

*Робота присвячена проблемі оцінювання ресурсів для виконання вимог ліцензування вищої освіти. Запропоновано розглянути проблему в трьох напрямках: оцінка наявних ресурсів по відношенню до ліцензійних вимог, визначення максимального ліцензійного обсягу при наявних ресурсах, оцінка необхідних ресурсів для забезпечення цільового ліцензійного об'єму. Наведено приклад оцінки матеріальних ресурсів*

*Ключові слова: комплексна оцінка, математична модель, проблеми ліцензування, ресурси вищої освіти*

*Работа посвящена проблеме оценки ресурсов для выполнения требований лицензирования высшего образования. Предложено рассматривать проблему в трех направлениях: оценка имеющихся ресурсов по отношению к лицензионным требованиям, определение максимального лицензионного объема при имеющихся ресурсах, оценка необходимых ресурсов для обеспечения целевого лицензионного объема. Приведен пример оценки материальных ресурсов*

*Ключевые слова: комплексная оценка, математическая модель, проблемы лицензирования, ресурсы высшего образования*

# TOWARDS MODELING OF COMPREHENSIVE ASSESSMENT FOR LICENSING IN HIGHER EDUCATION

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## 1. Introduction

In the modern society information technologies, services, quality become the determinative factors of success of any business. The questions of quality management are especially relevant in social sphere, since organization oriented on quality of its processes provides the improvement of people living standards.

Information computer technologies (ICT) are the powerful tool for increasing the performance of decision-making processes. Formalization of management problems and adequate mathematical models provide ICT with techniques and methods of solving the application problems in different domains and improving business performance. Higher education is a unique social and economic environment. The quality of its functioning influences many processes of successive development of society. Therefore elaboration of ICT in higher education domain remains the challenging problem for specialists in computer sciences.

ICT in universities support their key business processes. Special information systems (IS) are necessary to provide educational process with tools for accounting students and their achievements, for distance and mobile learning. For these purposes virtual universities, e-learning platforms and portals are developed [1].

IS necessary for managing research process are oriented on organization of scientific events and sharing of scientists achievements. Conference management systems, digital libraries and bibliographic databases with papers' abstracts, rankings and citations are elaborated to support researches [2].

Management of methodical process requires software solutions for creation of modern courseware and its usage for teaching. For example special course software, intelligent tutoring systems, virtual laboratories, testing systems are created for this purpose [3].

To support financial activities the traditional book-keeping packages with adjustment for universities are used [4].

Various mail, telecommunication, document flow systems serve to manage university's information resources [5].

All these ICT are used by management in order to build an excellent development strategy for university.

Activities of higher education establishments (HEEs) are justified through licensing and accreditation of specialties and HEE as a whole [6].

Algorithms of data preparation and processing during licensing and accreditation have the common stages which allows designing of the generalized scheme of licensing process (fig. 1).

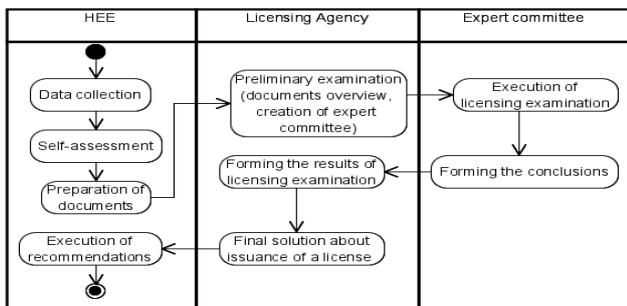


Fig. 1. Licensing process

On the stages of self-assessment and licensing examination it is necessary to evaluate the correspondence of resources supply HEE system to requirements of licensing conditions. This leads to the problem of comprehensive assessment. Formalization of this problem is the subject of many researches. For example issues of comprehensive assessment of education resources are considered in [7, 8]. The given work considers the problem of synthesis of mathematical models of comprehensive assessment of correspondence of HEE to licensing requirements.

The goal of this research is to formalize and build mathematical models of resources assessment with respect to licensing requirements fulfillment. These models have to define the appropriate data processing methods for the information technology of resources comprehensive assessment supporting licensing process in the university.

The rest of this paper is organized in the following way. Section 2 represents general scheme of comprehensive assessment of REP. Section 3 lays emphasis on the problem of resources assessment with respect to licensing requirements satisfaction. The corresponding mathematical models are described. Section 4 represents the case study of models application. Section 5 gives the conclusions and future directions of this research.

## 2. Problem Statement

In this work we consider the problem of evaluation of outcomes of HEE management based on comprehensive assessment of university's resources for educational process (REP) (fig. 2).

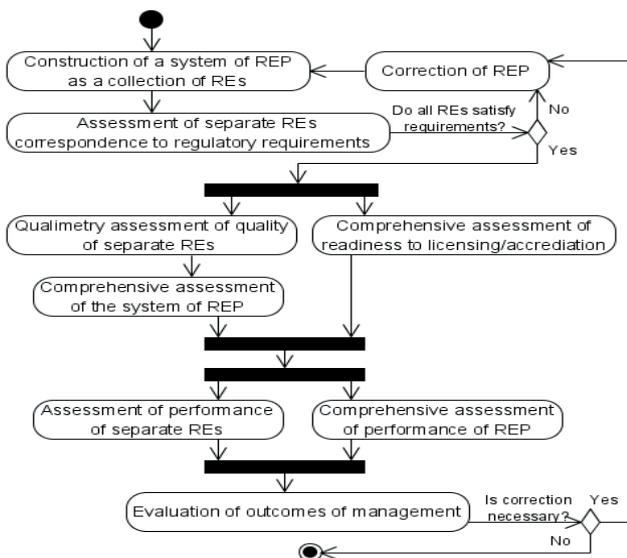


Fig. 2. Evaluation of results of university's functioning

The REP is a collection of separate resource elements (REs). A RE is defined as anything that is necessary to organize students' learning, for example, it can be can a classroom, a computer or a teacher.

First of all the separate REs have to be estimated. If they don't satisfy the conditions of regulatory requirements which set the minimal acceptable level of quality, then the further assessment doesn't have a sense. Based on individual estimates of REs the comprehensive assessment of REP can be found (fig. 2). This problem is solved in our previous work [8]. In parallel to provide management with estimates of readiness to licensing or accreditation procedures the corresponding comprehensive assessment must be accomplished. This is the subject of the given work. Based on the obtained estimates management can evaluate performance both of individual REs and of the whole system of REP. This makes the basis for overall evaluation of outcomes of the university's development project.

The given work is devoted to comprehensive assessment of fulfillment of regulatory requirements and specifications. It gives the estimate of readiness of HEE to provide educational services. The requirements are described in the document called Licensing Conditions, which considers exactly university's resources [6]. Therefore our research also is directed on resources comprehensive assessment.

## 3. Models of resources assessment in licensing problem

In order to formalize the problem of comprehensive assessment let's introduce some designations. We can distinguish different types of resources denote by the set  $\Phi$ , for example, material and technical, information, staff, financial, etc. Each RE can be referred to only one type of resources. Then the collection of REs of type  $\phi$  is denoted by  $R_\phi = \{r_{\phi j} : j \in J_\phi\}$ . Further we will distinguish  $R_\phi^0 \subset R_\phi$  – an initial set of REs (current resources that are evaluated) and  $\tilde{R}_\phi$  – an extended set of REs (subject to extension that must satisfy licensing requirements).

Each RE is characterized by the set of parameters. Depending on the type of resource  $\phi$  the set of these parameters may differ. Let's denote as  $A_j^\phi = (\alpha_{ij}^\phi)$  a column-vector of the values of parameters of RE  $r_{\phi j}$ . Then for all elements  $r \in R_\phi$  we can construct a matrix of parameters  $A^\phi = (\alpha_{ij}^\phi)$ ,  $j \in J_\phi, i \in I_\phi$ . The value of index  $j$  is uniquely defined by RE. Licensing requirements are represented by the vector  $\Lambda$ . REP must satisfy licensing requirements for licensing volume denoted by  $L$ .

We will distinguish  $L_0$  – a targeted licensing volume and  $L_{max}$  – a maximal licensing volume which can be supported by the fixed REP.

The problems of comprehensive assessment of fulfillment of requirements may include the following tasks.

1. Evaluate existing REP in order to license some specialty in volume  $L_0$ .
2. Find the maximal possible licensing volume  $L_{max}$  with regard to the existing REP.
3. Determine extended resources for the fulfillment of licensing requirements under licensing volume  $L_0$ .

Taking into account the above designations the first task can be formalized in the following way. For the given matrix of parameters' values  $A_0^\phi = \{\alpha_{ij}^\phi : r_j^\phi \in R_\phi^0, i \in I_\phi, j \in J_\phi\}$ , licensing requirements  $\Lambda$  and licensing volume  $L_0$  it is necessary to define the value of predicate

$$G(A_0^\phi, L_0) = \prod_{\substack{\lambda \in \Lambda, \\ \phi \in \Phi}} F_\lambda^\phi(A_0^\phi, L_0, \xi_\lambda^\phi),$$

where G is a composition of predicates  $F_\lambda^\phi$ :

$$F_\lambda^\phi(A_0^\phi, L_0, \xi_\lambda^\phi) = \begin{cases} 1, & \text{if requirement } \lambda \text{ is fulfilled,} \\ 0, & \text{otherwise} \end{cases}$$

where  $\lambda \in \Lambda$ ,  $\phi \in \Phi$ ,  $\xi_\lambda^\phi$  is a value of licensing requirement  $\lambda$ ,  $L_0$  is targeted licensing volume.

The comprehensive assessment is defined by the value of predicate G. In the case when  $G = 1$ , all licensing requirements are satisfied, i.e. estimated REP can provide licensing volume  $L_0$ .  $G = 0$  means that at least one requirement is not satisfied. In this case we have to revise value  $L_0$  or improve REP.

The second task is connected with evaluation of licensing volume  $L_{max}$  that can be supported by existing REP. It is necessary to define such value L which is maximal provided that all licensing requirements are fulfilled for the current REP. This can be formalized as follows:

$$L \rightarrow \max, \text{ under the constraints}$$

$$F_\lambda^\phi(A_0^\phi, L, \xi_\lambda^\phi) = 1, \forall \lambda \in \Lambda, \phi \in \Phi, L \geq 0.$$

The solution of the third task answers the question concerning what resources and in what volumes must be increased in order to support the targeted licensing volume. To formalize such task let's introduce the next designations. Let  $S_\phi$  be the set of samples of REs of type  $\phi$ . Each sample is characterized by the set of parameters  $\{\beta_{is}^\phi, i \in I_\phi, s \in S_\phi, \phi \in \Phi\}$  in a similar way as  $A_0^\phi$  for existing REP. Let  $x_s^\phi$  be the number of such samples by means of which the REP have to be extended. Addition of these REs makes the set of extended REP  $\tilde{R}$ .

If the requirement  $\lambda$  for the given  $L_0$  is not fulfilled, then it is possible to find the value  $\delta_i^\phi$  such that this requirement will be satisfied. In other words,  $\delta_i^\phi$  is the sum of values of i-th parameter of additional REs of type  $\phi$ . Let's introduce a predicate  $P_i^\phi(\delta_i^\phi, G(A_0^\phi, L_0))$ , which takes value 1, if the extended REP provides licensing requirements fulfillment that are connected with i-th parameter.

Taking into account the above assumptions and designations the task of definition of required extension of REP is formalized in the following way. It is necessary to find such values of parameters  $\delta_i^\phi$  under which the licensing requirements are satisfied and to find the number of the needed additional resource elements  $x_s^\phi$ :

$$\sum_{\phi \in \Phi} \sum_{s \in S_\phi} x_s^\phi \rightarrow \min, \sum_{\phi \in \Phi} \sum_{i \in I_\phi} \delta_i^\phi \rightarrow \min, \text{ under the constraints}$$

$$\begin{cases} P_i^\phi(\delta_i^\phi, G(A_0^\phi, L_0)) = 1, i \in I_\phi, \phi \in \Phi, \\ \sum_{s \in S} \beta_{is}^\phi x_s^\phi \geq \delta_i^\phi, i \in I_\phi, \phi \in \Phi, \\ x_s^\phi \in Z, x_s^\phi \geq 0, s \in S_\phi, \phi \in \Phi. \end{cases}$$

Hence the problems of comprehensive assessment of REP correspondence to licensing requirements can be considered from the point of view of three tasks: evaluation of existing REP, definition of maximal possible licensing volume on the given REP and definition of extended REP for specified licensing volume.

#### 4. Case Study

To demonstrate the application of suggested models we would like to consider the comprehensive assessment of fulfillment of requirements for licensing of specialty "Computer science" for training bachelors in our department. We consider licensing requirements related to material and technical and information supply.

Information supply requirements deal with places in library, number of core scientific journals and access to the Internet which is managed on the level of the whole university. That's why we suppose that these requirements are fulfilled thanks to HEE funds. Another requirement is related to the number of available books in the library. It can be managed on the level of department, i.e. a department may buy some books in its library. The licensing requirements state that for each subject there must be at least one book for three students. For the case study we demonstrate the subjects for bachelor training of the first year and the number of available books in Tab. 1.

For the first task we check whether the current number of books is enough for targeted licensing volume. For the licensing volume of 72 students the amount of all books for each subject should not be less than 24. As we can see this requirement is fulfilled for all subjects.

In the second task we would like to find the maximal licensing volume that can be claimed. It is determined by the minimal value of the possible licensing volumes for each subject. In our case study the maximal possible volume is equal to 80.

The goal of the third task is to find the required amount of books for each subject for specified licensing volume. Let the licensing volume be equal to 96. This value is equal to 33 in our case. We can see the additional required amount of books for each subject for the targeted licensing volume in Tab. 1.

**Table 1**

Information supply assessment (fragment)

Subject	Book	Available amount	Total amount for subject	Maximal licensing volume	Additional amount required for licensing volume of 96
Algorithmization and programming	1	11	30	90	2
	2	10			
	3	9			
Computer graphics	1	9	27	80	5
	2	8			
	3	10			
Discrete mathematics	1	8	31	93	1
	2	7			
	3	16			
Object-oriented programming	1	17	28	84	4
	2	11			

Our next experiment deals with comprehensive assessment of material and technical resources. According to licens-

ing requirements the need in classrooms must be satisfied on 100%. There are three types of classes in educational process and the total number of hours of each type is determined by educational plan. This includes lecture, practice and laboratory works hours per a week.

In order to have lecture class students of all groups must take places in a single classroom. The practice class requires one classroom for each group. And for laboratory work a group is divided into two subgroups. The classroom of each type is characterized by the following parameters: number of seats and the number of available hours.

To check whether the requirement of 100% classrooms availability is fulfilled we must first check for each type of classes whether the corresponding classrooms have enough seats and then check whether the sum of available hours is enough greater or equal to the number of hours defined by educational plan.

In this experiment the licensing volume of 72 students presupposes teaching of three groups, each with volume of 24, and subgroups of 12 students. The number of class hours per week is equal to 90 for all groups (15 classes per week for each group). The number of available hours is enough for the licensing volume of 72 students.

Moreover the existing classrooms allow to increase licensing volume from 72 to 96 (4 groups). But since all requirements must be fulfilled simultaneously, the possible licensing volume in this case study is bounded by the requirement about the necessary number of books and equals to 80. In order to provide licensing volume of 96 the appropriate number of books has to be added to the library.

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## 5. Conclusions and Future Work

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Licensing is one of the activities that take place in any HEE periodically. During licensing process management obtains the estimates of its current resources. Based on these data it is possible to conduct readiness assessment in order to prepare to official licensing procedure. Also such data can be the basis for construction of plans for future and development strategies concerning possible increment of licensing volume.

When talking about resources assessment with respect to licensing requirements fulfillment, we can deal with three classes of tasks described in this work. This includes evaluation of resources correspondence to licensing requirements under the specified licensing volume, calculation of maximal licensing volume provided by the current resources and determining the necessary extension of the current resources in order to satisfy licensing requirements under specified licensing volume.

The formalization of these tasks in the form of appropriate mathematical models allows to make the next steps in realization of information technology of licensing process support.

So our future work is connected with elaboration of algorithms for calculation of the parameters of the described models.

These models and algorithms will form the basis for the development of information system of university resources assessment for licensing process support.

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