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**COMPETENCE MODEL AS A TOOL FOR ESTIMATION OF STATE OF IT-COMPANIES IN UNIVERSITY'S BUSINESS CENTRE**

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**Анотація.** У статті розглядається бізнес-центр при університеті як механізм передачі нових наукоємних технологій промисловості. Для ІТ-компаній пропонуються чотири види інструментального вирішення поставлених завдань, серед яких побудова моделі компетенції компанії. Сформульовано концепції створення моделі компетенції Start-Up і Spin-Off компаній. Розроблено комплексний алгоритм формування моделі компетенції Start-Up-компанії, що містить математичне моделювання процесу навчання за допомогою когнітивних карт, що дозволяє оптимізувати процес формування компетенцій; алгоритм виявлення переліку найбільш запитаних компетенцій на основі методу парних порівнянь; оцінку стану компетенції на поточний момент часу, використовуючи такі характеристики, як рівень формування компетенцій, рівень вкладу дисципліни в компетенцію, втрати компетенції.

**Ключові слова:** бізнес-центр, Start-Up і Spin-Off-компанії, моделювання компетенції, алгоритм, моніторинг рівня компетенцій, когнітивна модель.

**Аннотация.** В статье рассматривается бизнес-центр при университете как механизм передачи новых наукоёмких технологий промышленности. Для IT-компаний предлагаются четыре вида инструментального решения поставленных задач, среди которых построение моделей компетенции компании. Сформулированы концепции создания модели компетенции Start-Up и Spin-Off компаний. Разработан комплексный алгоритм формирования модели компетенции Start-Up-компания, включающий математическое моделирование процесса обучения с помощью когнитивных карт, позволяющее оптимизировать процесс формирования компетенций; алгоритм выявления перечня наиболее востребованных компетенций на основе метода парных сравнений; оценку состояния компетенции на текущий момент времени, используя такие характеристики, как уровень формирования компетенций, уровень вклада дисциплины в компетенцию, потери компетенции.

**Ключевые слова:** бизнес-центр, Start-Up и Spin-Off-компания, моделирование компетенции, алгоритм, мониторинг уровня компетенций, когнитивная модель.

**Abstract.** This paper discusses the business center at the university as a mechanism for the transfer of new technology to industry. There are four types of tools proposed for IT-companies, among which the construction of models of competence. The concept of a competence model Start-Up and Spin-Off companies is formulated. An algorithm of a model of competence forming for Start-Up-companies is developed. It includes: mathematical modeling of the process of learning through cognitive maps, thus optimizing the process of formation of competence; detection algorithm list of the most sought-after competencies based on the method of paired comparisons; assessment of competence at the current time using features such as the level of formation of competences, the level of contribution to the discipline of competence, loss of competence.

**Keywords:** business center, Start-Up and Spin-Off-companies, competency modeling, algorithm, monitoring the level of competence, cognitive model.

## 1. The problem statement

At the stage of globalization and European integration of multilateral economic relations new benchmarks in the process of interaction between universities and enterprises are forming. The experience of western universities can play the most important part, since there were almost no research of cooperation between universities and enterprises in Ukraine [1].

Studies of such foreign scientists as S. Lange [2], A. Tormasov [3], H. Edmondson [4] are devoted to the problem of the interaction between industry and universities. In this studies were developed theoretical and methodological aspects of cooperation, incentive and motivational factors were analyzed in detail. Only small amount of scientific studies in this direction are carried in Ukraine. In most cases, they have the character of statement and analysis of the problem at the present stage of socio-economic development of the country [5, 6]. However, to date there are examples of solutions to this problem, in particular since 2012 S. Kharchenko, V. Sklar are actively promoting the theme of University-Business Cooperation (UBC) [7, 8].

Many universities use business centers as a mechanism for the transfer of new technology to industry. The main purpose is to create technologies that provide progress and implementation of innovations of the university science in industry, to develop a management system of maturity of Start-Up-companies in the business center and support tools for maturity management of the Start-Up-companies in the business center.

For IT-companies we propose four types of tools to solve this problem:

- 1) “calculator” to assess the advisability of creating the Start-Up-company;
- 2) simulation model development process, based on one of the selected models of software lifecycle;
- 3) the model of competence of the Start-Up-company;
- 4) “calculators” which are assessing the level of maturity of the company's aggregate indicators based on the five-level evaluation model of maturity.

Topicality of creating these tools is not only connected with the problem of transfer technology from the university environment to the industry. But also in the growing needs of large IT-companies in carrying out diagnostics of business processes of its customers, in the creation of complete and non contradictory business process models for the purpose of optimizing the functioning of the company.

The purpose of this article is the creation of the tools for assessing the state of IT-company, patronized by the business center at the university, the model of competence of the Start-Up-company in particular.

Competence Model of the Start-Up-company is a description in the prescribed form of indicators, characterizing the required level of its development. When hiring new employees, competence model allows you to choose exactly those employees that are necessary for the organization at this stage of its life cycle.

The result of the process of creating a competence model are competence profiles, developed to determine the actual level and the level of knowledge, skills (competences), which are required for specialists in Start-Up and Spin-Off-companies. It can be effectively used not only to check the current level, but also to form a plan for professional development and monitoring process. Competence profile is a list of competencies that belongs to a particular company. It defines not only what is expected of employees, but also how they should act. Development of profiles is a good way to test and adjust competence model, and also for obtaining Start-Up – University feedback.

## 2. Development of an integrated algorithm of forming a competence model

Effective mechanism to ensure the high quality of the learning process is the involvement of students in the Start-Up company work that makes it possible to directly observe the company-university feedback.

To improve quality of the specialist training in view of the Educational qualification characteristic (EQC) and Start-Up-companies requirements it is necessary to develop a complex algorithm of forming a competence model, which will provide an opportunity to overcome the disadvantages existing today in the specialist preparation:

- lack of interaction between the university and industry;
- lack of information about the influence of disciplines on the competences formation;
- errors during the formation of the sequence of studying disciplines and appointment of the number of credit units;
- lack of tools to assess the level of competence formation and level of preparedness of work in the Start-Up-company.

Analysis results of modeling allow making adjustments to the processes of formation and evaluation of competences, improving the education scheduling algorithm and monitoring the development of competences, organization process of the learning and the process of establishing Start-Up-company, thus providing an opportunity to increase the competence of graduates.

Consider the basic steps of a complex algorithm of forming a competence model, a block diagram is shown in fig. 1.

*Stage 1. Formation of Start-Up-companies competence profile.*

2.1. Creating a team of experts to compile competence profile of the Start-Up company that uses an interrogation of three groups of experts (experienced teachers of the various cycles, potential employers, experts from leading companies and organizations requiring qualified specialists of this area of training, representatives of the university administration, working in their specialty graduates).

Table 1. Matrix matching competencies and disciplines

Competence	Disciplines						The number of disciplines involved in the formation of the $i$ -th competence
	$S_1$	$S_2$	...	$S_j$	...	$S$	
$C_1$				Competence formed			
$C_2$							
...							
$C_i$	Card is of the $i$ -th			$C_i^j$	Competence		
...				In about $j$ -th discipline			
$C$							
The number of competencies, formed in about $j$ -th discipline							

The concept of competence is defined as the ability to apply knowledge skills and personal qualities to be successful in a particular field.

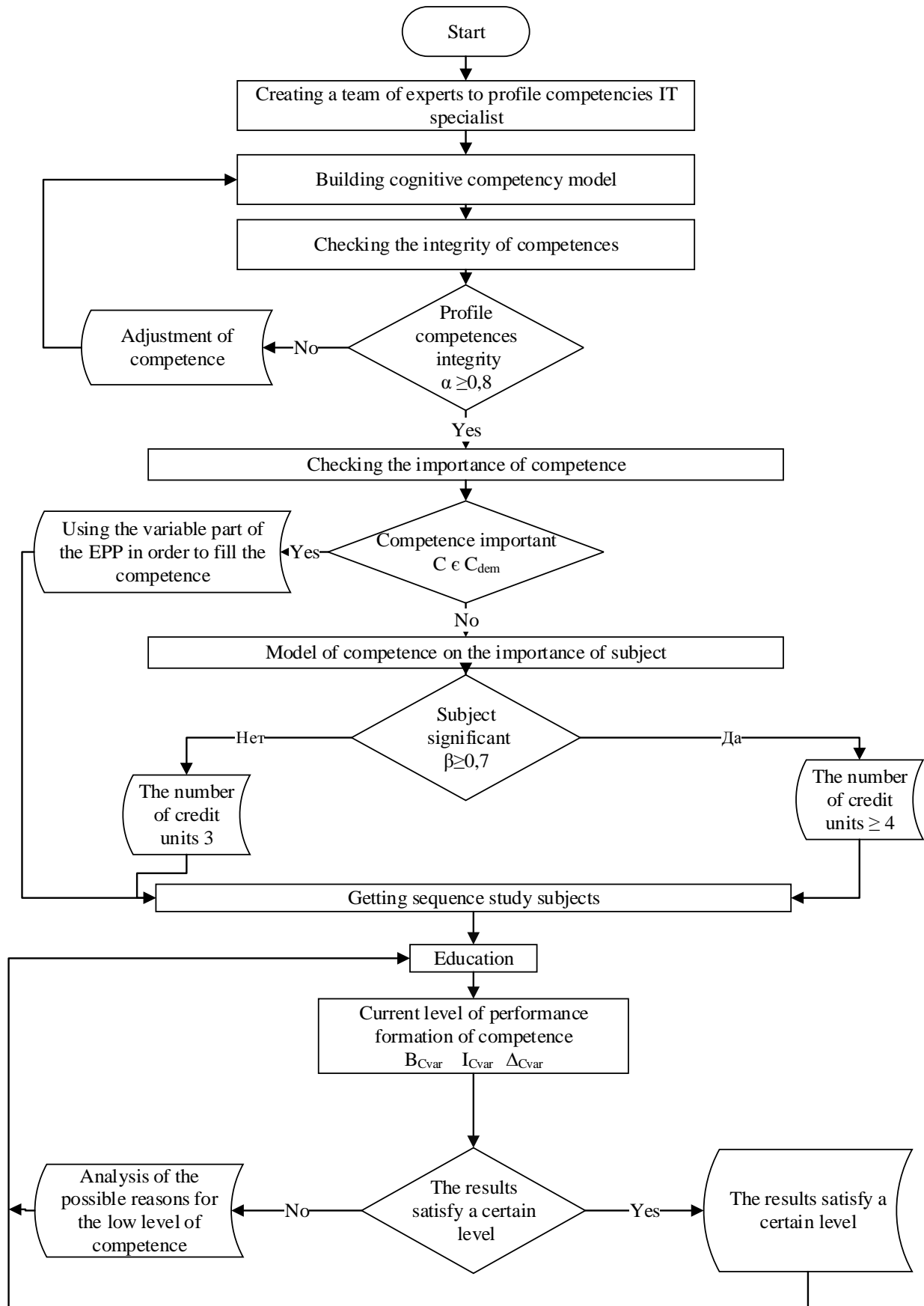


Fig. 1. Block diagram of the complex algorithm of forming a competency model of a Start-Up-company

Competence based on a set of knowledge, skills, experience, but not their totality, because include the ability of the person receiving education to self-learning, creative thinking, orientating in unusual and problematic issues, changing the form of its activities in accordance with the needs of the labor market.

Thus, competence – is an integrative property, personality characteristics, the indicator of successful activities that provides a person's ability to realize their potential [9].

For each competency, it is necessary to construct a list of disciplines that directly influence on its formation. For this, we consider the matrix relations between competencies and disciplines (table 1).

Vertically we arrange the list of competencies and horizontally – the list of disciplines. When there is a connection between competence and discipline (fig. 1) in the appropriate cell of the matrix appears part of the competence  $C_i^j$  ( $i$  – number of competence;  $j$  – number of discipline), which is formed within this discipline [10].

Using of this procedure helps to identify competencies, formation of which is not ensured by detail and activity content, or ensured inadequate (with one or two disciplines), or is not supported by the EPP (educationally professional program) practical unit. In addition, to identify disciplines, clearly overwhelmed by the amount of competences in the formation of which they participate. Summary sections are entered in the matrix for convenience. The final column shows the number of disciplines. The final line shows the number of parts of competences formed in the discipline. Redundancy of disciplines involved in the formation of the same competence, as well as redundancy of competencies formed within a discipline complicates the EPP design process and makes quality control of the educational process more difficult in the future [11].

Filling in the matrix should be, if possible, regular enough to ensure the obligatory formation of the competences in the disciplines' learning cycles established by the MES of Ukraine. The variable component of the disciplinary and activity content should improve the quality of the distribution of competences in the disciplines and sections of EPP, take into account the requirements of employers, revealed preferences of the importance of certain competencies.

Regular relationship matrix allows performing laboriousness distribution by the disciplines and practical sections of the EPP, because the laboriousness in the competence approach depends on the total performance of the EPP subsection, that is the number of competencies and learning outcomes are formed and developed in it [11].

The completed table illustrates the links between the cells vertically and horizontally, and allows you to get the following information: the horizontal line of each competence defines its content structure: the distribution of competence parts by identified disciplines. This allows developing a set of key descriptors, each of them determines target formation of the competence part within each discipline. This excludes repetitions when studying various disciplines, it is possible to establish interdisciplinary connections. It is possible to integrate academic disciplines and to create new courses or other forms of learning activities. Structuring competence on the identified disciplines reflects in the passport of competence [10].

A vertical column carries the selection of competencies in the formation of which this discipline is involved. There is coordination between studying of the discipline of logic and the logic of the formation of competencies. Based on the developed competencies maps identified in the column of discipline, formed the integral target descriptors, that determine the focus of the educational process in this subject area.

The proposed procedure finally generates a list of disciplines and types of practice, providing qualitative declared formation of competencies of graduates. To allow performing certification of competencies is the most important stage of the development of competence-oriented EPP of the university. Proceed to the development of the curriculum with the distribution of laboriousness, taking into account the contribution of each subsection of EPP in the process of form-

ing the set of competences and work programs of disciplines, specifically involved in the formation of competence model of specialist and Start-Up-company.

The proposed procedure allows managing the functioning of the educational process, both in terms of teaching bachelors and masters, and updating it based on the developed Start-Up – University feedbacks.

It is possible to carry out the mathematical modeling of the learning process through cognitive maps, thus optimizing the process of competence formation based on building a cognitive map of competence, which represents the connections that occur between disciplines in the process of competence.

2.2. Building a cognitive model of competence. The prerequisites for the development of the IT-specialist’s cognitive competence model are the lack of necessary data about the mutual influence of studied disciplines on each other and on the formation of competence. Cognitive map – a type of mathematical model that allows to formalize the description of a complex object, problem or system functioning and to identify the structure of causal relations between the elements of the system, a complex object, components of the problem and assess the effects due to exposure to the elements or change in the nature of relations [10].

Cognitive competence map is represented as a directed weighted graph. Here is the set of vertices:

$C$  – competence;

$S$  – disciplines that directly affect the competence;

$s$  – disciplines, that indirectly affect the competence;

$R$  – the set of edges connecting the disciplines with the competence and disciplines between each other (fig. 2).

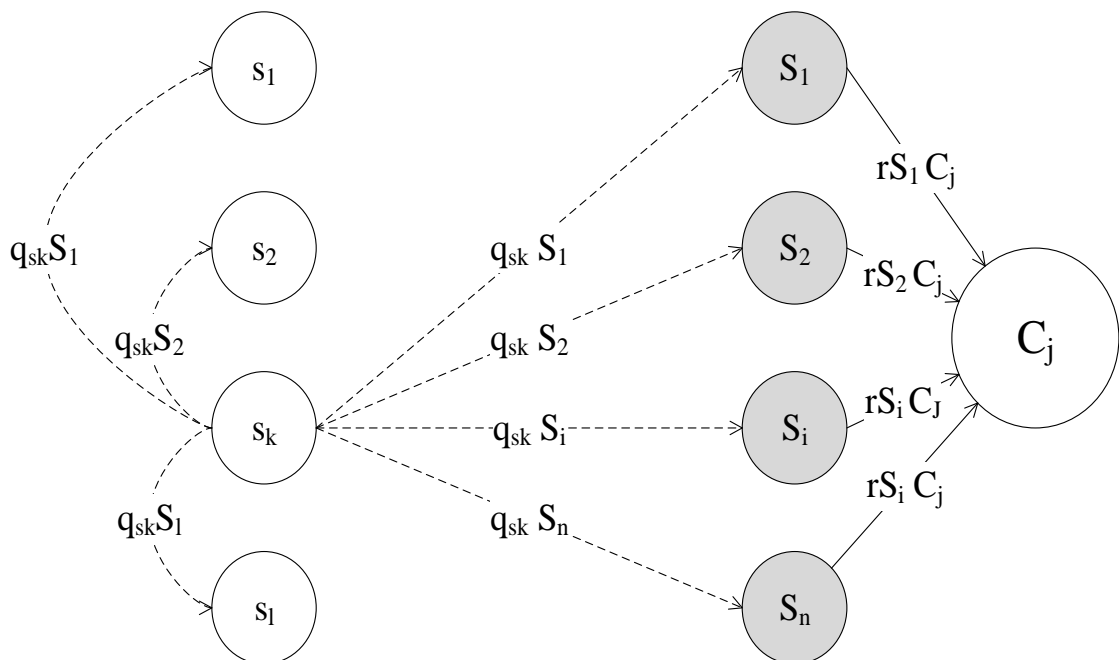


Fig. 2. Simulation of competence

● – a direct effect, ○ - indirect effect,  $\rightarrow$  –link of the direct influence,  $\dashrightarrow$  – link of the indirect influence.

Collection and processing of expert data consists of 4 stages:

1) a survey of experts to form the matrix  $W$ , which determines the dependence of competence from various disciplines that are forming it directly:

$$W = \begin{pmatrix} w_{S_1C_1} & w_{S_1C_2} & \dots & w_{S_1C_j} & \dots & w_{S_1C_m} \\ w_{S_2C_1} & w_{S_2C_2} & \dots & w_{S_2C_j} & \dots & w_{S_2C_m} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ w_{S_iC_1} & w_{S_iC_2} & \dots & w_{S_iC_j} & \dots & w_{S_iC_m} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ w_{S_nC_1} & w_{S_nC_2} & \dots & w_{S_nC_j} & \dots & w_{S_nC_m} \end{pmatrix},$$

where  $i = \overline{1, n}$ ,  $j = \overline{1, m}$ ,  $n$  – the number of disciplines studied  $S$ ,  $m$  – the number of formed competencies,  $w_{S_iC_j}$  defined as

$$w_{S_iC_j} = \begin{cases} 1, & \text{if } S_i \text{ forms } C_j. \\ 0, & \text{otherwise} \end{cases}.$$

And the matrix  $V$ , defining dependence of disciplines  $S$  from disciplines  $s$  that are indirectly forming  $C$ :

$$V = \begin{pmatrix} v_{s_1S_1} & v_{s_1S_2} & \dots & v_{s_1S_d} & \dots & v_{s_1S_t} \\ v_{s_2S_1} & v_{s_2S_2} & \dots & v_{s_2S_d} & \dots & v_{s_2S_t} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ v_{s_kS_1} & v_{s_kS_2} & \dots & v_{s_kS_d} & \dots & v_{s_kS_t} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ v_{s_lS_1} & v_{s_lS_2} & \dots & v_{s_lS_d} & \dots & v_{s_lS_t} \end{pmatrix},$$

where  $k = \overline{1, l}$ ,  $d = \overline{1, t}$ ,  $l$  – number of studied disciplines  $s$  that affect the discipline  $S_d$ ,  $t$  – number of disciplines, directly affecting competence:

$$v_{s_kS_d} = \begin{cases} 1, & \text{if } s_k \text{ forms } S_d; \\ 0, & \text{otherwise} \end{cases};$$

2) experts rank disciplines in order of importance of their impact on the competence (discipline);

3) checking the consistency of expert opinion (calculation of the concordance coefficient);

4) applying the Fishburne rule for the calculation of weights of influence of the competence components on its formation.

Because of data processing, the matrix  $W$  and  $V$  are converted into the matrix  $R$  and  $Q$ , which have the influence weight of disciplines on the competence and of disciplines on the discipline:

$$R = \left\| r_{S_iC_j} \right\|,$$

where  $r_{S_iC_j}$  – weight of influence of the discipline  $S_i$ , which affects the competence  $C_j$ , and:

$$\sum_{i=1}^n r_{S_iC_j} = 1,$$

$$Q = \left\| q_{s_kS_d} \right\|,$$

where  $s_k S_d$  – weight of influence of discipline  $d_s$ , which affects the discipline  $Dt$ , and:

$$\sum_{k=1}^l s_k S_d = 1.$$

Introduction of weighting coefficients allows us to supplement the constructed competence model for representing as a directed weighted graph.

The developed model is the basis for compiling the competence profile and developing its assessment procedures. Application of methods of graph theory (Breadth-first traversal, Depth-first traversal) allows creating a sequence of studying disciplines, which is necessary in the curricula development.

For verification of a competences demand questionnaires of the formed experts group are used. Competences are recommended to combine in groups and carry out an analysis in each group. For «Software engineering» specialty such groups are: general cultural and professional competence, competence of operational activities, project and technological activities, organizational and management activities and experimental research activities, marked in EQC [12].

2.3. Checking the integrity of competence. Consider the competence as a system and enter its system characteristic as the integrity of competence – assessment of influence of a set of disciplines, making up structure of competence, on its formation.

The degree of influence of the disciplines on the competence is realized by using the entropy approach. Entropy is understood as a possibility degree of control over the competence formation, taking into account the measure of disciplines influence – magnitudes which values are in an interval from 0 to 1. It is proposed to use the formulas of calculation the entropy according to Shannon for competence:

$$H = \sum_{j=1}^m p_j \log_2 p_j,$$

where  $p_j$  – probability of influence of discipline on competence.

Mutual influence of disciplines on competence:

$$H_{inter} = H_0 - H,$$

where  $H_0 = \sum_{i=1}^n H_i$ ,  $H_i$  – entropy of discipline,  $n$  – the number of disciplines.

Then, the magnitude of participation of each discipline in the formation of competence  $\alpha$ , averaged on all disciplines:

$$\alpha = \frac{H_0 - H}{H_0}, \text{ where } 0 \leq \alpha \leq 1.$$

Than  $\alpha$  is closer to one, that more all set of disciplines participates in formation of competence. On the basic of a statistical experiment will enter linguistic classifier, forming threshold values  $\alpha \geq 0,8$ , which allows to interpret competence as a “Holistic”.

2.4. Checking the importance of competence. Expert data processing is carried out by a method of pairwise comparisons: in a matrix of pairwise comparisons, where the preference of competences is expressed by Boolean variables. Each  $g$ -th expert from  $k$  respondents evaluates the degree of importance of competence  $C_i$  with magnitude  $a_{gi}$  (on the scale of Harrington), each expert’s assessment of competencies of the group is described by a matrix  $A$ :

$$A^g = (a_{ij}^g)_{i,j=1}^n,$$



$$\text{where } a_{ij}^g = \begin{cases} 1, & \text{if } a_{ij} \geq a_{ji} \\ 0, & \text{if } a_{ij} < a_{ji} \end{cases}.$$

Matrices of all the experts' estimates are summarized:

$$B = \sum_{i=1}^k A^g = (b_{ij})_{i,j=1}^n.$$

Introduce evaluation matrix group of the importance of competences:

$$\hat{A} = (\hat{a}_{ij})_{i,j=1}^n,$$

$$\text{where } \hat{a}_{ij} = \begin{cases} 1, & \text{if } b_{ij} \geq b_{ji} \\ 0, & \text{if } b_{ij} < b_{ji} \end{cases}.$$

The demand of each competence is determined by summation of Boolean variables in the corresponding row of the matrix:

$$D_{C_i} = \sum_{i=1}^n \hat{a}_{ij}.$$

Vector  $D = (D_{C_i})$  is formed, according to the elements of which the list of the most demanded competences is formed by the majority rule:  $C_{dem} = \{C_1, C_2, \dots, C_m\}$ , defining priorities of disciplines in the process of further planning of the variable part of the main educational program.

The result of the first stage is the formation of a profile of competences according to the model, identification of the most demanded competences, definition of the degree completeness of the disciplines structure, forming competence, formation of the list of "significant" disciplines.

*Stage 2. Research of competence model on the importance of discipline.*

The importance degree of a discipline is assessment of influence of each discipline on competence formation. In order to determine the degree of each discipline's influence the average degree of the  $S_i$  discipline influence on the competence is determined:

$$\bar{H} = H - H_{S_i},$$

$$H_{S_i} = \sum_{j=1}^m p_i(j) \cdot H_j(S_i),$$

where  $H_{S_i}$  – average entropy of competence, on condition, that the state of discipline  $S_i$  is fixed,  $p_i(j)$  – probability, that the  $i$ -th discipline is in the  $j$ -th state, considering all chains of influence.

$$H_j(S_i) = \sum_j p_j \log p_j,$$

where  $H_j(S_i)$  – entropy of discipline influence on the competence,  $p_j$  – the probability of discipline influence, considering each chain of influence. Relative assessment of the influence of the  $i$ -th discipline on the formation of competence:

$$\beta_{S_i} = \frac{H - H_{S_i}}{H},$$

where  $0 \leq \beta \leq 1$ .

The proximity  $\beta$  to 1 means a greater influence of a discipline. The weight of discipline influence on competence determined by using values  $\beta$ :

$$\mu_{S_i} = \frac{\beta_{S_i}}{\sum_{i=1}^n \beta_{S_i}},$$

where  $i$  – is the number of disciplines that form the competence.

On the basis of a statistical experiment introducing linguistic classifier, forming threshold  $\beta \geq 0,7$ , which allows to interpret competence as “significant”.

The result of the second stage is the definition of the influence impact of each discipline on competence.

*Stage 3. Assessing of the level of competence formation, as the possibility of participation in the Start-Up-company at current moment of studying.*

The choice of the generalized criterion caused by multiple disciplines, which form the competence and therefore the accumulation of student competence, is dependent on the points accumulated in the discipline by student, and the weight of the discipline influence.

To assess the degree of the competence formation the integral additive criterion is used:

$$B_C = \sum_{i=1}^n \mu_{S_i} \cdot b_{S_i},$$

where  $B = (b_{S_1}, b_{S_2}, \dots, b_{S_n})$  – vector whose components are the points in the disciplines which are forming the competence.

System characteristics of the competence model can determine the degree of participation of each discipline for the entire system and get the weights of influence on the competence of the disciplines where  $m$  – number of disciplines studied at a given time (table 2).

Table 2. System Specifications competence model

Name	Purpose	Units of measurement	Current value	Minimum	Maximum
The level of competence formation	Show the current status of competence and borderline values	Units of score-rating system adopted in high school, [0;100]	$B_{C_{var}} = \sum_{i=1}^m B_{C_{S_i}}$	$B_{C_{min}} = \sum_{i=1}^m B_{C_{min S_i}}$ , where $B_{C_{min S_i}} = \mu_{S_i} \cdot b_{min S_i}$	$B_{C_{max}} = \sum_{i=1}^m B_{C_{max S_i}}$ , where $B_{C_{max S_i}} = \mu_{S_i} \cdot b_{max S_i}$
Level of the discipline contribution to the competence	Shows a relative measure of the level of competence formation	Units in percent, $I_C \in [0,1]$	$I_{C_{var}} = \frac{B_{C_{cur}}}{b_{max}}$	$I_{C_{min}} = \frac{B_{C_{min}}}{b_{max}}$	$I_{C_{max}} = \sum_{i=1}^m \mu_{S_i}$
Loss of competence	Shows the loss of competence	Units in percent, $\Delta \in [0,1]$	$\Delta_{C_{var}} = I_{C_{max}} - I_{C_{var}}$		$\Delta_{C_{max}} = \frac{b_{max} - b_{var}}{b_{max}}$

The minimum value of the competence level of formation  $B_{C_{min}}$  for certain period of studying in the university gives a chance for a student to be involved in the work of Start-Up-company at the appropriate stage of the five-level model of the life cycle (LC).

Developed procedure for assessing the competence level formation is required for following monitoring of competence, which is an important system element of managerial decisions support in the organization of the learning process.

Result – an assessment of the students competence level that specifies ability to participate in the work of Start-Up-company at the appropriate stage of its life cycle, based on its model, considering degree of disciplines influence on the competence formation.

### 3. Conclusion

Based on the analysis of problems of modernization of Ukrainian education, should be noted that the business center at the University has the following advantages:

- graduate from the university at least specialists with work experience in Start-Up team and Spin-Off company, as a maximum – ready IT-company;
- reduce the gap between the professional competence level of IT-specialist and a graduate of the University.

The developed algorithm of forming a competence model, comprising: an algorithm for data collection and expert information processing, required to build the model; cognitive model of competence; an algorithm for detection of the most demanded competencies list, based on the method of paired comparisons; assessment of the competence at the current time.

There were identified system characteristics of a competence model and developed a procedure that allows calculating their quantitative values for the following monitoring of competence, which is an important element of managerial decisions support system in the organization of the interaction university – industry through the Start-Up-company.

Further development we see in developing of the “calculators” algorithms, assessing the advisability of creating a Start-Up company and the company's level of maturity on set of indicators, based on the five-level maturity assessment model, based on the model of competence.

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