these cases it is possible to select the most related expert estimates. According to [22], the zone of rational adjustment corresponds to the Pareto distribution. In the matrix of pairwise comparisons, the RMSD can take a value from 0 to 0.5. According to the Pareto rule, it is proposed to determine the lower limit of the SLE within 20% of the maximum value, that is, at the level of $0.5 \cdot 20\% = 0.1$. Thus, matrices of pairwise comparisons, for which the RMSD of the estimates of the consistency of individual judgments exceed 0.1 ($\sigma > 0.1$), can be corrected by the indicated methods.

4 Cloud IT Service Selection Process

The main operation of the system approach is the division of the whole into its component parts. The task can be divided into subtasks, goals into subgoals, etc. If necessary, this process can be repeated, which will lead to tree-like hierarchical structures. The process of choosing cloud IT services is complex, poorly formalized, poorly structured, so it is important to think through the decomposition operation clearly. One of the methods of simplifying the complex is the decomposition method, which consists in dividing the whole complex into simpler and smaller parts.

In this regard, we justify the decomposition of the concept of solving the problem according to the methodology developed by F.I. Perehudovym and V.Z. Yampolskyi [21]. The global goal - the choice of cloud IT services for implementation in the corporation is based on the formation of a strategy that includes three components: corporate strategy, business strategy and functional strategy. Next, based on the "life cycle" for the functional strategy, we will distinguish (decomposition) the standard stages: data collection and analysis; data evaluation; decision-making [23] (Figure 7).

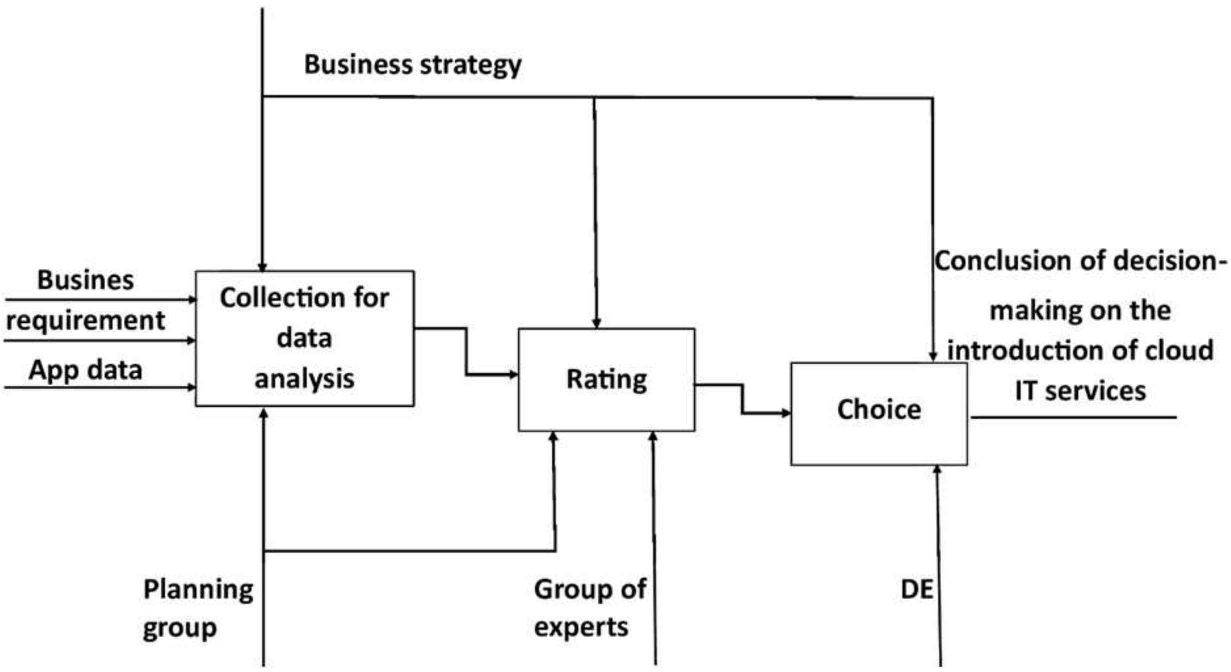

Fig. 7: Decomposition of the decision-making process when choosing cloud IT services

Input information for the analysis will be: definition of high-level business requirements; definition of cloud service model and deployment model; data about providers and applications, etc. At the output of the analysis process, a set of applications will be obtained, which is subject to evaluation. Based on the results of the evaluation, we receive a score for each program, based on which a decision on implementation is made.

The evaluation process according to the feature "goal initiation space" is decomposed into 2 stages: evaluation of effectiveness and evaluation of the possibility of transition.

At the first stage, compliance with the standards is determined, and thus the possibility of using the evaluated applications at the enterprise.

At the second stage, after filtering out applications that cannot be used, an analysis of the possibility of the enterprise transitioning to cloud technologies is carried out in comparison with other alternatives, where their priority for implementation is determined.

The assessment is carried out by a group of experts in accordance with the examination tasks. Figure 8 shows the decomposition of the assessment process. At the end of the evaluation process, we get a matrix of decisions about the implementation of cloud IT services.

At the last stage, "Choice", the DM conclusion is drawn about the introduction of cloud IT services at the enterprise.

A client-server architecture was chosen for this project, which is known to be of two types: with two and three levels. For our system, a three-tier architecture is best suited, which will consist of the following components:

1. The client level is a part of the application that is designed for interaction with the user (User Interface).
2. The server is the part of the application that contains all the business logic of the application. The client layer can access server functions through a hard-defined interface.

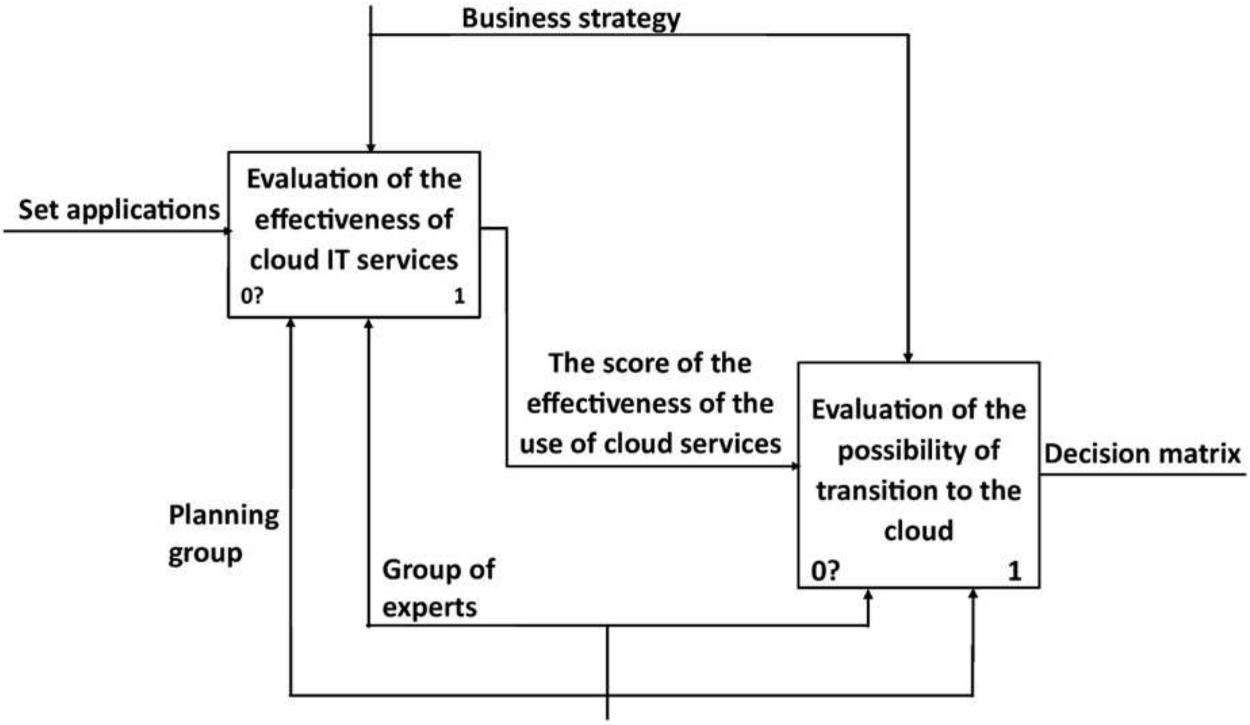

Fig. 8: Decomposition of the assessment process

3. Data Layer - the level of working with the database. This part of the system gives the server access to the database. Choosing this approach guarantees the following advantages:
   –high level of system security;
   –high level of scalability and flexibility;
   –high productivity.

The general scheme of the client-server architecture with three levels is shown in Figure 9.

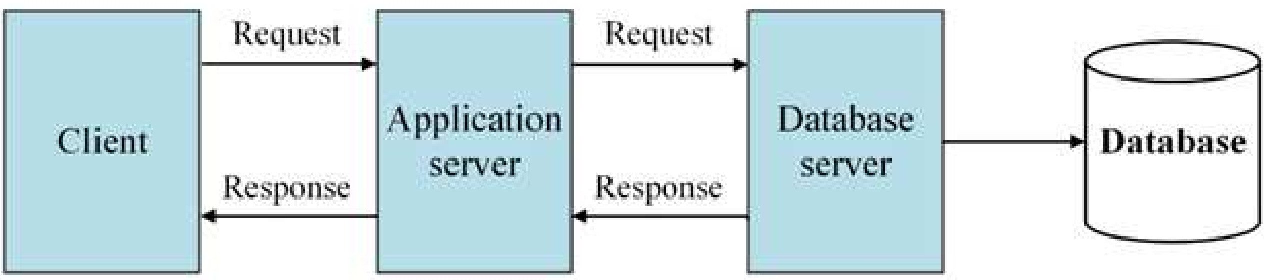

Fig. 9: General diagram of a three-level client-server architecture

Bringing the architecture to the client-server model is at the heart of the REST architectural style for developing API. Thanks to this limitation, the system acquires such desirable characteristics as performance, simplicity and flexibility, scalability, adaptability and ability to change, portability and reliability [24].

The MVC architectural pattern was chosen to design the system. MVC is a scheme of dividing the data layer of the application, the user interface and the logic of the application into three separate and independent components. Thus, the modification of each of the three components can occur independently, which gives advantages in portability and scalability of the system [25]. For the development of the system, the following requirements for technical means were defined:

– programming language – JavaScript;
– programming platform – Node.js;
– development environment – Visual Studio Code;
– database management system – MySQL.

5 Algorithm of the sequence of actions using the proposed decision support models

In the proposed method of decision-making support for the selection of cloud IT services for implementation, the following sequence of actions can be distinguished in the form of a block diagram (Fig. 10), which is used to evaluate and select programs for implementation in the corporation using the proposed models.

For the operation of the project, a database was created on the server, which contains basic data for evaluating the possibility of switching to cloud IT services and choosing the most suitable provider. MySQL was chosen for its development. To store information in the MySQL database, 10 tables were created: experts, applications, providers, services, criteria, weights of criteria of economic value, weights of IS level criteria, cost of applications in the cloud, assessment of the possibility of transition, economic value of transition [26], [27].

The home page of an authorized user consists of several elements (Fig. 11):

– the header, which contains the logo, the information field about the authorized user, the Logout button, which allows you to log out of the user, the navigation menu, which includes the following items (Providers, Reports, Start evaluation, Experts);
– the main part of the page, which is filled with a short instruction for using the system;
– a footer that contains useful information about the developer, contact details, copyright.

6 Conclusion

The paper examines the problems of effective implementation of a cloud IT environment at an enterprise (organization), considering the risks of information security, considers current approaches to the development of models of enterprise (organization) migration to the cloud environment. The authors improved the method of evaluating the implementation of cloud IT environments considering the criteria of information security and developed the DSS for the selection of cloud IT services at the enterprise. The website ”Making decisions when switching to cloud IT services” was developed as a system implementation.

When performing the work, the methods of system analysis, the method of analyzing hierarchies, the method of expert evaluations, and a multi-criteria approach have been used.

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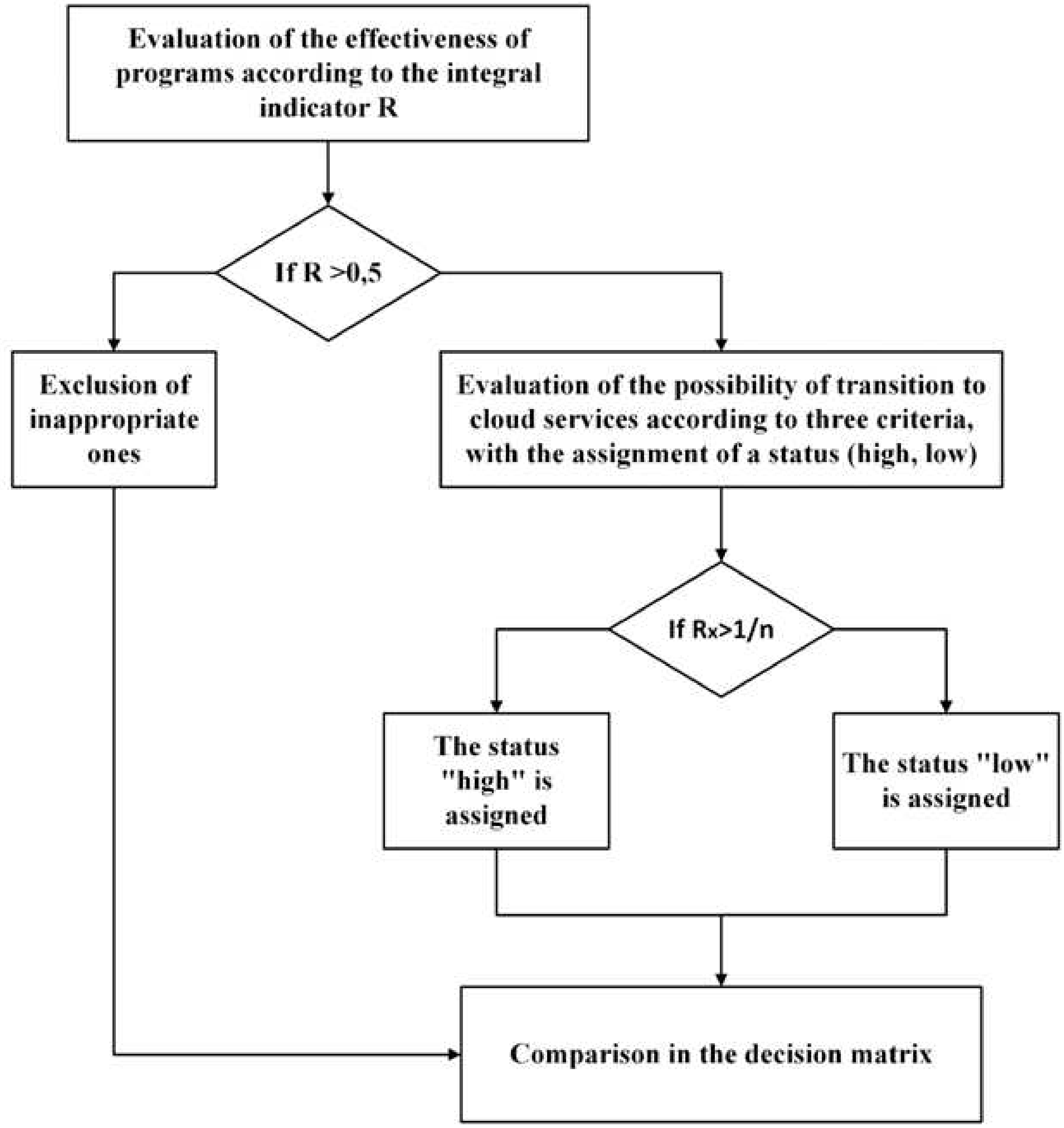

Fig. 10: Scheme of evaluation and selection of cloud IT services for implementation in the corporation using the proposed decision support models

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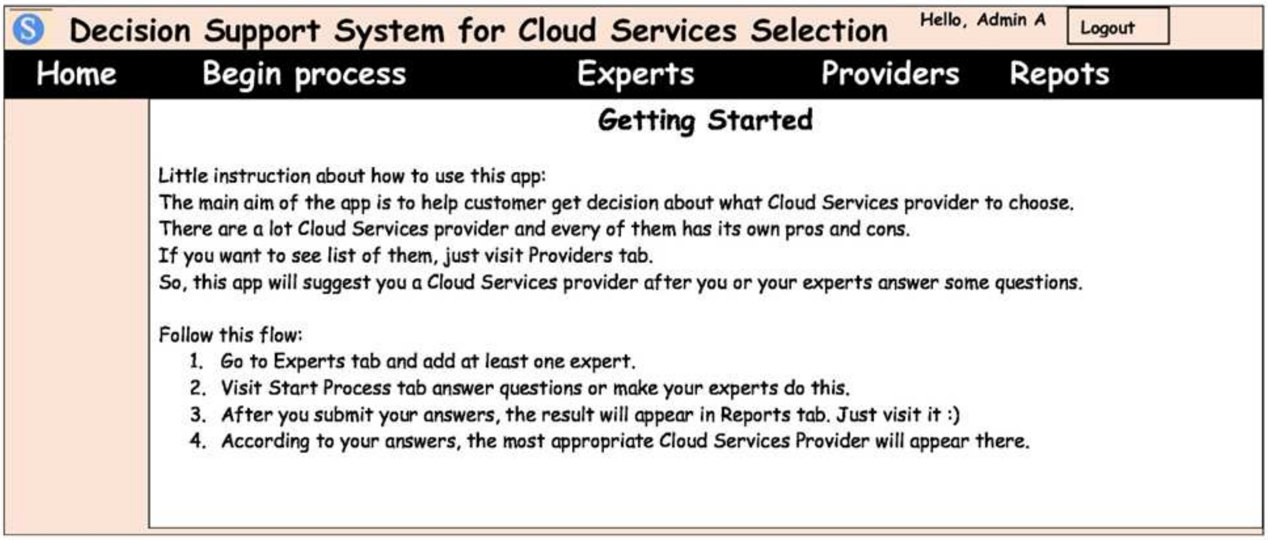

Fig. 11: Home page of the software tool

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