UDC 65.014.12
DOI: 10.15587/2312-8372.2017.109117

Hodakov V.,
Kozel V.,
Sokolov A.

ANALYSIS OF INFORMATION TECHNOLOGY OF THE MANAGEMENT SYSTEM OF THE HIGHER EDUCATIONAL INSTITUTION

Виконано аналіз впливу зовнішніх факторів на діяльність вищого навчального закладу. Запропоновано алгоритм формування та оптимізації схеми руху інформаційних потоків в системі управління ВНЗ. Розроблено алгоритм оптимізації руху інформаційних потоків на рівні показників. Запропоновано формальну модель ВНЗ, яка дозволяє враховувати внутрішні та зовнішні чинники, які безпосередньо впливають на якість системи управління. Виявлено переваги та недоліки моделі і пропозиції щодо вдосконалення інформаційної моделі ВНЗ.

Ключові слова: *система керування, інформаційний потік, зовнішнє середовище, система інформаційного обслуговування.*

1. Introduction

Innovations in the management of higher education institutions (HEIs) on the basis of information technologies are a key mechanism that allows raising the level, quality of education and, as a consequence, the competitiveness of the educational institution. Designing information management systems and improving them (reengineering) is always connected with the analysis of information flows circulating in the system and the external environment. To design a management system and relevant information technologies, it is necessary to analyze the information flows that circulate during the operation of the system.

In the process of life, HEIs improve, adjust the strategic goals of their activities and, naturally, make the necessary changes in the structure of the management system, including the HEI organizational structure, introducing, for example, new units.

Therefore, one of the main conditions for the effective functioning of the management system is a constant analysis of information flows. The flow displays interaction with both the external environment and internal divisions. The analysis of flows makes it possible to establish rational links between sources and receivers of information and ways of its circulation. These aspects are prerequisites for reengineering new information technology, the purpose of which is improvement, in order to increase the efficiency of the activity of the higher education institution, including the quality of education. Thus, the task of analyzing information flows in the HEI is relevant.

2. The object of research and its technological audit

The object of research is the system of management of a higher educational institution. Higher educational institution is a complex organizational, technical and socioeconomic system, bound by specific relationships with many objects and the external environment (Fig. 1).

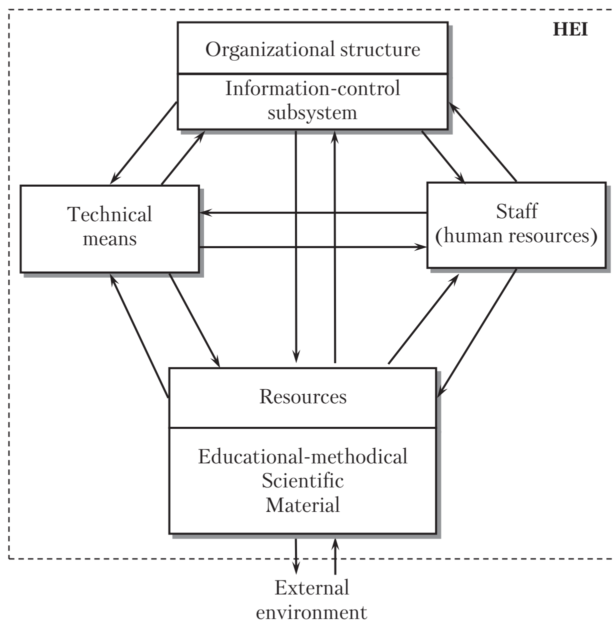

Fig. 1. HEI information structure

Here are the features that characterize HEI as a complex anthropogenic dynamic system:

– HEI structure is non-stationary. Changes occur both as a result of internal development, and regular and accidental influences of the environment;
– most of the state parameters are non-stationary;
– the presence of a large number of nonlinear dependencies;
– a set of feedbacks;
– lack of a final planning horizon.

One of the most problematic places in the HEI management system is the lack of consideration of the influence of external and internal factors that influence the HEI activity.

The main conditions for building a model of management of a higher education institution on the basis of information technologies are as follows:

– analysis of the external environment for the main functions of the HEI;
– reengineering of HEI information model based on the analysis of information flows;
– improvement of the HEI unified information environment.

3. The aim and objectives of research

The aim of research is introduction of information technology and building of a model of HEI management system. The model should reflect the impact of HEI external impacts through the analysis of information flows to improve the management quality.

To achieve this aim, it is necessary to solve the following tasks:

1. To identify the list of main external and internal factors affecting the HEI activity.
2. To determine the role and place of the model of information flows in the general model of the functioning of a higher education institution.

4. Research of existing solutions of the problem

The issues of building management systems in higher education and reforming the education system in recent years are reflected in a number of works [1–5].

The society does not always have an understanding of the relationship between the education system and the country's economy, region, understanding that higher education is the primary and the basis of the state's welfare [2, 5].

The problems of supporting the development of the education system are social and are among the priorities for the development of society and the state. The education system is directly related to national interests and national security, based on definitions [1]. Education prepares the future of the country by training personnel for all the environments of the state [5]. At the same time, the prospects for the development of the education system can't be considered only through the prism of the economy, it is necessary to move from economic centrism to socio-centrism and cultural centrism [6].

Education is a primary, prerequisite, pre-economic resource capable of awakening the economy, bringing dynamism into it, providing a leap in the development of production. Education creates the foundation for the welfare of society and is the guarantor of the independence of the nation [5].

Currently, the education system of Ukraine, like many other industries, refers to losing their positions in Europe and the world. It is necessary to re-engineer the management processes of the higher education system, to bring the number of graduates to the needs of the economy in line with the development prospects.

To the construction of models of HEI management there are various approaches, for example, Weber's classic approach, which studied the model of the HEI activity from the standpoint of a bureaucratic organization. Veblen viewed the HEI as a capitalist organization, and Parsons analyzed the HEI from the position of the social system.

The author [7] argues that a competitive model of HEI management should be based on the principles of strategic management, quality management, budgeting and information integration of processes.

HEI structure should be viable, flexible and dynamic, allowing to solve the problems of the development of the country's economy, therefore the development of a scientifically grounded system of management of a higher educational institution in modern conditions is urgent [7, 8].

The complex approach proposed in [9–11] involves the implementation of the educational process, but does not consider the system from the position of management.

The paper [12] identifies the main problems of integration in the development of a HEI unified information environment. The ways of solving all integration problems are fulfilled with the help of the web service.

Another approach [13] considers only the quality of education and offers an evaluation of the potential and HEI overall evaluation. The model [14] considers the education system from a physical point of view, but does not take into account the influence of economic factors and the labor market.

Using the approaches of scientists [15, 16] allows to analyze the influence of the experience of lecturing on the quality of education, but do not determine the influence of external factors on the education quality.

Ukraine declared its adherence to world trends and experience. However, this is not fully achieved, because economic, political and other factors are special for each country and not just to adapt the experience of other countries.

5. Methods of research

To analyze the object of research and develop information models, elements of the constructive theory and problem-oriented tools of formalization and modeling of the information movement processes are used. The analysis of information interaction between the HEI units is based on the complex use of graph theory – for the implementation of decisions on the collection of primary information. The theory of sets and queuing systems (QSs) is used to construct traffic flow models and to evaluate the effectiveness of using information processing tools and modeling the operation of software components.

6. Research results

Any educational institution interacts with the external environment, in connection with which it is necessary to adapt to changes, for sustainable functioning, because of this, HEI is regarded as an «open system». An open system depends on energy, information, entrants, decisions of MES, which come from the external environment. Any HEI has a connection with the external environment and depends on it.

From the point of view of the system approach, HEI is a system for converting input information and resources into final products, in accordance with their goals. The main factors that have a direct and indirect impact on HEI are shown in Fig. 2.

Let's consider some direct factors of influence:

– the market of entrants is determined by the economy, culture and population of the country. As can be seen from the graph in Fig. 3, the population in Ukraine catastrophically falls, and therefore the number of potential entrants is proportionally reduced;
– there is an economic downturn in the country, which leads to a reduction in jobs, which entails an overabundance of HEI graduates and an inconsistency between

 ISSN 2226-3780

budget orders and jobs. The economic situation in Ukraine today is about 50 % of the 1991 economy, which means that the need for HEI graduates is decreasing;
– labor resources that train specialists in the HEI are directly related to HEI internal structure.

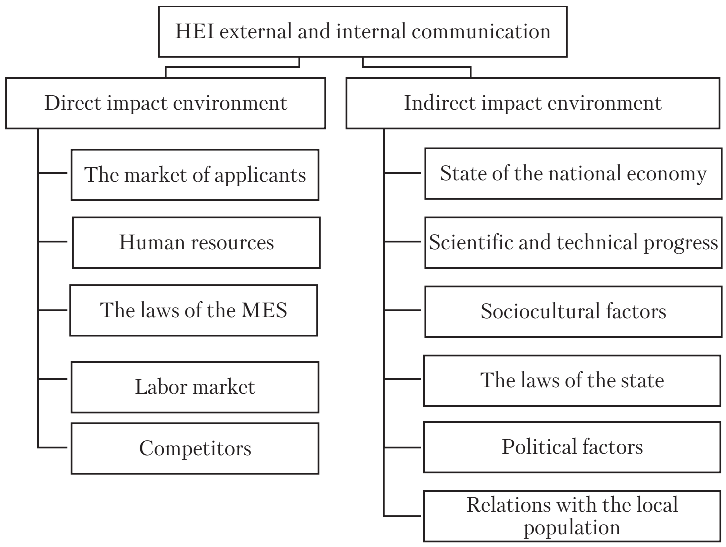

Fig. 2. Factors influencing the HEI activity

Thus, the influence of external factors on HEI activity has a direct impact and these factors should be taken into account when building the HEI information model. Organizational structure is an HEI internal component, which directly affects the HEI effectiveness.

The main features of the organizational structure are the division into separate components: faculties, departments, etc. At the same time, the activities and functioning of individual structures must necessarily be coordinated. At HEI, coordination functions are performed by the head – rector, implementing the coordination management [5].

As can be seen from the structure, it displays the degree of subordination, but does not carry any information about information flows and coordinating functions. Taking as a basis the HEI organizational structure and conducting its analysis with information flows, we have the opportunity to re-engineer the management system, which makes it possible to increase the HEI efficiency.

Let's consider the movement of information flows within the HEI organizational structure. The condition for the effective functioning of the management system is the monitoring and analysis of information flows, the establishment of rational links between sources and receivers of information.

Let's introduce the following definitions. An information flow is a partial movement of data from one packet of information to another. A package of information is a set of information data, united by any parameters or characteristics and representing a single block of information. The information indicator is a part of the information package that directly participates in the information flow. An information model is a scheme for the movement and interaction of information in the system, displaying a complete understanding of the relationships and paths of data without indicating the physical properties of the object.

The most popular representation of the information flow is its mapping in the form of an oriented graph [1, 3], which vertices are information packets, and the edges – the transfer of data from one packet to another.

The solution of this task does not cause difficulties with a small number of information packets, however, with the increase in their number, there is duplication, data loss, redundancy. In this connection, the task is to develop an algorithm for converting an information flow into a graph, taking into account information indicators.

The implementation of this algorithm consists of a number of steps.

Step 1. All the set of information packets $A=\{a_{ij}\}$ will be conditionally divided into three groups (subsets) (Fig. 3):
– packets arriving at the system, $A_1=\{a_{i1}\}$, $i=1,2,...,f_1$, where f_1 is the maximum number of incoming packets;
– packets circulating within the system $A_2=\{a_{i2}\}$, $i=1,2,...,f_2$, where f_2 is the maximum number of internal packets;
– outgoing information packets, $A_3=\{a_{i3}\}$, $i=1,2,...,f_3$, where f_3 is the maximum number of outgoing packets.

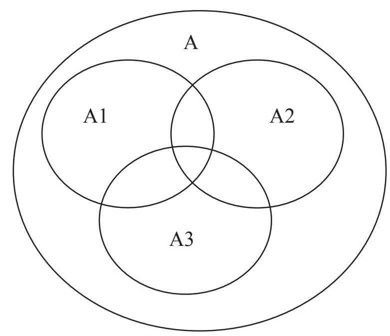

Fig. 3. The distribution of the set A into subsets A_1, A_2, A_3

Thus, let's describe the entire set of information packets as:

$$A=A_1\cup A_2\cup A_3. \quad (1)$$

The result of the separation of information flows into subsets is shown in Table 1.

Table 1

The distribution of the set A into subsets A_1, A_2, A_3

Set A_1	Set A_2	Set A_3
a_{i1}	a_{i2}	a_{i3}
…	…	…
$a_{f_1 1}$	$a_{f_2 2}$	$a_{f_3 3}$

Step 2. Let's number the lines for each set A_1, A_2, A_3 in the following way. Let's use the set $B=\{b_{mn}\}$ as the numerator, where m – the row number, n – the attribute of belonging to one of the sets A. Since there are 3 sets, then $n=\overline{1,3}$. Given the fact that the number of threads in each subset is different, the number of rows filled will be different.

Table 2

Numbering of subsets A_1, A_2, A_3

No.	Set A_1	№	Set A_2	№	Set A_3
b_{11}	a_{i1}	b_{12}	a_{i2}	b_{13}	a_{i3}
…	…	…	…	…	…
$b_{m_1 1}$	$a_{f_1 1}$	$b_{m_2 3}$	$a_{f_2 2}$	$b_{m_3 3}$	$a_{f_3 3}$

Step 3. Each packet of information consists of a set of indicators $a_{ij} = \{p_{xy}\}$ and it is formed due to the partial transfer of data $p_{x_k y_r}$ from other information packets $a_{i_k j_r} = \{p_{x_k y_r}\}$. Let's write this as follows: a_{ij} $(a_{i_1 j_1}, ..., a_{i_k j_r})$; in parentheses, a lot of information packets that participate in creating a package a_{ij} are displayed. Thus, Table 2 is transformed in Table 3.

Table 3

Packages of information and their components

No.	Set A_1	No.	Set A_2	No.	Set A_3
b_{11}	$a_{i1}(a_{i_1 j_1}, ..., a_{i_k j_r})$	b_{12}	$a_{i2}(a_{i_1 j_1}, ..., a_{i_k j_r})$	b_{13}	$a_{i3}(a_{i_1 j_1}, ..., a_{i_k j_r})$
…	…	…	…	…	…
$b_{m_1 1}$	$a_{f_1 1}(a_{i_1 j_1}, ..., a_{i_k j_r})$	$b_{m_2 3}$	$a_{f_2 2}(a_{i_1 j_1}, ..., a_{i_k j_r})$	$b_{m_3 3}$	$a_{f_3 3}(a_{i_1 j_1}, ..., a_{i_k j_r})$

Step 4. Since all the information packets are numbered, let's replace the expression $a_{ij}(a_{i_1 j_1}, ..., a_{i_k j_r})$ by an equivalent one $a_{ij}(b_{i_1 j_1}, ..., b_{i_k j_r})$, as a result get Table 4.

Table 4

Information packets with numbering

No.	Set A_1	No.	Set A_2	No.	Set A_3
b_{11}	$a_{ij}(b_{i_1 j_1}, ..., b_{i_k j_r})$	b_{12}	$a_{ij}(b_{i_1 j_1}, ..., b_{i_k j_r})$	b_{13}	$a_{ij}(b_{i_1 j_1}, ..., b_{i_k j_r})$
…	…	…	…	…	…
$b_{m_1 1}$	$a_{i_k j_k}(b_{i_1 j_1}, ..., b_{i_k j_r})$	$b_{m_2 3}$	$a_{i_k j_k}(b_{i_1 j_1}, ..., b_{i_k j_r})$	$b_{m_3 3}$	$a_{i_k j_k}(b_{i_1 j_1}, ..., b_{i_k j_r})$

Step 5. To reduce the duplication of information packets belonging to different subsets, let's construct the Table 5 in several vertices of the graph on the basis of data from Table 4.

Table 5

Mapping the vertices of a graph with information packets

No. of vertice	Set A_1	Set A_2	Set A_3
1	b_{i1}	$b_{i_k 2}$, if $a_{i_k 1} = a_{i_k 2}$	$b_{i_k 3}$, if $a_{i_k 1} = a_{i_k 3}$
…		b_{i2}, if $a_{i_k 1} \neq a_{i_k 2}$	$b_{i_k 3}$, if $a_{i_k 2} = a_{i_k 3}$
z			b_{i3}, if $a_{i_k 2} \neq a_{i_k 3}$

Step 6. Filling in Table 5, let's proceed to the direct construction of the graph. Let's take the vertices of the graph in an arbitrary order on the basis of Table 5, the number of vertices from 1 to z (Fig. 4).

Then, using Table 5, let's determine the value of b_{ij}, from the number of the vertex z_i, and from Table 4 on the found value b_{ij} is determined $a_{ij}(b_{i_1 j_1}, ..., b_{i_k j_r})$. Based on the list $a_{ij}(b_{i_1 j_1}, ..., b_{i_k j_r})$ in Table 5 we look $(z_1, ..., z_k)$ for the vertices corresponding to $(b_{i_1 j_1}, ..., b_{i_k j_r})$, and connect the vertices $(z_1, ..., z_k)$ with the vertex z_i by arcs directed to the vertex z_i (Fig. 5). Thus, these arcs serve as edges.

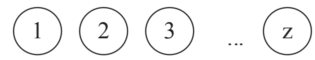

Fig. 4. Vertices of the information flow graph

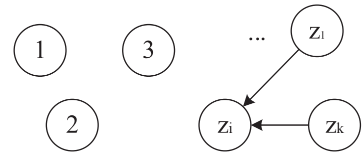

Fig. 5. Graph of information flows

As a result, let's obtain a graph model of the system in the form of an oriented graph, in which all interactions between the information packets are indicated in an arbitrary order. Let's call this graph an unordered graph. Thus, an unordered graph carries in itself visual information of the interaction of only two vertices, and does not give complete information on the influence of some information flows on others.

It is necessary to convert an unordered graph into an ordered graph, which will allow to split the entire set of information flows into levels.

To do this, the entire set of information data $A = \{a_{ij}\}$ is presented in the form of a set of documents $D = \{d_{ij}\}$, where $i \in I$, $j \in J$, and information packets – in the form of documents. The whole set of information data of the control object can be represented in the form of four sets:

$D_1 = \{d_{i1}\}$ – set of input documents;

$D_2 = \{d_{i2}\}$ – set of output documents;

$D_3 = \{d_{i3}\}$ – set of intermediate documents;

$D_4 = \{d_{i4}\}; D_4 = D_1 \cap D_2 \setminus D_3$ – set of transit documents.

It is possible to assume that $D = D_1 \cup D_2 \cup D_3$, then we can talk about the decomposition of the component parts, and the first level of the graph information model (GIM1) is the set of vertices of all documents $D = \{d_i\}$ and the set of arcs $U = \{u_j\}$ connecting these vertices:

$$G = (D, U), \tag{2}$$

where $D = \{d_i\}$ – the set of vertices of the graph G; $U = \{u_j\}$ – the set of arcs of the graph G, $\mathrm{i} = \overline{1,n}$; $j = \overline{1,m}$.

Thus, the initial information model of information flows can be represented as an oriented non-planar graph, as shown in Fig. 6.

Let's introduce the following definitions. The vertices d_i and d_j are called weakly connected in the graph G if there exists a path from d_i to d_j under the condition $i \neq j$ [1]. That is, part of the data or all the data from the d_i document go into the d_j document.

The vertices d_i and d_j are said to be strongly connected if there is a contour in the graph $G(D, U)$ passing through the vertices d_i and d_j, including loops. That is, some of the data from the d_i document is transferred to the d_j document, and the rest of the data is transferred to other documents.

 ISSN 2226-3780

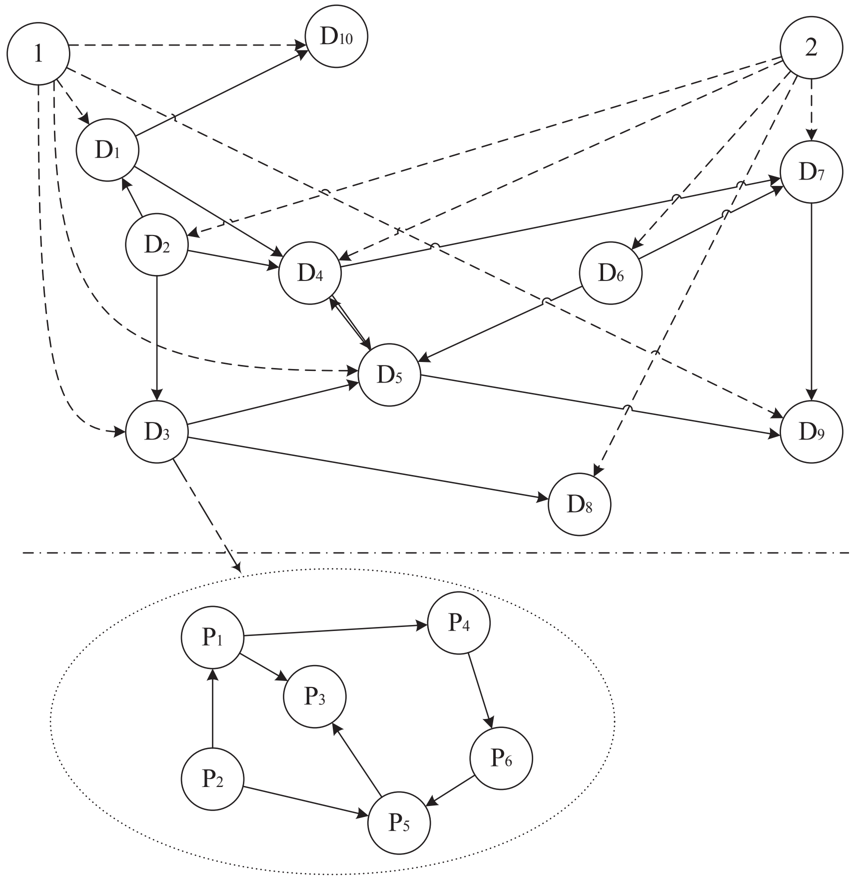

Fig. 6. The graph of information flows

To analyze GIM1, it is necessary to form an adjacency matrix M that reflects the topological properties of the graph $G(D, U)$. For a set of all documents, the matrix M will be of square dimension $n*n$, where n is the total number of documents in the object. The total number of threads circulating in the system can range from a few hundred to a million.

The matrix is formed according to the following condition:

$$e_{ij} = \begin{cases} 1, & \text{if there is a path from } i\text{-th to } j\text{-th vertice,} \\ 0, & \text{if there isn t a path from } i\text{-th to } j\text{-th vertice.} \end{cases}$$

The total number of transit paths in a graph from the vertex d_i to the vertex d_j is defined by the expression:

$$M^n = M * M * \ldots * M = M^{n-1} * M, \quad (3)$$

where $M_{n*n} = (e_{ij})$ – the first-order adjacency matrix, each element of which maps a path of length equal to one at $i = \overline{1,n}$, $j = \overline{1,m}$; $M^n = (e_{ij})^n$ – an n-order adjacency matrix, each element of which maps the path from the i-th vertex to the j-th length equal to n.

A formal analysis of the properties of the sequence (3) makes it possible to extract loops, cycles, contours, feedbacks, input and output elements of the structure, maximal or minimal routes, connectivity intervals, duplicating and redundant links in the graph $G(D, U)$ [1].

If all the elements of the matrix M located on the main diagonal are 0, then there are no loops in the graph.

The maximum route in the graph is determined by the following relation:

$$S_i = \max_{i \in n} \sum_{j=1}^{n} e_{ij}^n. \quad (4)$$

If all the elements of the column of the matrix are zero $\sum_{j=1}^{n} e_{ij}^n = 0$, this means that the given vertex of the graph is an input for the structure under consideration, and if all elements of the string are zero $\sum_{i=1}^{n} e_{ij}^n = 0$, the vertex of the graph is an output.

If there are elements in the matrix below the main diagonal and they are not equal to zero, this means that the system has feedbacks in the form of loops and cycles.

To identify the strongly connected vertices of a graph, that is, cycles and contours, it is necessary to construct a transitive closure matrix of the graph in the following form:

$$\tilde{M} = M^n \bigcup M^{n-1} \bigcup \ldots \bigcup M \bigcup \dot{I} = (M \bigcup \dot{I})^n, \quad (5)$$

where n – the order of the adjacency matrix; $\dot{I}$ – the identity matrix.

The strongly connected subgraphs $V(D, U)$ of the graph $G(D, U)$ are defined as the intersection of the vertices of accessible and counter-reachable from the given vertex:

$$V(d_i) = R(d_i) \bigcap_{i=1}^{n} Q(d_i), \quad (6)$$

where $R(d_i) = (d_i) \bigcup_{j=1}^{n} [G^j(d_i)]$ – the subset of vertices of the graph $G(D, U)$ accessible from the vertices d_i in j intervals; $Q(d_i) = (d_i) \bigcup_{j=1}^{n} [G^{-j}(d_i)]$ – the subset of the vertices of the graph $G(D, U)$, from which the vertex d_i is attained for j intervals.

The obtained strongly connected subgraphs are numbered in ascending order, and the vertices belonging to them, in the further analysis, do not participate.

As a result, the original graph is divided into K of strongly connected structures that do not have cycles and contours distributed over levels:

$$V(D) = \bigcup_{i=1}^{K} V(d_i). \quad (7)$$

Each strongly connected subgraph can be identified as a subsystem of the information structure of the considered control object.

To synthesize the optimal structure of information flows, it is necessary to specify an optimization criterion (objective function), which can be chosen as a numerical function on the graph $G \in (D, U)$.

A numerical function on the vertices of a graph is assumed to be given if each vertex of the graph is associated with a certain number $l_i \in Z$:

$$\forall(d_i \in D)\,\exists\,(l_i \in Z)\big|\,[l_i = l(d_i)]. \qquad (8)$$

A numerical function on arcs of an oriented graph is considered given if each arc is put in correspondence with the number $h_j \in Z$:

$$\forall(u_i \in U)\,\exists\,(h_i \in Z)\big|\,[h_i = h(u_i)]. \qquad (9)$$

The optimal value of a numerical function on the set of paths for vertices and arcs of the graph $G(D, U)$ is defined in accordance with the additive or multiplicative form:

$$\begin{cases} I_1(D) = \underset{d_i \in D}{opt} \sum_{i=1}^{n} l(d_i), \\ I_2(D) = \underset{d_i \in D}{opt} \prod_{i=1}^{n} l(d_i); \end{cases} \qquad (10)$$

$$\begin{cases} I_3(U) = \underset{u_i \in U}{opt} \sum_{i=1}^{n} h(u_i), \\ I_4(U) = \underset{u_i \in U}{opt} \prod_{i=1}^{n} h(u_i). \end{cases} \qquad (11)$$

Depending on the formulation of the optimization problem, the minimum or maximum values of the objective functions (8) and (11) are determined.

As an example for the graph shown in Fig 6, an adjacency matrix $M=(e_{i,j})$ is constructed (Fig. 7), which non-zero elements, after excluding loops, cycles, contours and feedbacks, correspond to the routes of information flow between the documents. As can be seen from Fig. 7, it contains two columns and three rows, all of whose elements are zero. Therefore, documents d_2 and d_6 are input, and d_8, d_9 and d_{10} are output.

D	1	2	3	4	5	6	7	8	9	10	σ_0	σ_1	σ_2	σ_3	σ_4
1	0	0	0	1	0	0	0	0	0	1	2	1	1	0^*	
2	1	0	1	1	0	0	0	0	0	0	3	3	3	1	0^*
3	0	0	0	0	1	0	0	1	0	0	2	1	0^*		
4	0	0	0	0	1	0	1	0	0	0	2	2	0^*		
5	0	0	0	1	0	0	0	0	1	0	1	0^*			
6	0	0	0	0	1	0	1	0	0	0	2	2	0^*		
7	0	0	0	0	0	0	0	0	1	0	1	0^*			
8	0	0	0	0	0	0	0	0	0	0	0^*				
9	0	0	0	0	0	0	0	0	0	0	0^*				
10	0	0	0	0	0	0	0	0	0	0	0^*				
											10	7	6		
											9	5	4		
											8		3	1	2
											5	4	3	2	1

Fig. 7. Adjacency matrix

To order the structure of the information flow graph, the following algorithm is proposed:

$$\begin{cases} \forall(i \in n)\,[\exists\,(e_{ij}) \neq 0]\left|\left(\sigma_i^0 = \sum_{j=1}^{n} e_{ij}\right)\right., i = \overline{1,n}; \\ \exists\,(k \subset n)\forall(i \in k)\exists(e_{ij}=0)\left|\left(\sigma_i^k = \sigma_i^0 - \sum_{j=1}^{k} e_{ij}\right)\right., i = \overline{1,k}, \end{cases} \qquad (12)$$

where $i=\overline{1,n}$ – the number of rows of the matrix M; $j=\overline{1,n}$ – the number of columns of the matrix M; σ_i^0 – the sum of non-zero elements of the i-th row of the matrix M; σ_i^K – the sum of the non-zero elements of the i-th row, after subtracting the non-zero column elements in the k-rows of which the zeros were obtained in the previous step.

The values σ_i^0, σ_i^1,..., σ_i^k, are recorded to the right of the adjacency matrix in columns, and below the columns are the document numbers for which zero values were obtained in the k-th column.

Fig. 8 shows the graph $G_S(D, U)$ obtained from the initial graph $G(D, U)$ with preservation of primary connections between vertices.

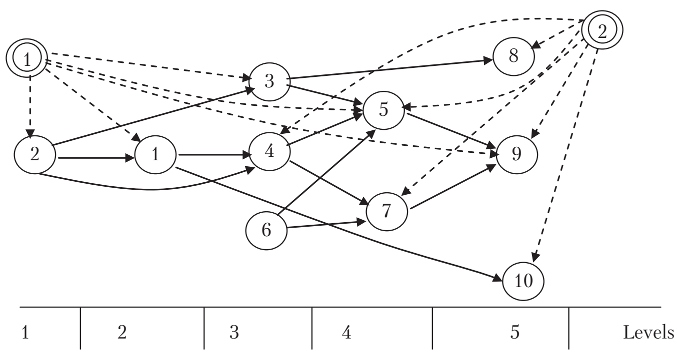

Fig. 8. The graph of ordered information flows

Using the graph ordering algorithm given above, the time for generating the initial data for the information support of the HEI ACS is reduced by software.

Let's consider the second level (GIM2) – the interaction of indicators $P=\{p_{ji}\}$.

To construct the GIM2 as the initial data, let's use the adjacency matrix constructed above (Fig. 10) and the exponents. Since each packet of information consists of a set of indicators and is formed due to the partial transfer of data $e_{ij}=\{p_{xy}\}$ from other information packets $p_{x_k y_r}$, let's perform a substitution e_{ij} for the set $\{p_{xy}\}$, where $i=x$, y – the index number of the i-th document, in rows and columns. Let's will replace the value «0» with the zero matrix, and the value «1» of the table with the corresponding matrix, which is formed according to the following condition:

$$p_{ij} = \begin{cases} 1, \text{ if from } i\text{-th to } j\text{-th} \\ \quad \text{there is transfer of indicator,} \\ 0, \text{ if from } i\text{-th to } j\text{-th} \\ \quad \text{there isn't transter of indicator.} \end{cases}$$

At the end of the transformation, let's obtain the adjacency matrix of the indicators.

A graph model of the movement of indicators allows to determine the main indicators that will serve as the base fields of the ICS database. In the future, the graph model of indicators is optimized by means of a transformation from a linear structure to a graph of the «tree» type.

Let's consider the simplest document circulation on an example of three documents and some indicators of these documents.

Documents:
– order to enroll students;
– certificate of the student about the place of study;
– journal of registration of certificates.

At the request of the student, the student's certificate from the place of work is formed on the basis of the order on enrollment. When issuing a certificate to the hands, it is registered in the journal.

In the initial version, the graph model of such document circulation is represented by a simple graph of three documents and two edges (Fig. 9) and a simple adjacency matrix (Fig. 10).

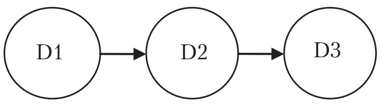

Fig. 9. Graph model of document circulation

Doc	D1	D2	D3
D1	0	1	0
D2	0	0	1
D3	0	0	0

Fig. 10. Adjacency matrix of document circulation

Let's consider the indicators of each document that participate in the movement.

Indicators D1:
P1.1 – Name;
P1.2 – Order No.;
P1.3 – group.

Indicators D2:
P2.1 – Name;
P2.2 – Order No.;
P2.3 – group;
P2.4 – Name1;
P2.5 – Reference number.

Indicators D3:
P3.1 – Name;
P3.2 – Reference number;
P3.3 – issue date.

Next, let's transform the adjacency matrix of the document, taking into account the indicators. As a result, let's obtain the adjacency matrix of the indicators (Fig. 11).

The obtained graph of the motion of the indicators is shown in Fig. 12.

Further analysis of the adjacency matrix of indicators and the graph model of the movement of indicators allows to determine the basic indicators. These are the indicators: P1.1; P2.1; P2.5, which are primary, as well as to propose the creation of database fields.

In the future let's consider the HEI interaction with the external environment.

The system of education in HEIs is focused on obtaining basic knowledge, skills, such system monitors the external market, that is, analyzes the labor market – the labor market analysis system (LMAS).

Document		D1			D2					D3		
		P1.1	P1.2	P1.3	P2.1	P2.2	P2.3	P2.4	P2.5	P3.1	P3.2	P3.3
D1	P1.1	0	0	0	1	0	0	0	0	0	0	0
	P1.2	0	0	0	0	1	0	0	0	0	0	0
	P1.3	0	0	0	0	0	1	0	0	0	0	0
D2	P2.1	0	0	0	0	0	0	0	0	1	0	0
	P2.2	0	0	0	0	0	0	0	0	0	0	0
	P2.3	0	0	0	0	0	0	0	0	0	0	0
	P2.4	0	0	0	0	0	0	0	0	0	0	0
	P2.5	0	0	0	0	0	0	0	0	0	1	0
D3	P3.1	0	0	0	0	0	0	0	0	0	0	0
	P3.2	0	0	0	0	0	0	0	0	0	0	0
	P3.3	0	0	0	0	0	0	0	0	0	0	0

Fig. 11. Adjacency matrix of document circulation on indicators

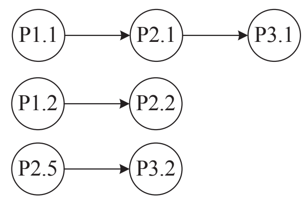

Fig. 12. Graph model of the movement of indicators

A scheme for the movement of information flows in a higher educational institution, the influence of external and internal factors on the main HEI activity of (Fig. 13) is developed.

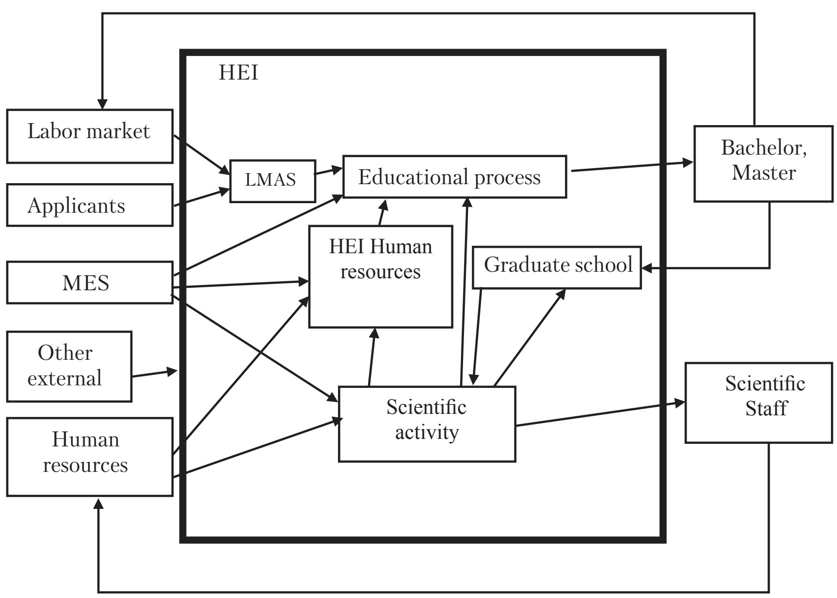

Fig. 13. Scheme of the movement of HEI information flows

In the information scheme (Fig. 13) two external circuits and several intra-HEI ones are distinguished:
– the external contour of influence on the labor market;
– the external contour of influence on scientific personnel (labor resources);
– the internal contour of interaction between educational activities and scientific;
– the internal contour of interaction between educational activities and labor resources.

Having determined the main factors (external and internal) that directly influence the HEI activity, as well as feedback loops, let's present the HEI formal model in the form of:

$$D=\left\{L_m\left(L_r\left(m,b\right),S_p\left(c,d\right)\right);\,M\left(z,n\right);A\left(a\right);\,E;\,I\right\}, \qquad (13)$$

where D – HEI activity; L_m – labor market; $L_r(m,\ b)$ – labor resources m masters; b – bachelors; c – candidates; d – doctors; M – Ministry of Education (legislation and nomenclature); $S_p(c,\ d)$ – scientific personnel; A – applicants; a – population; E – economic factors; I – information service.

This information scheme allows to identify the main factors affecting the HEI activities, including the quality of education, as well as build a HEI formal model. These factors can include the resulting contours of interaction between the HEI and the external environment.

7. SWOT analysis of research results

Strengths. The carried out researches of introduction of the developed model of information interaction allows to obtain the following effect:

– get rid of redundancy in HEI management system;
– reduce the load on the HEI computer network.

The proposed algorithm for formation of the flow of information flows in the HEI management system makes it possible to shorten the time for formation of the flow of information flows in the management system, that is, to reduce material costs for the analysis of the HEI management system.

Weaknesses. The use of the proposed algorithm entails additional material costs for the modernization of already implemented control systems related to the reorganization of existing databases.

Opportunities. Additional opportunities to achieve the aim of research are in the following likely external factors. Higher educational institutions are widespread in the former Soviet republics. All their management systems today can be considered obsolete both physically and morally. At the same time, the results obtained as a result of the implementation can become a basis for the further development of research into management systems. In particular, the influence of the organizational structure on the quality of education and analysis of the existing document workflow in HEI can be studied.

Threats. The threats in implementing the research results are related to two main factors. The first of them is the lack of sufficient HEI financing for the purchase of modern computers and software. Since the economy in the former Soviet Union is in a state of decay, additional investments from research organizations are being used to solve this problem.

The second factor is the market of modern software for control systems offered by world leading companies. Such software packages include software products of the company «1C». Advantages of this solution include the complex solution of individual tasks, but all control subsystems are connected at the level of data transfer, thereby increasing the redundancy of information.

8. Conclusions

1. The main external and internal factors that directly influence the HEI activity are defined:

– population;
– activities of the Ministry of Education and Science;
– labor market;
– labor resources.

2. A formal HEI model is proposed, which allows eliminating the redundancy of information circulating in the system. Using the algorithm of analysis and optimization of information flows:

– the tasks on optimization of HEI information structure in the system are solved;
– the interaction between the units is determined;
– rational relationship between the sources and receivers of information and the ways of its circulation are established.

References

1. Andrushchenko, V. P. Osnovni tendentsii rozvytku vyshchoi osvity na rubezhi stolit [Text] / V. P. Andrushchenko // Vyshcha osvita Ukrainy. – 2001. – No. 1. – P. 5–9.
2. Zhuk, Yu. Treba vmity dyvytys u vichi, abo v Bolonskyi protses slid vkhodyty z ukrainskym pozytyvnym dosvidom, vrakhovuiuchy realii [Text] / Yu. Zhuk // Osvita. – 2005. – No. 12. – P. 17–25.
3. Sokolova, N. A. Imitatsionnaia model' protsessa distantsionnogo obucheniia [Text] / N. A. Sokolova, O. O. Boskin // Modelirovanie obiektov i sistem AAEKS. – 2004. – Vol. 1, No. 13. – P. 50–62.
4. Yakusevych, Yu. H. Analiz problem reformuvannia osvity ta pobudova formalizovanykh modelei VNZ [Text] / Yu. H. Yakusevych // Problemy informatsionnyh tehnologii. – 2015. – No. 17. – P. 100–109.
5. Hodakov, V. E. Vysshee obrazovanie: vzgliad so storony i iznutri [Text] / V. E. Hodakov. – Kherson: KhNTU, 2006. – 338 p.
6. Vulfson, B. L. The World Educational Space in the Mirror of Comparative Pedagogy [Text] / B. L. Vulfson // Otechestvennaia i zarubezhnaia pedagogika. – 2012. – Vol. 1, No. 4. – P. 27–42.
7. Uvarova, T. G. Transformatsiia upravleniia VUZom na printsipah menedzhmenta znanii [Text] / T. G. Uvarova // Problemy sovremennoi ekonomiki. – 2007. – Vol. 4, No. 24. – P. 349–352.
8. Gavrilova, T. A. Razrabotka korporativnyh sistem upravleniia znaniiami [Electronic resource] / T. A. Gavrilova, L. Yu. Grigorev // BIG-Peterburg. – Available at: \www/URL: http://www.big.spb.ru/publications/bigspb/km/create_kms.shtml
9. Zhukovskya, I. E. Innovative aspects of enhancement of management processes in the higher educational institution on the basis of application of modern information and communication technologies [Text] / I. E. Zhukovskya // Open Education. – 2016. – No. 4. – P. 17–22. doi:10.21686/1818-4243-2016-4-17-22
10. Kosmacheva, I. M. Subsystem of control of access in university information systems [Text] / I. M. Kosmacheva, E. P. Yakovleva // Vestnik of Astrakhan State Technical University. Series: Management, Computer science and Informatics. – 2016. – No. 2. – P. 25–34.
11. Kovalevsky, V. Formation of modern information educational environment: experience of orenburg state university [Text] / V. Kovalevsky, V. Bykovsky, T. Volkova, E. Dyrdina // Informatizatsiia obrazovaniia i nauki. – 2015. – Vol. 2, No. 26. – P. 15–23.
12. Shakhgeldyan, C. Integration of University Information Resources into the Unified Information Environment [Text] / C. Shakhgeldyan, V. Kryukov // Proceedings of the 10-th International Conference of European University Information Systems (ENUS 2004). – Slovenia, 2004. – P. 321–327.

13. Riesen, Yu. S. Mathematical Modeling of the Educational Process in Assessing the Quality of a Higher Education Institution's Operation [Text] / Yu. S. Riesen, A. A. Zakharova, M. G. Minin // Informatsionnoe obshchestvo. – 2014. – No. 3. – P. 25–33.
14. Hubalovsky, S. System Approach, Modeling, Simulation as Educational Technologies in Algorithm Development and Programming [Text] / S. Hubalovsky // Procedia – Social and Behavioral Sciences. – 2015. – Vol. 191. – P. 2226–2230. doi:10.1016/j.sbspro.2015.04.267
15. Akhmedova, Kh. G. Use of information technologies to increase the quality of the univeristy education [Text] / Kh. G. Akhmedova, I. Yu. Kvyatkovskaya // Vestnik of Astrakhan State Technical University. Series: Management, Computer science and Informatics. – 2015. – No. 1. – P. 124–130.
16. John, S. P. The integration of information technology in higher education: A study of faculty's attitude towards IT adoption in the teaching process [Text] / S. P. John // Contaduria y Administracion. – 2015. – Vol. 60. – P. 230–252. doi:10.1016/j.cya.2015.08.004

АНАЛИЗ ИНФОРМАЦИОННОЙ ТЕХНОЛОГИИ СИСТЕМЫ УПРАВЛЕНИЯ ВЫСШИМ УЧЕБНЫМ ЗАВЕДЕНИЕМ

Выполнен анализ влияния внешних факторов на деятельность высшего учебного заведения. Предложен алгоритм формирования и оптимизации схемы движения информационных потоков в системе управления ВУЗа. Разработан алгоритм оптимизации движения информационных потоков на уровне показателей. Предложена формальная модель ВУЗа, позволяющая учитывать внутренние и внешние факторы, которые непосредственно влияют на качество системы управления. Выявлены достоинства и недостатки модели и предложения по усовершенствованию информационной модели ВУЗа.

Ключевые слова: система управления, информационный поток, внешняя среда, система информационного обслуживания.

Hodakov Viktor, *Doctor of Technical Science, Professor, Head of the Department of Informational Technologies, Kherson National Technical University, Ukraine, e-mail: hodakov.victor@gmail.com, ORCID: http://orcid.org/0000-0002-8188-9125*

Kozel Viktor, *Senior Lecturer, Department of Informational Technologies, Kherson National Technical University, Ukraine, e-mail: k_vic@ukr.net, ORCID: http://orcid.org/0000-0002-2627-2499*

Sokolov Andrey, *PhD, Associate Professor, Department of Informational Technologies, Kherson National Technical University, Ukraine, ORCID: http://orcid.org/0000-0001-8442-6137*