Modelling the Choice of Optimal Structural Business Process Model in a Telecommunications Company

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***Abstract* – This paper considers the problem of optimal structural business process model choice in a telecommunications company using mathematical methods and mathematical model construction. For modelling this problem a hierarchical structure is proposed due to a number of advantages. The paper offers a modified Analytic Hierarchy Process method to solve the given problem that leads to gaining adequate results. The paper discusses the results of modelling and gives recommendations how to increase the efficiency of telecommunications company activity. The recommendations are based on the model calculations obtained.**

***Keywords* – AHP method, business process model, eTOM, graph model, multi-criteria decision problem, pairwise comparison matrix, telecommunication branch**

I. Introduction

Nowadays the Ukrainian telecommunications companies face a problem of activity improvement aimed at granting high-quality services and maintenance of competitive positions on both domestic and foreign markets. To solve this problem, the telecommunications companies must use the mechanism of economic activity focused on the process management; improvement of the end-to-end business processes requires a high level of automation and decrease of operating costs and improvement of the customer service quality. It provides a choice of the optimal structural business process model.

The research paper [11] gives a set of business process structural models of which it is proposed to choose the optimum, as well as substantiation and a detailed description of a set of selection criteria. The alternative structural models include the following: enhanced Telecom Operation Map, Information Technology Infrastructure Library, Control Objectives for Information and related Technology, Telecommunication Process Classification Framework of the American Productivity and Quality Center, Porter's model (Value Chain Model), International Business Language of the PWC, Business Technology Optimization lifecycle approach of the HP.

As the criteria for comparison and choice of various models the following were chosen: openness, systematisation, business or technology orientation, depth of elaboration, appreciation of information technology specificity, appreciation of telecom industry specificity.

To obtain adequate results of optimal telecommunications company's business processes structural model choice, it is important that a decision to be taken is based not only on deductive logic, but also applying appropriate mathematical methods. As a primary element of activity, the decision-making concept considers the decision as a deliberate choice of one of several alternatives. Application of mathematical methods for decision-making involves construction of a mathematical model, which formally represents a problem situation, i.e. a decision-making situation.

The aims of this paper are:

- to build a mathematical model for choosing optimal structural business process model for telecommunications companies;
- to offer a mathematical tool for a systematic approach to decision-making problems, the use of which will lead to adequate results.

The problem of optimal structural business-processes model choice in telecommunication branch should be viewed as a multi-criteria decision problem.

The multi-criteria decision problem is a mathematical model of making the optimal decision according to several criteria that reflect the evaluation of various qualitative and quantitative characteristics of the objects on which the decision is made [8].

It should be noted that in order to analyze and to solve the practical multi-criteria decision problem of optimization, one should apply only those definitions and conceptions, methods and procedures, which would lead to adequate conclusions and recommendations.

II. Hierarchy Model Description

The proposed model for choosing the optimal structural business process model in a telecommunications company is a hierarchical scheme - a weighted graph with the structural relations "consist of". Such structure of model was chosen based on certain advantages of hierarchical models over models of other kinds; namely, they [7]:

- enable investigation of the degree of influence of the priorities of elements of the top levels on the priorities of elements of the bottom levels;
- give detailed information on the structure of the investigated problem;
- are steady, that is small indignations cause insignificant effect;
- are flexible, i.e. addition of elements to a well structured hierarchy does not destroy its characteristics.

So, let's consider, in more detail, the concept of hierarchy. Let «≤» be order fuzzy binary relation in some set of X [4], [13]. For any relation $x \leq y,\ x, y \in X$, it is possible to define the relation $x < y$, which means $x \leq y, x \neq y$. They say that y covers x if $x < y$ and there is no such $z \in X$, that $x < z < y$.

Let X be a finite partially ordered set with the greatest element $\bar{x}$ [7]. The set X is a hierarchy if there is such a partition X into subsetsL_k, $k = \overline{1,h}$, where the $L_1 = \bar{x}$, the following conditions are satisfied:

1) $x \in L_k \implies x^- \subset L_{k+1},\ k = \overline{1, h-1}$, where
$x^- = \{y | x \text{ covers } y\}$;
2) $x \in L_k \implies x^+ \subset L_{k-1},\ k = \overline{2,h}$, where
$x^+ = \{y | y \text{ covers } x\}$.

For each $x \in X$ there exists a weight function, whose value depends on the problem, for which a hierarchy is built:

$$w_x: x^- \to [0,1], \sum_{y \in x^-} w_x(y) = 1$$

Sets L_k are referred to as levels of the hierarchy, and w_x - the priority functions with respect to element x.

So, the hierarchy is a certain type of system, based on the assumption that elements of the system can be grouped in certain sets. Elements of each group are under influence of a certain group and, in turn, affect the elements of other group. We shall consider that elements in each group (levels) of hierarchy are independent.

Thus, the model of an optimal structural business process model choice in the telecommunication branch represents a hierarchy for which $L_1 = \{p\}$, where p corresponds to the investigated problem, and each level of hierarchy L_k corresponds to its elements (to alternatives and criteria of a choice) (Fig. 1).

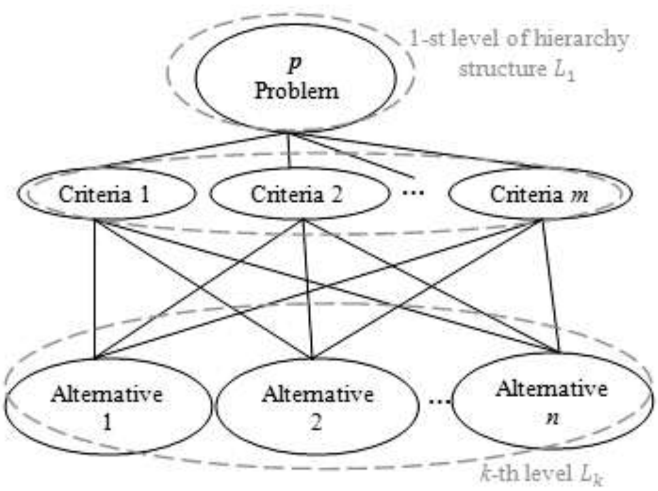

Fig. 1. The structure of the graph model of an optimal structural business process model choice

To achieve the objective of a scientific research, it is necessary to define priorities of the elements of each level of the hierarchy L_k in the constructed hierarchical model concerning the overall objective *(p)* - a choice of optimal structural business process model in a telecommunications company. In other words, we shall define priorities (weight factors) for tops of any level of the root structure of the graph model relative to the top $p = L_1$ which is the maximum element of the hierarchy (the root of the tree).

Let, $X = x_1, \ldots, x_n \subseteq L_k$, and $F = f_1, \ldots, f_m \subseteq L_{k-1}$. It can be seen that $F = L_{k-1}, X = L_k$. Let the element $p \in L_1$, such, that any element of the set F belongs to the set p^-. For each element x_i, $i = \overline{1,n}$ priority of this element ($w_{f_j}(x_i)$) is determined concerning each element $f_j, j = \overline{1,m}$ of the previous level. For each element f_j from a level of hierarchy L_{k-1} its priority $w_p(f_j)$ is determined concerning $p \in L_1$. If we designate as $w(x_i)$ the function of elements' priority from X concerning *p*:

$$w(x_i) = \sum_{j=1}^{m} w_{f_j}(x_i) w_p(f_j). \quad (1)$$

The equation (1) represents the process of weighing the priorities x_i regarding the elements f_j by means of the priorities f_j regarding *p* and can be written down in a matrix form:

$$W = B\overline{W}, \quad (2)$$

where elements of a matrix in which elements are defined as $b_{ij=}w_{f_j}(x_i)$, $i = \overline{1,n}, j = \overline{1,m}$ and elements of vectors W, $\overline{W}$ – are $w(x_i)$ and $w_p(x_j)$, accordingly.

It is obvious, that the process of consecutive calculation of the priorities $x_1, \ldots, x_n \subseteq L_k$ may be continued on induction relative to the elements of levels $L_{k-1}, \ldots, L_1$, thus defining the priorities of any element of the hierarchy regarding the overall objective L_1.

The received priorities of all elements regarding the main objective represent the weight factors of the graph model's tops.

To obtain the values of the weight factors of the graph units from the investigated problem, it is expedient to use the Analytic Hierarchy Process (AHP) method in view of the constructed hierarchical model features.

III. The Analytic Hierarchy Process Model Description and Way of Its Modification

It should be noted that the AHP method is the most reasonable way to solve the multi-criteria decision problems in a complex combination with the hierarchical structures rather than an approach based on linear logic. Applying deductive logic, the decision maker passes a complex way of construction of logic chains, so that afterwards, being based only on intuition, to unite the various conclusions derived from these deductive references. In addition, the approach based on the logic chains cannot lead to the best solution, as the opportunity of reaching compromises between the factors which lay in different circuits of logic thinking can be lost in this case.

It is necessary to consider that, for the decision of the task under consideration, it is necessary to use such principles as identity and decomposition, discrimination, comparison of judgments and synthesizing. The AHP method is based on the following principles: it is a regular procedure for hierarchical representation of the elements, which reflects the essence of any problem. This method consists of decomposition of a problem into simpler components and further processing of the sequence of the decision maker's judgments by pair-wise comparisons. The relative degree of importance (intensity) of the elements' interaction in the hierarchy is expressed as a result. The AHP includes the procedures for synthesis of multiple opinions; getting the priority criteria and finding alternative solutions [10].

But it is also known that at the calculation of the vector of weights, AHP has an implicit modelling error which consists in incompatibility of the matrices of elements of pair-wise comparisons of the hierarchical model, made by experts or decision maker. That is, because those values of elements of the matrix of pair-wise comparisons are formed on the basis of subjective judgments and cannot be precisely measured.

One more powerful disadvantage of the AHP method is that, for the multi-criteria decision problems with qualitative criteria, the application of linear convolution, as it is stipulated by the use of this method, is not justified and the item will not lead to receiving adequate results [9].

Thus, to solve a multi-criteria decision problem, namely, to make a choice of an optimal structural business process model, it is necessary to apply the AHP method with its insignificant modifications, which will lead to gaining adequate results.

So, let's consider in more detail the application of the modified AHP method on the basis of nonlinear criteria convolution for a choice of an optimal structural business process model of a telecommunications company.

First, it is necessary to estimate the importance of separate elements of various levels of the hierarchical model and to find their priorities. For this purpose, according to AHP, there are built pair-wise comparison matrices of the hierarchy elements $A = (a_{ij})$ with dimension $n \times n$ where each element a_{ij} of the matrix of elements relative to weights represents the relation of the *i*-th object weight with the *j*-th object weight:

$$a_{ij} = w_i / w_j$$

Elements of the matrix $A = (a_{ij})$ will be defined by the following rule:

$$a_{ij} = \begin{cases} 1, \text{if elements have the identical importance,} \\ 3, \text{if } w_i \text{ is not more essential than } w_j, \\ 5, \text{if } w_i \text{ is more essential than } w_j, \\ 7, \text{if } w_i \text{ is much more essential than } w_j, \\ 9, \text{if } w_i \text{ absolutely surpasses } w_j. \end{cases}$$

It is necessary to note that on drawing up a pair-wise comparison matrix, the elements a_{ij} can accept values 2, 4, 6 and 8 and their inverse values with the purpose of looking for compromises in an estimation of those elements which almost do not differ from each other.

The substantiation of a nine-mark scale usage at the comparison of the importance (weights) of elements of the hierarchy has been reflected in T.Saati's works [7], [10].

In order to avoid a modelling mistake, the matrix of pair-wise comparisons $A = (a_{ij})_{n \times n}$ should be consistent. Generally, consistency is understood in this way: when there is a basic set of raw data, all other data can be derived logically from them, using the transitive relation [7]. Matrix *A* is called consistent, if $a_{ij} a_{jk} = a_{ik}$ for $i, j, k = \overline{1, n}$, $i \neq j$. A degree of consistency is the maximum or principal eigenvalue of the matrix *A* - λ_{max}, and the corresponding eigenvector provides the orderliness of priorities [1], [2].

That is, the consistent matrix of pair-wise comparisons *A* should possess the following properties:

- All elements of a matrix *A* are positive:

$$a_{ij} = w_i / w_j > 0, \ (i, j = \overline{1, n});$$

- The matrix *A* is inverse symmetric:

$$a_{ij} = w_i / w_j = 1 / {}^{w_j}\!/_{w_i} = 1 / a_{ji}, (i, j = \overline{1, n});$$

$$a_{ii} = w_i / w_i = 1, (i = 1,2, \dots, n).$$

- The matrix *A* - is compatible:

$$a_{ik} a_{kj} = \frac{w_i}{w_k} \cdot \frac{w_k}{w_j} = \frac{w_i}{w_j} = a_{ij};$$

$$a_{ij} = a_{ik} a_{kj}, \text{ for all } i, j, k = \overline{1, n};$$

- Number *n* equals to the maximum eigenvalue (λ_{max}) of the consistent invertible symmetric matrix *A* [7], [2], and a normalized vector-column $w = (w_1, w_2, \dots, w_n)^T$ is a sole one corresponding to the correct matrix eigenvector, that is:

$$A(w) = nw.$$

Let's note that at the realization of AHP in practice, it appears that the strict inequality is satisfied $\lambda_{max} > n$ and the components $w_1, w_2, \dots, w_n$ of the vector of weights will not be coordinated with the data contained in the matrix of pair-wise comparisons $A = (a_{ij})_{n \times n}$, namely, the equality $a_{ij} = w_i / w_j$ is broken.

To avoid a modelling mistake, it is proposed to form a matrix of pair-wise comparisons $A = (a_{ij})_{n \times n}$ for each level of the hierarchical model based on the data only about certain basic elements [14]. A basic set is understood as a minimal by quantity defining set of the matrix elements. The choice of the certain basic set of elements depends on the scheme of comparison of objects, which will ensure the most reliable results from the expert.

To solve this multi-criteria decision problem, we have chosen the construction of the set of pair-wise comparison matrices based of the first-row elements.

Proceeding from the properties 1) - 2), the elements from the main diagonal of the matrix A – are known and equal to one. Further, the expert (decision maker) compares the first object with the weights of other elements of the matrix's first row; therefore, we receive the value $a_{11}, a_{12}, \ldots, a_{1n}$. The described method for finding elements from the first line of the matrix of pair-wise comparison has been entitled "the Scheme of comparison with the sample" [14] in whose role the first object acts.

Other elements of the matrix of pair-wise comparison are on the basis of the properties 2) - 3):

$$a_{ij} = a_{i1}a_{1j} = a_{1j}/a_{1i}, \quad i,j = \overline{1,n}. \tag{4}$$

Let's note that the matrix A constructed on the basis of the first-row elements according to the formula (4), will satisfy to the properties 3) - 4) [12], [14].

After the matrix $A = (a_{ij})_{n\times n}$ is generated by means of the formula (4), it is necessary to calculate a vector of priorities on the given matrix; in mathematical terms, finding the main eigenvector of weights which after normalization becomes a vector of priorities:

$$w = (w_1, w_2, \ldots, w_n)^T$$

Its components are calculated by the formula:

$$w_i = a_{1n}/a_{1i}, \; i = \overline{1,n} \tag{5}$$

The vector of weights w, calculated by formula (5) mismatches the requirement of rationing as its last component is equal to one. With the purpose for rationing of a weights vector of elements from hierarchical model, we use the formula:

$$\acute{w_i} = w_i / \sum_{i=1}^{n} w_i \tag{6}$$

As a whole, the proposed in [14] modification of the method appears essentially easier than the initial method, both at the stage of formation of the matrices of pair-wise comparison and during finding the weight vector. Besides, it is completely relieved of a modelling mistake as it satisfies the properties of compatibility of the matrices of pair-wise comparisons.

The next step is to determine the final priorities of elements of the hierarchical model concerning the overall objective by the formula (1) or (2).

It should be noted that the use of AHP, on which the linear convolution of criterions (1) is based, is not always admissible and motivated, especially for the multi-criteria decision problems with a finite set of possible decisions.

More universal, from the point of view of the scope of application, is nonlinear convolution:

$$\min_{j=\overline{1,m}} w_{f_j}(x_i) w_p(f_j), \; i = \overline{1,n} \tag{7}$$

which is proved by the leading Russian scientist V.G. Nogin based on Y.B.Germejer's theorem and whose application is proved for the widest class of multi-criteria problems with a finite set of admissible decisions [14], [15].

According to the proof, if the following conditions are simultaneously met:

1) the set of possible decisions is finite;
2) the set of criteria on it is positive;
3) the person, who makes decisions, operates rationally[5],

any decision chosen can be received as a result of maximization of the function – $\min_{j=\overline{1,m}} w_{f_j}(x_i) w_p(f_j), i = \overline{1,n}$, in the set X with the certain positive weight factors.

The initial two conditions for this class of multi-criteria problems are satisfied, as the set of possible decisions (as well as the quantity of criteria) is finite and values of criteria are positive, if they are calculated on the basis of AHP. Satisfaction of the third condition is also obvious. Thus, the application of specified nonlinear convolution for the solution of a multi-criteria decision problem is considered and proved.

So, for the solution of a practical multi-criteria problem with a finite set of possible decisions for the choice of an optimal structural business process model in a telecommunications company, is such $x^* \in X$, for which:

$$x^* = \arg\max_{x\in X} \min_{j=1,m} w_{f_j}(x_i) w_p(f_j), \; i = \overline{1,n} \tag{8}$$

For the solution of a practical multi-criteria decision problem with a finite set of possible decisions for the choice of an optimal structural business-processes model in a telecommunications company it is advisable to use a modified AHP method.

IV. Practical Realization

During the research, the full dominant hierarchy by T.Saati was constructed. Levels of the given dominant hierarchy are in the order of subordination from the top down:

1) on the upper level - the basic problem is the choice of an optimal structural business process model in a telecommunications company;
2) on the second level – criteria, on which the structural models are estimated and selected, namely: openness, systematisation, business or technology orientation, depth of elaboration, appreciation of information technology specificity and appreciation of telecom industry specificity;
3) on the lower level - 7 basic alternatives of the choice, namely, various structural business process models.

Thus, the model for choice of an optimal structural business process model in the telecommunication branch represents a three-level hierarchy which is shown in Fig. 2.

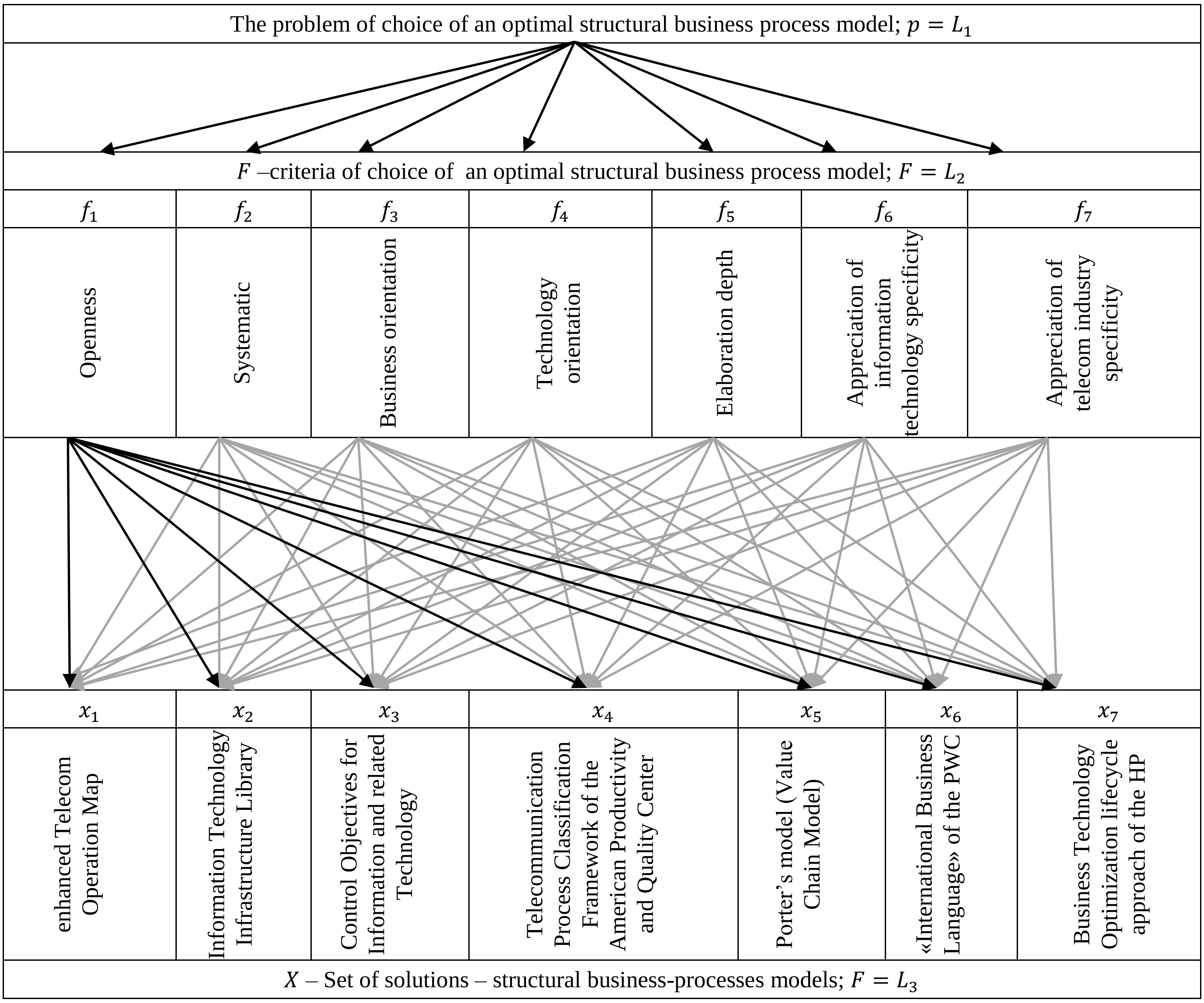

Fig. 2. The structure of the hierarchical model for choice an optimal structural business process model in telecommunication branch.

Being based on the results of a comparative analysis of a set of structural business process models after various criteria, which are specified in [11], it is necessary for the decision maker to construct matrices of pair-wise comparison using (4) and to calculate vectors of priorities using (5), (6), namely:

- matrix of pair-wise comparison of criteria $f_j, j = \overline{1,m}$ in relation to the main objective p;
- seven matrices of pair-wise comparison of alternatives $x_i, i = \overline{1,n}$ in relation to each criterion $f_j, j = \overline{1,m}$.

The result of modelling calculations by the modified AHP is the vectors of priorities of the hierarchical model elements received on the basis of matrices of pair-wise comparison and synthesis of general priorities of the choice alternatives regarding the objective (Tab. I).

As shown in Tab. 1, an optimal structural business process model in a telecommunications company is enhanced Telecom Operation Map (eTOM) - a systemic, high-level business-oriented model aimed at providing any technological services, including IT.

V. Conclusions

So, as a result of the research, a mathematical hierarchical model for the choice of an optimal structural business process model in telecommunications companies is proposed. It is the first time that a method for calculation of weight factors of a graph hierarchical model of a decision-making problem based on techniques of pair-wise comparisons is proposed. But the proposed way of calculation of weight factors of the graph model units and definition of the optimum decision is based on the use of the modified AHP method, which will allow avoiding certain modelling mistakes in the choice of an optimal structural business process model and will yield adequate results.

TABLE I

CALCULATION OF THE GENERAL PRIORITIES OF THE CHOICE ALTERNATIVES REGARDING THE OBJECTIVE

Criteria $f_j, j = \overline{1,7}$	f_1	f_2	f_3	f_4	f_5	f_6	f_7	Total priority (linear convolution of criteria), (1)	Total priority (nonlinear convolution of criteria), (7)
Weight $w_p(f_j)$	0,15	0,45	0,08	0,05	0,08	0,05	0,15		
Alternatives $x_i, i = \overline{1,7}$	Weight relative to the criteria $w_{f_j}(x_i)$								
x_1	0,14	0,31	0,22	0,08	0,39	0,14	0,40	**0,275556**	**0,0038462**
x_2	0,14	0,10	0,04	0,23	0,08	0,28	0,08	0,114187	0,0032609
x_3	0,14	0,10	0,04	0,23	0,08	0,28	0,08	0,114187	0,0032609
x_4	0,14	0,31	0,22	0,08	0,19	0,07	0,20	0,227445	0,0035545
x_5	0,14	0,06	0,22	0,08	0,08	0,03	0,08	0,088374	0,0014218
x_6	0,14	0,06	0,22	0,08	0,13	0,05	0,08	0,093204	0,0023697
x_7	0,14	0,06	0,04	0,23	0,06	0,14	0,08	0,087047	0,0032609

As a result of the research carried out on the basis of modelling calculations, recommendations are received for increasing activity efficiency of a telecommunications company, namely, the optimal structural business process model eTOM is defined as a structural business process model, which covers all aspects of activity of a service provider and other companies of the telecommunication branch.

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Olga Korzačenko. Telekomunikācijas nozares uzņēmuma optimālā biznesa procesu strukturālā modeļa izvēles modelēšana
Šajā rakstā aplūkots telekomunikāciju nozares uzņēmuma optimālā biznesa procesu struktūrmodeļa izvēles problēmas risinājums, kas balstīts uz matemātisko metožu izmantošanu un matemātiskā modeļa izveidi. Izvēles problēmas modelēšanai tika piedāvāta hierarhiskā struktūra, ņemot vērā virkni tās priekšrocību, kā analizējamās problēmas struktūras detalizēts atainojums, iespēja izpētīt augstāko līmeņu elementu prioritāšu ietekmes pakāpi uz zemāko līmeņu elementu prioritātēm, elastīgums un noturība. Darbā piedāvātais optimālā telekomunikāciju nozares biznesa procesu struktūrmodeļa izvēles modelis pēc savas būtības ir hierarhija – svērtais grafs ar struktūras saiknēm „sastāvēt no”, kuru elementi ir alternatīvas un izvēles kritēriji, kas izvietoti dažādos grafa modeļa sakņu struktūras līmeņos (attiecībā pret galotni – galveno mērķi). Lai sasniegtu zinātniskā pētījuma mērķi, darbā ir noteiktas prioritātes (svara koeficienti) katra līmeņa virsotnēm modeļa grafa sakņu struktūrā attiecībā pret virsotni, kas ir hierarhijas maksimālais elements. Tika noteikts, ka pētāmās problēmas grafa virsotņu svara koeficientu vērtību iegūšanai ir izdevīgi izmantot hierarhiju analīzes metodi, kas balstās uz identiskuma, dekompozīcijas, diskriminācijas, spriedumu

salīdzināšanas un sintezēšanas principiem, ņemot vērā izveidotā hierarhiskā modeļa īpatnības. Rakstā izanalizēta hierarhiju analīzes metodes izmantošana, risinot nosprausto problēmu, kā arī norādīti tās trūkumi, un, precīzāk - elementu pāru salīdzinājumu matricu nesaskaņotība un lineāro kritēriju konvolūcijas izmantošanas nelietderība, izvēloties optimālo risinājumu. Ņemot vērā iepriekšminēto, tika piedāvāts izmantot modificēto hierarhiju analīzes metodi, kas ļaus iegūt adekvātus rezultātus. Darbā sniegti modelēšanas rezultāti un, balstoties uz modeļu aprēķiniem, iegūti ieteikumi telekomunikāciju nozares uzņēmuma darbības efektivitātes uzlabošanai, un, precīzāk, optimālā biznesa procesu struktūrmodeļa eTOM ieviešanai.

Ольга Корзаченко. Моделирование выбора оптимальной структурной модели бизнес-процессов предприятия телекоммуникационной отрасли
В данной статье рассмотрено решение проблемы выбора оптимальной структурной модели бизнес-процессов предприятия телекоммуникационной отрасли, которое основывается на применении математических методов и построении математической модели. Для моделирования проблемы выбора была предложена иерархическая структура из-за ряда её преимуществ, а именно: детализированное представление структуры исследуемой проблемы; возможность исследовать степень влияния приоритетов элементов верхних уровней на приоритеты элементов нижних уровней; гибкость; устойчивость. Предложенная в работе модель выбора оптимальной структурной модели бизнес-процессов телекоммуникационной отрасли представляет собой иерархию – взвешенный граф со структурными соотношениями «состоять из», элементами которой являются альтернативы и критерии выбора, расположенные на разных уровнях корневой структуры графа-модели относительно вершины – главной цели. Для достижения цели научного исследования в работе определены приоритеты (весовые коэффициенты) для вершин каждого уровня корневой структуры графа-модели относительно вершины, которая является максимальным элементом иерархии. Определено, что для получения значений весовых коэффициентов вершин графа исследуемой проблемы, целесообразно использовать метод анализа иерархий, который основывается на принципах идентичности, декомпозиции, дискриминации, сравнения суждений и синтезирования, учитывая особенности построенной иерархической модели. В статье проанализировано использование метода анализа иерархий для решения поставленной проблемы, также указано на его недостатки, а именно несогласованность матриц попарных сравнений элементов и нецелесообразность использования линейной свертки критериев при выборе оптимального решения. Принимая это во внимание, было предложено использование модифицированного метода анализа иерархий, что приведет к получению адекватных результатов. В работе приведены результаты моделирования и на основе модельных расчетов получены рекомендации по повышению эффективности деятельности предприятия телекоммуникационной отрасли, а именно, внедрение оптимальной структурной модели бизнес-процессов eTOM.