

Development of the Information and Analytical System in the Control of Management of University Scientific and Educational Activities

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Abstract: In the article a concept of the result-oriented management is presented. The concept is based on the methodology of the indicative planning of the university scientific and educational activities and presented as formalized procedures. Particular attention is paid to the system of indicators, their formalization and algorithms to design the analytics of the educational system functioning. Moreover, the incentive rating model for the scientific and educational activities of the university staff is considered. The model contains the indicators that agree with the university indicative plans. In addition, in the article the structure scheme of the management of the information flows in the information and analytical system in the contour of the university management is described. The agent-oriented approach to the management of the scientific and educational activities of the university is considered. The rule base for the evaluation of the indicators state is described. It allows determining the state of the indicator regarding the achievement of the desired state of the scientific and educational activities and formalizing the dataset for the evaluation of the attainability of the university development plan. The information and analytical system in the contour of the management of the scientific and educational

activities of the university is presented as a tool for the management of the university business-processes.

Keywords: indicative planning; rating assessment; information systems; information and analytical system; strategic planning; operational planning; scientific and educational activities of a university

Introduction

The relevance of the research topic is high, because higher education institutions play an important role in the market economy [1]. They have a right to determine the development directions, goals and methods to achieve them on their own.

Universities as independent structures should apply work methods and management models that are used at the national level, develop alternatives to their future behavior depending on changes of the outside environment, i.e. apply a strategic approach to the regulation of scientific and educational activities (SEA) [2]. One such strategic approach is result-oriented management (ROM), which is based on the strategic plan of the university development.

Management of the university under modern conditions requires an integrated solution of many problems caused by both external and internal factors. Requirements of the university management are increasing, which leads to the inclusion of information systems in the control loop [5]. The information system in the control loop of scientific and educational activities of the university should not only provide to the administration of the university information about the current and future state, but also identify problem areas of the university SEA functioning and develop corrective actions to strengthen work in this direction [6].

The subject of this research is the methods and models of the information support of the result-oriented management processes [7].

The basic idea of the work is the application of modern information technologies to the implementation of the university research and education planning system as a purpose-program management system that is oriented to accessibility of final results of the development plan and uses indicative planning as a management tool for the research and education activities [8].

The goal of the research is the development of an information and analytical system, which is based on the result-oriented management concept and provides sustainable development of the university business processes.

The novelty of the proposed approaches is in use of modern ICT and indicative plans. They are based on the models of sustainable development of the scientific and educational system, as well as on the monitoring of educational resources, which are aimed at reaching the high level of quality of education or educational processes.

The scientific significance of the project is in the development of integrated technology of university management based on the midterm indicative planning of the university SEA and the creation of the incentive system based on this technology.

The research positions and their novelty are the following:

- the conceptual model of ROM, which is aimed at the information support of planning processes and management of the university business processes, and makes it possible to link task goals and current social and science important results of the university SEA development;
- the information support method of indicative planning of the university SEA based on a purpose-program approach; system of indicators, which characterizes the development clusters of the university SEA; and monitoring system that allows detecting «bottlenecks» at the planning process;
- the model of the incentive rating system, which is connected with university development indicative plan and implements the control function of its execution;
- the rule base for the evaluation of the attainability of the university development plan; the plan is presented as a decision bank and formalized by the agent-oriented technology for the design of intellectual management systems;
- the information and analytical system in the contour of management of the university SEA; the system supports the processes of planning and management at a medium term perspective, monitoring and analysis of the operating control for the corrective actions formulation, which when combined focus on achieving the goals and tasks of education system development.

1 Planning and Assessment Methods and Models of Scientific and Educational Activities of the University

1.1 Conceptual Management

The information content of the conceptual *result-oriented management* (ROM) model is to bring the university to the desired criteria of the SEA development. The activities are determined by each owner of the business process within operational, strategic plans and education system policy. Such policy is intended to link decisions concerning the development and functioning of the university SEA and their efficiency and effectiveness for the university and the education system as a whole [9, 10].

Schematic description of the conceptual model of ROM is shown in the Fig. 1. As seen from the figure, the planning process of SEA in the mid-term is based on the iterative approach, thereby characterizing the principle of the «sliding» planning.

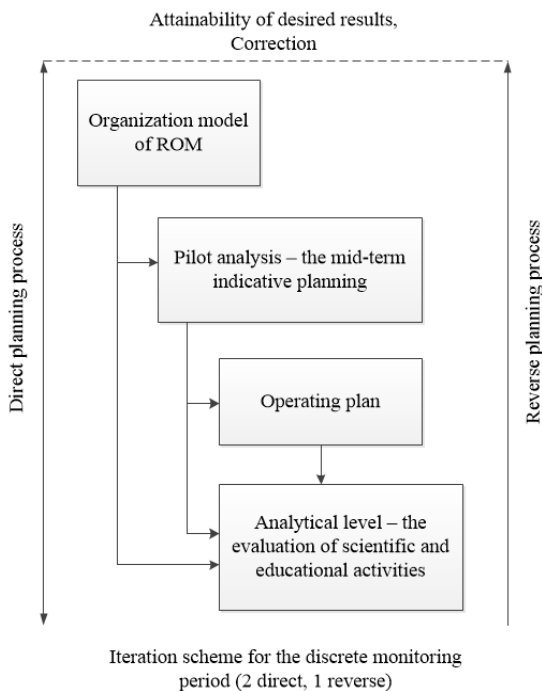


Figure 1

Schematic description of the conceptual model of ROM

The *methodology of the results-oriented management* is designed to link decisions concerning the development and functioning of the university SEA and their efficiency and effectiveness for the university and the education system as a whole. This ROM methodology is designed for the university business process management through the development of strategic indicative plans.

A university as a complex system has a main management contour (Fig. 2). It is a strategic indicative midterm plan of the university development that obeys its own law of behavior (regulatory documents, criteria for national accreditation systems, rankings of world universities, etc.). The subject of management is administrative management. It controls the scientific, educational, administrative and financial university activities based on the ROM concept according to the midterm strategic indicative university plan. The plan must correspond to the university mission and vision, which are depicted as a vector of driving influences \vec{Z} .

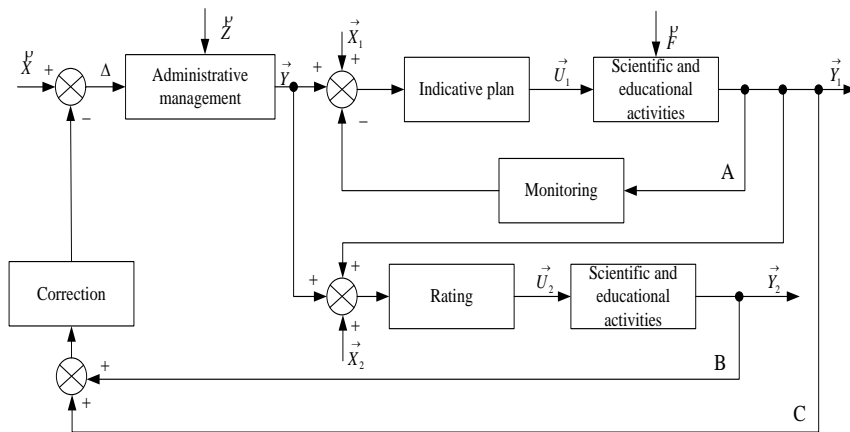


Figure 2

Structure scheme of the management of the university SEA based on the indicative planning and rating

The input (\vec{X}) of the system is various indicators of university activities, the state of the resources (intellectual, educational and financial). The vector \vec{Y} is an output of the system and it allows for judging the whole of the university activities.

On the scheme there are three contours of university SEA management: A – indicative planning, B – rating system, C – adjustment.

In the A contour the input (\vec{X}_1) is the indicators of indicative plans, which are realized according to the main strategic directions of the university development.

The output of this contour (\vec{Y}_1) characterizes university SEA. SEA are affected by driving influences \vec{F} . The indicative planning performs the management (\vec{U}_1) of SEA at the beginning of the academic year and each term it monitors the results of plan execution.

The input of the B contour is the rating indicators (\vec{X}_2) and the results of the indicative planning (\vec{Y}_1) of the A contour. The rating system performs the management (\vec{U}_2) that implements the incentive mechanism of objects of the educational business process of the university.

The C contour contains A and B contours. It implements the feedback to the administrative management in order to adjust the system by corrective actions. The adjustment of university SEA allows reconsidering and creating the corrective actions in the implementation of the university strategic indicative plan in the

ROM model. In this way the *flexible management* of the university educational business process is performed.

1.2 Information Support Method of the Indicative Planning of the SEA

The *information support method of the indicative planning of the SEA* is a procedure for information support of the planning process.

The first stage: the development of the information base of the SEA characteristics defined in the form of information resources: goal-setting system (strategic directions of SEA development, targets and tasks); hierarchical system of indicators (target indicators, integrated indicators, criteria and an index passport); strategic indicative plans and ratings checklists corresponding to the in-house hierarchy (faculties, departments, ATS).

The second stage: data acquisition depending on the level of compliance with targets and tasks of the indicative plan through the information interaction interface; activation of the system with the automated monitoring of the realization of strategic indicative plans at control points of time.

The third stage: the first step: information and analytical processing of monitoring results (activation of system procedures with the automated monitoring of indicators) by evaluation of the index of goal achievement (IGA) for each indicator according to the formula:

$$IGA = I_{nm} \left(i_{mr}^n \right) = \frac{I_{nm} \left(i_{mr}^n \right)_{fact}}{I_{nm} \left(i_{mr}^n \right)_{plan}} \cdot 100\% \quad (1)$$

where $I_{nm} \left(i_{mr}^n \right)$ is the integrated indicator m, which characterizes the basic indicator n; in brackets there is a simple index r, which expresses an integrated indicator, i.e. IGA will be determined both for integrated indicators and for simple indicators of the entire plan.

Such evaluation of indicative plans indicators allows determining «bottlenecks» in the management, i.e. making management problems «recognizable», thereby indicating the main task of the system with the automated monitoring. Second step: formation of the analytics of the university SEA and definition of qualitative and quantitative evaluation of the educational process according to the control statistics reports. Third step: analysis of the plans indicators, whose IGA is less than 50%, for decision making on the level of an administrative unit (dean, vice-rector, rector). Fourth step: development of the final information reports on the monitoring of the scientific and educational activities.

Fourth stage: general evaluation of the attainability of the university SEA development plan (activation of the rule base), providing recommendations for correction of the rating system indicators and strategic plans indicators for the next planning period.

1.3 The Model of the Incentive Rating System for the Cadre Personnel of ATS

The composition of rating lists is performed in correspondence with the accepted systems of indicators. They allow measuring the volume, quality and efficiency of the work done based on the scoring system. The total score of a lecturer is calculated as a sum of points for all indicators, which later are summarized into group indicators. The total scores for each type of SEA are generated using sums of group indicators. And the resulting score is a sum of indicator of each type of activity:

$$\left\{ \begin{array}{l} R_{\Sigma} = \sum_{i=1}^3 R_i \\ R_i = \sum_{j=1}^m r_j \\ r_j = \sum_{l=1}^n q_l \end{array} \right. , \quad (2)$$

where RS – the total score; R_i – the points that are obtained for i -th type of SEA; r_j – the points for j -th group indicator; p_l – the points for l -th indicator.

According to the ROM concept the rating indicators are approved annually. They are derived from the strategic indicative plans of the university in general and each department in particular. In this way, the rating indicators reflect the level of goals achievement and the development objectives on the current academic year. In this regard, each employee of the university including heads of all departments and deans makes a personal contribution to the overall strategic development of a department, faculty and the university in general by creation and implementation of his/her own individual indicative plan.

The creation of the internal rating system to evaluate the university SEA and the incentive mechanism based on it allows the university to manage efficiently the scientific and educational process in the context of strategic management and planning (Fig. 3).

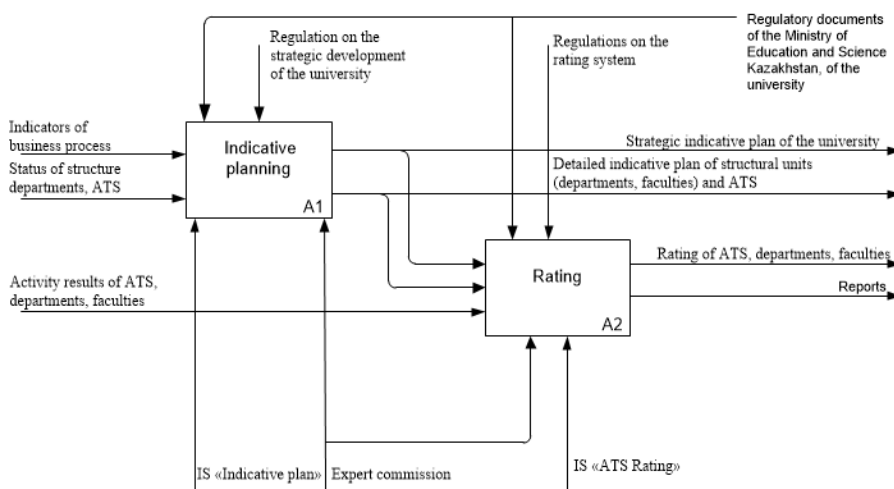


Figure 3

Scheme of the indicative planning and rating interaction

The driving influences on «Indicative planning» and «Rating» are regulated by the documents of Ministry of Education and Science of the Republic of Kazakhstan, documents about university strategic development plan and about rating system. The input parameters for the «Indicative planning» system are indicators of business processes, status of structure departments and ATS. The output of the system is the university strategic plan, indicative plan of structural units (departments, faculties) and ATS, which in their turn are the input parameters for the «Rating» system. Apart from those, the input parameters for the «Rating» system are the results of ATS, departments and faculties activities. The output of the «Rating» system is the ratings of ATS, departments, faculties, as well as various other reports. These systems are implemented in the information systems «Indicative planning» and «ATS Rating».

2 The Usage of Agent-oriented Approach to Management of the University SEA

The structure scheme of the information management in the information and analytical system within the university management (IASUM) consists of such components as (Fig. 4): storage is a module with the information about main university resources; handler is a module to forecast, analyze and compare the indicators of the medium-term planning results; programmer is a module to plan the indicators for the medium-term period and to establish the incentive program as rating points for the specific type of activity; regulator is a module to account

and evaluate the indicators of the university activities; corrective module to correct the development strategy, which implies the correction of indicators of different aspects of the university activities.

The agent-oriented approach to the management of the university SEA allows answering the three important questions: where is the organization now (monitoring); in what direction, according to the senior management’s view, it should develop in future (planning); how is it going to achieve the state, where the senior management want to see it (correction, stimulation).

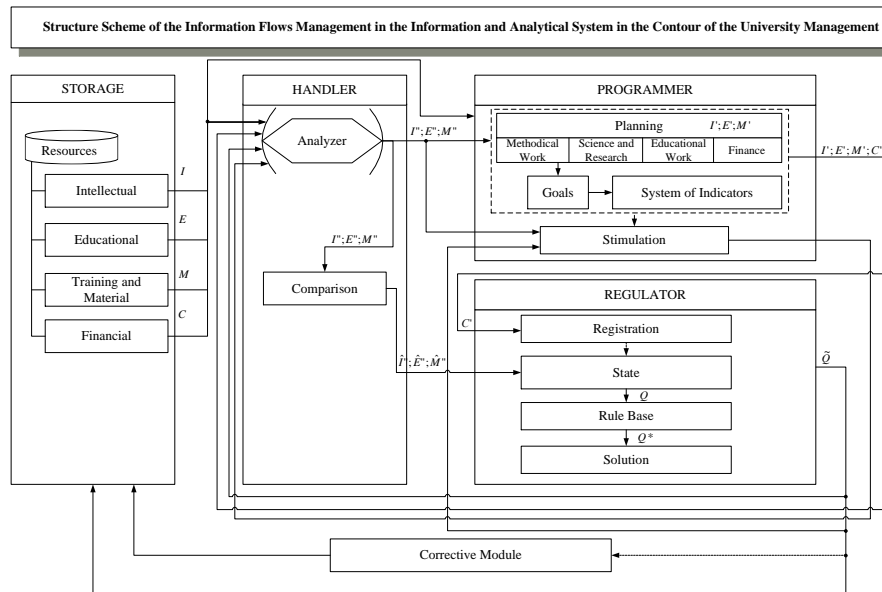


Figure 4

Structure scheme of the information flows management in the information and analytical system in the contour of the university management

An agent of the IASUM of the SEA is an intellectual management mechanism. Its functionality provides evaluating the internal state of the university SEA and making recommendations to university management. They are aimed at eliminating problem spots within the strategy of the university development, thereby, characterizing the problems «recognition». The agent model of the IASUM of the SEA can be represented as a set of values, which describe the process of the agent functioning:

$$A(P, F, O, U), \tag{3}$$

where P is the indicators of the SEA development, which characterize the desired state of the university development for the planning period; F is the actual state of the university SEA, which is expressed as the actual realization of the

development indicators at the control point of the evaluation of the university development; O is the indicators of the agent performance; they are the marks of the evaluation of the university SEA development plan, which characterize the efficiency of the development strategy and recommendations on the correction measures for achieving the development plan; U is a bank of the control parameters; they are the rating indicators, which are determined annually to stimulate the university staff; it is necessary for the analysis of the development of the SEA directions and for the strengthening the indicators of the problem spots in order to eliminate them.

According to the classification, the agent is a *model of agent based on the goal*. Its functioning requires not only the knowledge about the current state, but about the goal as well, which describes the desirable situations of the university SEA development.

The Fig. 5 presents the technological scheme of the agent work. Its principle is that after each checkpoint the monitoring of the SEA is performed by comparing the actual values of the indicators of the SEA development with the planned ones.

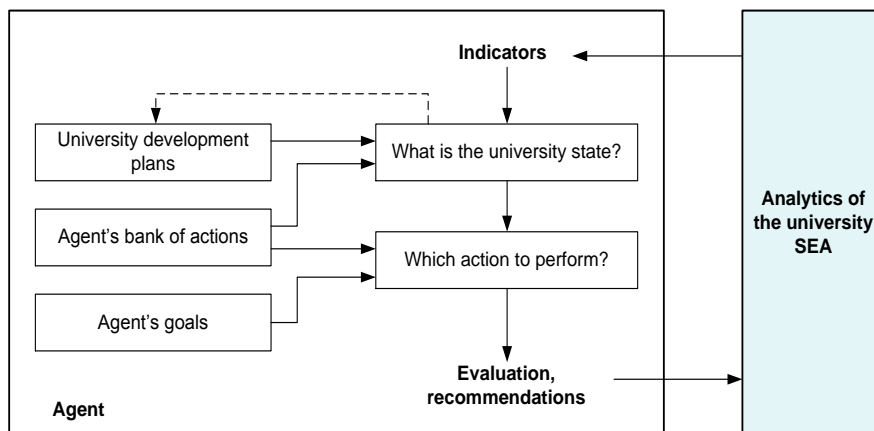


Figure 5

Technological scheme of the agent work

The evaluation of the current indicators of the development plan allows answering the question «What is the university state?». The answer is formed from the bank of agent actions with indicators of the agent performance. The indicators of performance are rules. A set of such rules is a *rule base of the agent actions*. Based on these rules, it is possible to judge about the value of an indicator with respect to the achieving of the desired state. It is formulated in such terms as not effective, satisfactory, effective.

After the current state of the university SEA is known, it is necessary to determine «Which action to perform?». For this, from the bank of actions the agent selects the coefficients to correct the points of the rating indicators according to the

recommendations, which were obtained after the analysis of the university SEA. When choosing a model of the rating indicators correction the agent goals are taken into account. They are expressed by the simple law as achieving the desired state of the SEA development. Thereby, the result of the agent's work is the determination of the evaluation of the plan effectiveness and the development of corrective actions. The chosen measures in the form of recommendations and correction coefficients are transferred to the executive mechanisms of the agent. In this way, the connection with the subsystem «ATS Rating» is realized. In it the recalculation of the rating points will be made, after a decision maker (DM) confirms those corrective actions.

The actions bank of the agent is a rule base with a structure shown in the Fig. 6. The production model was used as a knowledge representation model.

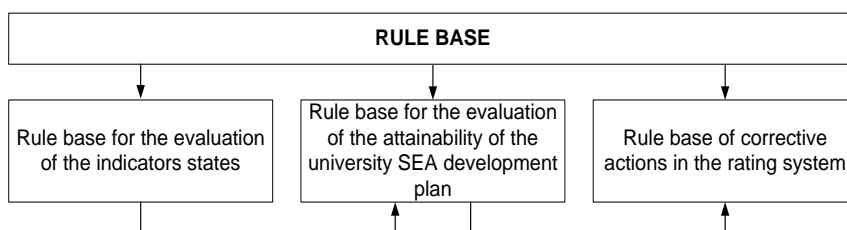


Figure 6

Structure scheme of the agent rule base

The rule base for the indicators evaluation allows checking the indicator state regarding the achievement of the desired state of the SEA development and formalizing a dataset for the evaluation of the attainability of the university development plan (Fig. 7).

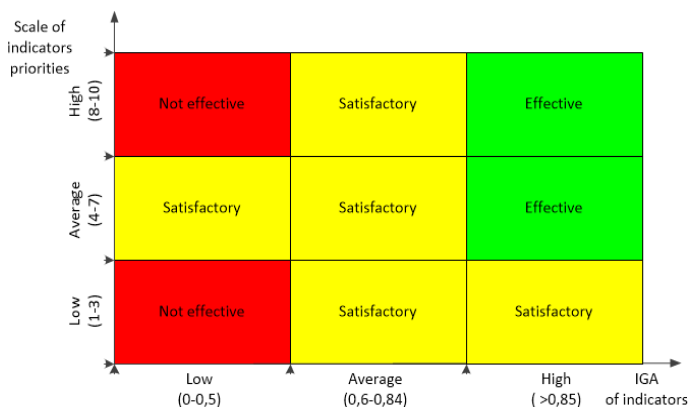


Figure 7

Structure scheme of the rule base for the evaluation of the indicators state

The graphic interpretation of the rule base is presented in the Fig. 7. An example of production has the following notation:

IF $Pr(i_r) \in \langle high \rangle$ *AND* $IGA(i_r) \in \langle medium \rangle$
THEN $Indicator\ state \in \langle satisfactory \rangle$

Table 1 presents the rules, which evaluate the attainability of the university SEA development. It can be read in a following way:

IF ($Indicator\ priority \in \langle high \rangle$ *OR* $Indicator\ priority \in \langle average \rangle$)
AND $Indicator\ state \in \langle satisfactory \rangle$ *AND* $Quantity > 75$
THEN $Plan\ evaluation \in \langle satisfactory \rangle$

Table 1
Rule base to evaluate the plan effectiveness and recommendations

№	Operation	Indicator priority	Indicator state	Quantity (%)	Plan evaluation	Recommendations
1	AND	high average	effective	> 75	effective	
2	AND	high average	satisfactory	> 75	satisfactory	To correct the indicators in the rating
3	AND	high average	not effective	> 75	not effective	To reconsider the plan entirely
4	AND	average low high	effective not effective	> 75 25	satisfactory	To correct the indicators in the rating
5	AND	high average high average	effective satisfactory	50-75	satisfactory	To correct the indicators in the rating
6	AND	high average high average	satisfactory not effective	50-75	not effective	To reconsider the plan entirely
7	AND	high average high average	effective not effective	50-75	not effective	To reconsider the plan entirely

8	AND	high	effective	< 50	not effective	To reconsider the plan entirely
		average				
		high	satisfactory			
		average				
9	AND	high	satisfactory	< 50	not effective	To reconsider the plan entirely
		average	not effective			
		high				
		average				

Based on the recommendations made a model of correction coefficients is activated, while the points of the rating indicators are determined, according to the following rule:

IF the plan indicators are needed to be corrected

IF the indicators are in the rating THEN the rating points multiply by the coefficient 0,3

ELSE include the indicators into the rating AND assign the highest priority.

In such a way, the feedback model was created to evaluate the attainability of the university SEA development plan and to work out corrective actions, which are aimed to decrease the deviation of real values of the development indicators from the planned ones. Thereby, the result-oriented management is performed.

3 Development of the Information System in the Control Loop of the Scientific and Educational Activities of the University

The analysis of modern information systems of university management shows that the process of informatization is mainly oriented on automation of educational process, functioning of educational portals and distance learning. The blocks of planning, monitoring and analytical processing of results of the university SEA based on the strategic plan exist only in a few Kazakhstani universities and are closed resources [14-18].

The information and analytical system in the contour of the management of the university SEA has a modular structure (Fig. 8). Each module is connected with the information database of the university. The database is an information source for all types of management; the database elements are available almost for all the university departments according to their access privileges.

The modules of the indicative planning, incentive system, analytical processing and the intellectual module were developed.

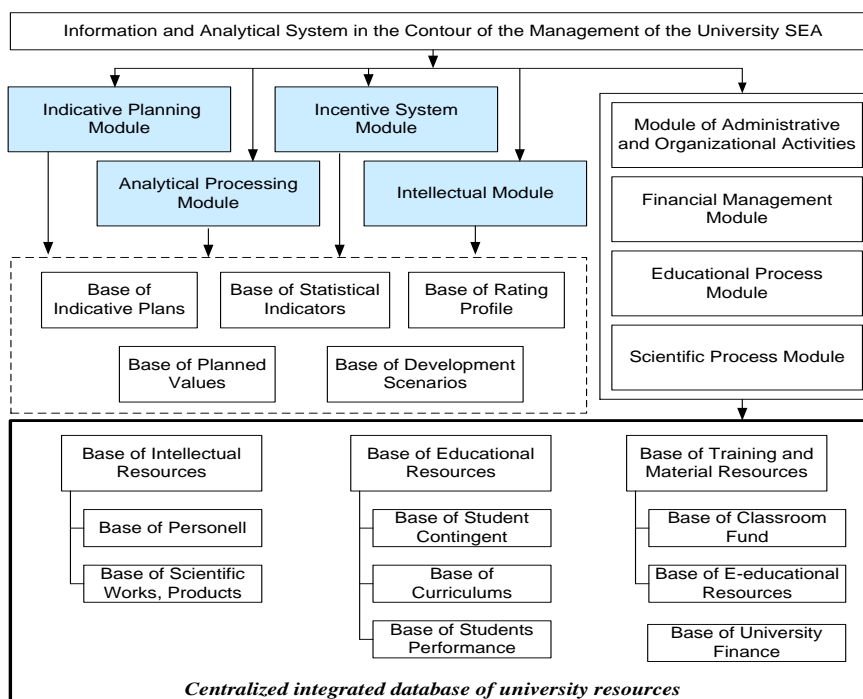


Figure 8

Structure of the IASUM of the university SEA

The created IASUM of the SEA is implemented according to the client-server architecture. The server side consists of the database server (MS SQL Server 2014) and web-server (IIS). The client side is realized as a web-application (.NET Framework) with the functions of data entry and editing. For the data access the ADO.NET technology was used, which simplifies the process, in particular, in distributed Internet applications. The structure of the subsystems of the IASUM of the SEA is presented in the Fig. 9.

IASUM is a system that is composed of two main subsystems – «Indicative planning» and «ATS Rating» which provide:

- the automated calculation of the integrated indicators of the indicative plan and the cumulative scores for the rating questionnaire;
- the monitoring and the analytical processing of data for estimation of level of indicative plans execution and rating lists formation;
- the flexible management of the structure and content of the indicative plan;
- the values of indicators by request;
- the authorized user access to indicative plans and rating questionnaires;
- the centralized administration of the group access rights;
- the automation data conversion and data export to the given format.

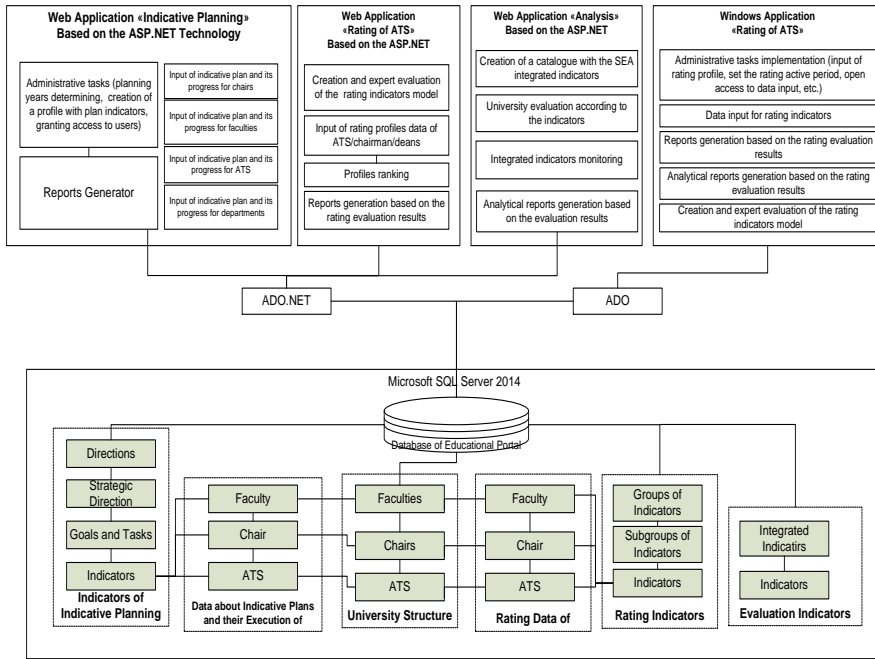


Figure 9
Structure of the subsystems of the IASUM of the university SEA

The subsystem «Indicative Plan» (Fig. 10) provides an automated process of the mid-term indicative planning of the university and analyzes the effectiveness of the plan.

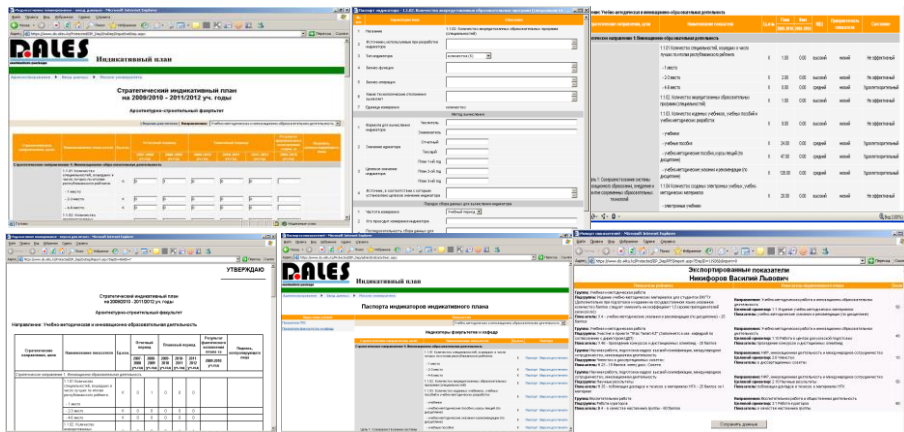


Figure 10
Interface of the «Indicative Plan» subsystem

The subsystem «ATS Rating» is designed to evaluate the SEA of the university professors according to their main activity directions. Key indicators, which determine the evaluation, are exported from the subsystem «Indicative Plan».

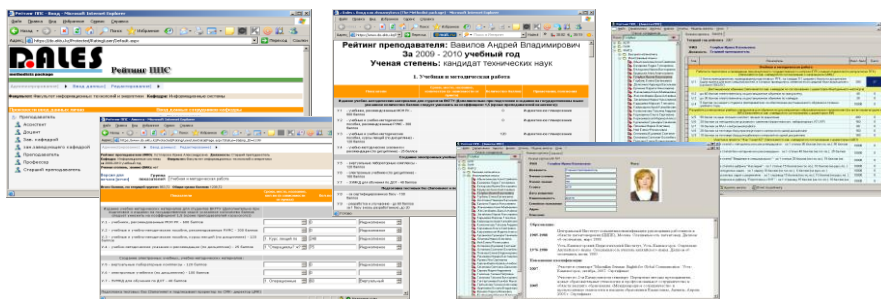


Figure 11
Interface of the «ATS Rating» subsystem

Conclusion

It can be concluded that the practical results obtained in the experiment confirm the feasibility and usefulness of the theoretical developments, which together with the information system present a work tool for the management and planning of the university SEA.

According to the results of the study, the following conclusions can be made.

A conceptual model of the result-oriented management was developed, aimed at information support of planning and university business processes management, which allows linking targets and current socially and scientifically significant results of the development of the university scientific and educational activities.

A method was developed for the information support of the indicative planning of the scientific and educational activities, based on the result-oriented approach; the indicators system that characterizes clusters of the development of the university scientific and educational activities, and the monitoring system, which allows identifying «bottlenecks» in the management process.

All the indicators of the scientific and educational activities were systematized. Based on them a system of indicators was proposed, which consist of two levels: integrated indicators and indices. The integrated indicators show the state of the SEA, they meet the main accreditation criteria to evaluate the system of higher education.

The rating model was developed to stimulate university employees, which is integrated with the indicative planning system, for flexible regulating of ATS employees activities through rating parameters.

A rule base was created to evaluate the attainability of the university development plan. It is a set of solutions of the management intellectual mechanism of the information and analytical system, which is formalized by the agent-oriented technology for the design of intellectual management systems.

The information system was developed in the control loop of the university scientific and educational activities, supporting the process of planning and management in the mid-term, monitoring and analysis of the operational management for the development of corrective actions intended to the achievement of goals and tasks of the educational system.

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