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USING ECONOMIC AND MATHEMATICAL MODELS AND METHODS TO ASSESS THE HUMAN CAPITAL OF A COMPANY IN THE FIELD OF IT INDUSTRY

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The problem of effective use of human resources represents an extremely difficult socio-economic challenge, therefore, currently there has been a marked increase in interest in the evaluation of human capital as the most important resource that provides competitive advantages for modern companies in every field. The aim of this study is to assess human capital of the company's employees on the basis of expert approach using a competence model and aggregated indices randomization method. The article clarifies the concept of human capital as the basic structural element of intellectual capital, presents a brief overview of the most common models and methods of human capital assessment and demonstrates the necessity of realization of a competence-based approach in the evaluation of the company's employees and personnel segmentation. The possibility and the advantage of application of the aggregated indices randomization method (AIRM) to produce a comprehensive assessment of the level of competence of employees of the international division of a Russian company in the field of IT industry is demonstrated. The division based in St. Petersburg is engaged in the development of custom software and modernization of corporate information systems in the financial industry, telecommunications, online-travel, mobile development, Internet projects and media. This study employs mathematical methods (aggregated indices randomization method, expert score), comparative methods (analysis, synthesis, classification), as well as the general logic methods of scientific concept construction. The scientific novelty of the research lies in the fact that, based on existing research, the authors propose a new instrumental technique, realizing the algorithms for assessing the human capital of the company's employees, the results of which reveal the priorities in the field of recruitment, development and motivation of the staff, thereby implementing a rational approach to using human and financial resources of the company. The practical significance of the study lies in the development of methodological tools for human capital assessment that can be used for managing other information technology companies.

Keywords: human capital; models and methods of human capital assessment; competence; competence; competence model; aggregated indices randomization method; personnel segmentation; competitiveness

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ПРИМЕНЕНИЕ ЭКОНОМИКО-МАТЕМАТИЧЕСКИХ МОДЕЛЕЙ И МЕТОДОВ ДЛЯ ОЦЕНКИ ЧЕЛОВЕЧЕСКОГО КАПИТАЛА СОТРУДНИКОВ КОМПАНИИ В СФЕРЕ IT-ИНДУСТРИИ

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Проблема эффективного использования человеческих ресурсов представляет собой чрезвычайно сложную социально-экономическую задачу, поэтому в настоящее время значительно возрос интерес к оценке человеческого капитала как важнейшего

ресурса, обеспечивающего конкурентные преимущества современных предприятий в любой сфере деятельности. Цель исследования – проведение оценки человеческого капитала сотрудников предприятия на основе экспертного подхода с использованием модели компетенций и метода рандомизированных сводных показателей. Уточнено понятие «человеческий капитал» как базовый структурный элемент интеллектуального капитала, проведен краткий обзор наиболее распространенных моделей и методов оценки человеческого капитала, обоснована необходимость реализации компетентностного подхода при оценке сотрудников предприятия и сегментации персонала. Показана возможность и преимущество применения метода рандомизированных сводных показателей (МРСП) для получения комплексной оценки уровня компетентности сотрудников российского подразделения международной компании в сфере IT-индустрии. Подразделение в Санкт-Петербурге занимается разработкой заказного программного обеспечения и модернизацией корпоративных информационных систем в области финансовой индустрии, телекоммуникаций, онлайн-путешествий, мобильной разработки, интернет-проектов и масс-медиа. Использовались математические методы (метод рандомизированных сводных показателей, экспертная балльная оценка), сравнительно-сопоставительные методы (анализ, синтез, классификация), а также общелогические методы построения научной концепции. Научная новизна исследования состоит в том, что на основе существующих разработок предложена новая инструментальная методика, реализующая алгоритмы оценки человеческого капитала сотрудников предприятия, результаты которой позволяют выявить приоритетные направления в сфере подбора, развития и мотивации персонала, тем самым осуществить рациональный подход к использованию человеческих и финансовых ресурсов предприятия. Практическая значимость исследования заключается в разработке методического инструментария по проведению оценки человеческого капитала, который может быть использован в управленческой деятельности других предприятий в сфере информационных технологий.

Ключевые слова: человеческий капитал; модели и методы оценки человеческого капитала; компетенция; компетентность; модель компетенции; метод рандомизированных сводных показателей; сегментация персонала; конкурентоспособность

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In the context of modern Russian economy focused on innovative socially-oriented development model, the community is rapidly becoming conscious of the fact that a company's development, competitiveness and efficiency is determined not by the physical assets but by the human capital, which is a combination of knowledge, skills, innovativeness and creativity of people, which allow to create well-being, both in personal and social terms.

In this regard, the assessment and accumulation of human capital, as the most valuable resource of intellectual capital, is one of the companies' high-priority strategic tasks. It should be noted that the process of assessing the human capital of a company is very complex and highly individual, because each employee is a unique person, therefore, it is necessary to take into account the characteristics specific to a particular employee.

For the implementation of human capital assessment of companies' employees by Russian and foreign researchers, various models and methods are proposed that take into account the quantitative and qualitative characteristics of a person's abilities and skills, and also determine the value of human capital in cost and natural values [6]:

1. Cost-based models where the initial cost, the replacement cost and the opportunity cost of human assets are determined.

2. A monetary model based on determining the economic effect of the use of human capital.

3. Natural (temporary) assessment, implying the measurement of human capital in person-years of learning.

4. Values of human capital taking into account intangible behavioral values and monetary economic value.

Accordingly, the cost and value of human capital accumulated by individuals, the volume

of investments in human capital, the competitive advantages of the company resulting from the accumulation of human capital are subject to measurement.

One of the most common methods is the calculation of the human capital of an individual and its evaluation in the structure of the intellectual capital of the company. The theory is held by scientists such as Farr, Dublin and others. The method is based on the attempt to estimate the discounted cost of the flow of costs associated with the formation of human capital and the future flow of income, which will ensure the receipt of human capital of a particular individual [2].

An approach to the evaluation of human capital by analogy with physical capital has a fairly wide application. Within the framework of this method, the «initial cost» of a particular employee is determined by means of various methods of testing the employees of a company. Then, the coefficient of forgetting the knowledge is revealed, taking into account the term of participation of a particular employee in the company's activities.

With the expert approach, qualitative indices that characterize both the individual characteristics of a particular employee and the properties of company's employees in the aggregate are evaluated. The calculation procedure is carried out in three stages:

1. Identification of the key indices that describe the employee's contribution to the intellectual capital of the company.

2. Definition of a point scale for the estimation of each index.

3. Determination of the weight coefficient for each index, based on how often it is manifested in the employee being evaluated.

The average score for each employee is determined through calculations. The results obtained are analyzed and compared with the benchmark metrics obtained by the empirical method. The expert approach includes various modifications and is a necessary component of the assessment of human capital.

The evaluation of human capital can be carried out on the basis of directed investments. The costs for the professional development of a particular employee or all employees of the company are considered as long-term investments in the intellectual capital of the company. However, investments in human capital are economically justified only if the contribution of a particular employee improves the efficiency of the company.

This implies the expediency of segmentation of the personnel of the company. The main human resource management principle is the understanding that every employee carries a different level of value to the company, the same as every customer is important for the company, however, not equally, but depending on the amount of product consumed. On this basis, there are employees several times more valuable to the company than others [13].

The methodology for assessment of human capital of the employees of the Russian division of an international company in the field of IT industry is presented within the framework of this study on the basis of expert approach using a competence model and the aggregated indices randomization method.

The algorithm for assessing human capital of the company's employees was as follows:

1. Competence modelling based on five initial characteristics reflecting the competence of employees.

2. Determination of criteria for evaluating staff by developing an evaluation scale.

3. Determination of the estimation method. In this study, the aggregated indices randomization method (AIRM) was applied, which is used to evaluate complex objects. In our case, this is the individual competence of the employee, represented as a set of assessments of individual competences. In the conditions of uncertainty, it is rather difficult to accurately indicate the weight of specific competences, since it can be different for each job position, which determined the choice of this method.

4. Evaluation of employees according to the established rules.

5. Analysis of the results obtained by compiling an ASPID diagram of aggregated competence assessments of the employees of the company under study.

6. Segmentation of personnel for management decisions regarding employees of the company under study, including the development of individual programs for professional development of employees.

The competence model was used to assess the human capital of the employees of IT

companies. At the present time the approach to employee evaluation based on this model is the most common in both foreign companies and Russian organizations.

The competence of the individual worker (C_x) was evaluated with the help of a set of baseline characteristics:

x_1 – functional competences level;

x_2 – managerial skills level;

x_3 – corporate competences level;

x_4 – innovative competence level;

x_5 – social competence level.

In particular, the Senior .NET Developer position assumes that within the framework of functional competences the employee should have the following necessary skills:

1) understanding of C #, including the latest version of the ASP.NET MVC framework; ASP.NET MVC;

2) possession of software design skills;

3) possession of skills of object-oriented programming (OOP), and object-oriented design (OOD);

4) knowledge of design patterns;

5) knowledge of the database management system MS SQL Server and its components SSRS, SSIS;

6) knowledge of JavaScript and JavaScript-frameworks (jQuery, Angular.js, Backbone.js);

7) the ability to use the methods of test-driven development (TDD), as well as commercial applications on the .NET platform;

8) English language proficiency.

Below is a fragment of a competence model drawn up by the authors of this study. For example, such factor as the ability to make non-standard solutions was taken into account when determining the innovative competences (Fig. 1).

The above characteristics form the vector: $x = (x_1,..., x_n)$. Each characteristic constitutes certain features – y_n. If confined only to a set of estimates for each competence, then, most likely, it will not be possible to compare all the employees together in relation to all the competences at once. For example, one person's level of functional or corporate competence can be very high, but there is hardly a worker who surpasses others in all the competences at the same time.

Therefore, the aggregated indices randomization method (AIRM), which allows for multi-criteria evaluation of complex objects under conditions of uncertainty with the use of incomplete, inaccurate and non-numerical information, is used to analyze the evaluation summary of staff competence. This method was developed by Khovanov based on the ASPID (Analysis and synthesis of indices in the information deficit) methodology [18].

The values of five baseline characteristics x_1, ..., x_5 were determined within the framework of this study. The results are presented on the basis of a random sample of employees of the studied IT companies in the amount of 15. In total, 82 people participated in the evaluation activities.

As criteria, a scale for assessing behavioral indices was developed, which includes four levels:

0 – almost never manifested / not expressed;

1 – manifested sometimes / individual elements are expressed;

2 – is manifested in most situations / most of the elements are expressed;

3 – manifested always, in all situations / fully expressed.

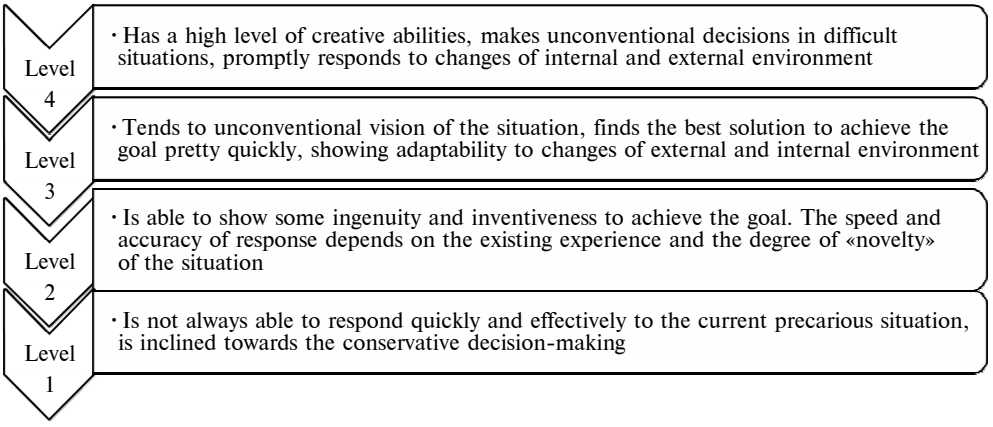

Fig. 1. Fragment of competence model for evaluation of the employees of IT companies

Table 1

Data (fragment) for determining the level of functional competences

Behavioral indices	Frequency of manifestation / intensity in employees														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Performs work qualitatively	2	3	2	1	1	3	3	1	3	2	2	2	2	3	3
Works with enthusiasm and interest	3	2	1	1	1	3	2	1	2	2	2	2	2	3	2
Does more than is formally required	1	3	1	1	1	3	2	1	2	2	2	2	1	3	1
Takes new tasks	2	2	1	1	1	3	3	1	2	2	1	2	2	2	2
Total score for all indices	8	10	5	4	4	12	10	4	9	8	7	8	8	11	8
Value	2.00	2.50	1.25	1.00	1.00	3.00	2.50	1.00	2.25	2.00	1.75	2.00	2.00	2.75	2.00

Below is a fragment of the data used to determine the level of functional competences on the basis of such index as passion for work (loves the job, tends to do it the best way possible, using existing knowledge and experience) (Tab. 1).

All indices that reflect the levels of all the above competences of the company's employees are defined similarly.

The final calculations of the competence values of the company's employees on the basis of five characteristics of the competence level are presented in Tab. 2.

Next, the smallest and largest values of the baseline characteristics were determined, the level of the particular competences of employees was defined.

Table 2

Competence values of the company's employees

Employee	x_1	x_2	x_3	x_4	x_5
1	1.90	1.70	1.60	1.00	2.00
2	2.2	2.1	2.1	2.5	1.5
3	1.50	1.50	1.50	1.50	1.00
4	1.50	1.50	1.60	2.00	1.00
5	2.0	1.4	1.3	1.0	0.0
6	2.7	2.8	2.5	2.0	3.0
7	2.0	1.8	2.0	2.0	2.0
8	1.0	1.1	1.3	1.5	2.0
9	1.20	1.70	1.30	1.50	1.50
10	1.8	1.7	2.0	2.0	2.0
11	1.10	1.30	1.40	2.00	1.50
12	1.5	1.6	2.0	1.5	1.5
13	1.40	1.50	1.50	1.50	1.50
14	2.0	2.1	2.8	2.5	3.0
15	1.50	1.60	1.50	1.50	1.50

x_1: min = 1.3; max = 3.0;
x_2: min = 1.1; max = 2.7;
x_3: min = 1.1; max = 2.8;
x_4: min = 1.0; max = 2.7;
x_5: min = 0; max = 2.5.

The function $q_i = q_i(x_i)$ is determined by the following formulas:

For the increasing function:

$$q_i(x_i) = \begin{cases} 0 & x_i \le \min_i, \\ \dfrac{x_i - \min_i}{\max_i - \min_i} & \min_i \langle x_i \le \max_i, \\ 1 & x_i \rangle \max_i . \end{cases} \quad (1)$$

For the decreasing function:

$$q_i(x_i) = \begin{cases} 1 & x_i \le \min_i, \\ \dfrac{\max_i - x_i}{\max_i - \min_i} & \min_i \langle x_i \le \max_i, \\ 0 & x_i \rangle \max_i . \end{cases} \quad (2)$$

Let us construct the system of indices q_1, ..., q_5, corresponding the assessment of competences of employees, in terms of the five criteria mentioned above, using formula (1) for the increasing function (Tab. 3).

Therefore, it is possible to draw a preliminary conclusion who is the most competent employee by each criterion. Thus, for example, by the criterion qi, the most competent employees are 2 and 4. Employees 5, 7 and 14 also have a fairly high level of competence by this criterion. It is worth noting that there is no such employee who would be more competent than the rest by all the criteria at the same time. Determination of (w) is a crucial moment in the summary assessment of human capital. Each component has its own «importance» or «value», the exaggeration or understatement of which can change the final assessment in the construction of the aggregated index [1].

Table 3

Competence indices for each employee (without weights), in points

Employee	q_1	q_2	q_3	q_4	q_5
1	0.529	0.353	0.200	0.000	0.667
2	0.647	0.588	0.600	1.000	0.500
3	0.294	0.235	0.133	0.333	0.333
4	0.294	0.235	0.200	0.667	0.333
5	0.588	0.176	0.067	0.000	0.000
6	1.000	1.000	0.867	0.667	1.000
7	0.588	0.412	0.467	0.667	0.667
8	0.000	0.000	0.000	0.333	0.667
9	0.118	0.353	0.000	0.333	0.500
10	0.471	0.353	0.467	0.667	0.667
11	0.059	0.118	0.067	0.667	0.500
12	0.294	0.294	0.467	0.333	0.500
13	0.235	0.235	0.133	0.333	0.500
14	0.588	0.588	0.667	1.000	1.000
15	0.294	0.294	0.133	0.333	0.500

The additional data on the weight of competences should be used in staff assessment. For example, innovation competence is a very important factor in the successful performance of an IT company's employees. Also, a large number of «incomparable» staff makes it worthwhile to introduce an aggregated index, which allows to linearly «harmonize» all evaluated employees at the level of their general competence, taking into account the values of the indices q_1, ..., q_5, as well as the weight of the competences in the coefficients w_1, ..., w_5. In other words, this figure reflects a person's competence not for each competence separately, but for all competences at once, taking their importance into account.

Under real conditions some additional information on the weighting factors is available, not of a numerical, but a comparative character, for example, «functional competence is more important than corporate» or «the level of social intelligence is, according to experts, just as important as the level of innovation activity».

Thus, non-numeric information is the most stable and easy to read in this case; it can be represented as a system of equations and inequalities (3):

$$I = \{w_r > w_s; w_u = w_v, ...\}. \quad (3)$$

Information about the relative weighting characteristics can be represented as a system of inequalities for the weighting coefficients (4):

$$I = \{w_2 > w_1 > w_3 > w_4 > w_5 ...\}. \quad (4)$$

The weighting coefficients of the competence characteristics of employees were identified by the expert commission, depending on their value for the studied IT companies. The functional competence (x_1) is the most important for the ordinary employees of the company; followed by the innovative competence (x_4), then social competence (x_5), then corporate competence (x_3), and finally, the managerial competence (x_2).

Let us define the procedure for the formation of scales of activities W_i. The first type of competence is measured on the 3-point qualimetric scale, $W_1 = \{3,2,1\}$; second, third and subsequent on the 2-score $W_2 = W_3 = W_4 = W_5 = \{2,1\}$, (i.e., m_i is the number of reference points in the i-scale that is equal to 3,2,2,2,2 respectively).

For each ω_{ik} reference point of all W_i competence scales, a specific quantity equivalent was calculated, that is, a weighting factor.

The total number of equivalents is defined by formula (5):

$$n = \sum_i m_i \quad (5)$$

$$n = 3 + 2 + 2 + 2 + 2 = 11.$$

Tab. 4 shows the values of the reference points of each competence evaluation scale (k is the current number of the reference point in the i-th scale).

Thus, we have obtained a scale of W vector evaluations, having L = 48 control points.

Using a 10-point scale is more familiar. Transition is possible by sorting the combination of values by descending g_ℓ values, and isolating the 9-limit values (0.59; 0.53; 0.51; 0.46; 0.43; 0.39; 0.36; 0.31; 0.26; 0.24). separating groups of evaluation combinations that can be correlated with final estimates of the scale I = {1,2,3,4,5,6,7,8,9,10}.

The results of the evaluation of each employee of the studied IT company are presented in Tab. 5.

On the basis of determination of weight characteristics of each of the five competences ($X_1 = 0.352$, $X_2 = 0.094$; $X_3 = 0.116$; $X_4 = 0.131$; $X_5 = 0.124$) and calculation of the aggregated values of competence of each evaluated employee of the studied IT company, an ASPID diagram was constructed (Fig. 2).

Table 4

Values of reference points of rating scales

Scales	Reference points	Rating weight
$i = 1$ w_1 $m_1 = 3$ $k = 1, 2, 3$	$\omega_{11} = 3$	$d_{11} = 0.23$
	$\omega_{12} = 2$	$d_{12} = 0.15$
	$\omega_{13} = 1$	$d_{13} = 0.07$
$i = 2$ w_2 $m_2 = 2$ $k = 1, 2$	$\omega_{21} = 2$	$d_{21} = 0.11$
	$\omega_{22} = 1$	$d_{22} = 0.04$
$i = 3$ w_3 $m_3 = 2$ $k = 1, 2$	$\omega_{31} = 2$	$d_{31} = 0.10$
	$\omega_{32} = 1$	$d_{32} = 0.03$
$i = 4$ w_4 $m_4 = 2$ $k = 1, 2$	$\omega_{41} = 2$	$d_{41} = 0.10$
	$\omega_{42} = 1$	$d_{42} = 0.05$
$i = 5$ w_5 $m_5 = 2$ $k = 1, 2$	$\omega_{51} = 2$	$d_{51} = 0.07$
	$\omega_{52} = 1$	$d_{52} = 0.05$

Table 5

Evaluation of each employee on a 10-point scale

Employee	Type of performance assessment	$g_t^{\omega}G$	Final score
1	2,2,2,2,1	0.46	7
2	2,2,2,2,2	0.53	9
3	2,1,2,2,2	0.48	8
4	2,2,2,2,1	0.46	7
5	1,2,1,1,1	0.31	3
6	2,2,2,2,2	0.53	9
7	2,2,2,1,2	0.53	9
8	1,1,1,1,2	0.26	2
9	1,2,2,1,2	0.42	5
10	2,2,2,2,2	0.53	9
11	2,2,1,1,2	0.41	5
12	1,1,1,2,1	0.29	2
13	1,2,2,2,2	0.45	6
14	2,2,2,2,2	0.53	9
15	2,1,2,2,2	0.46	7

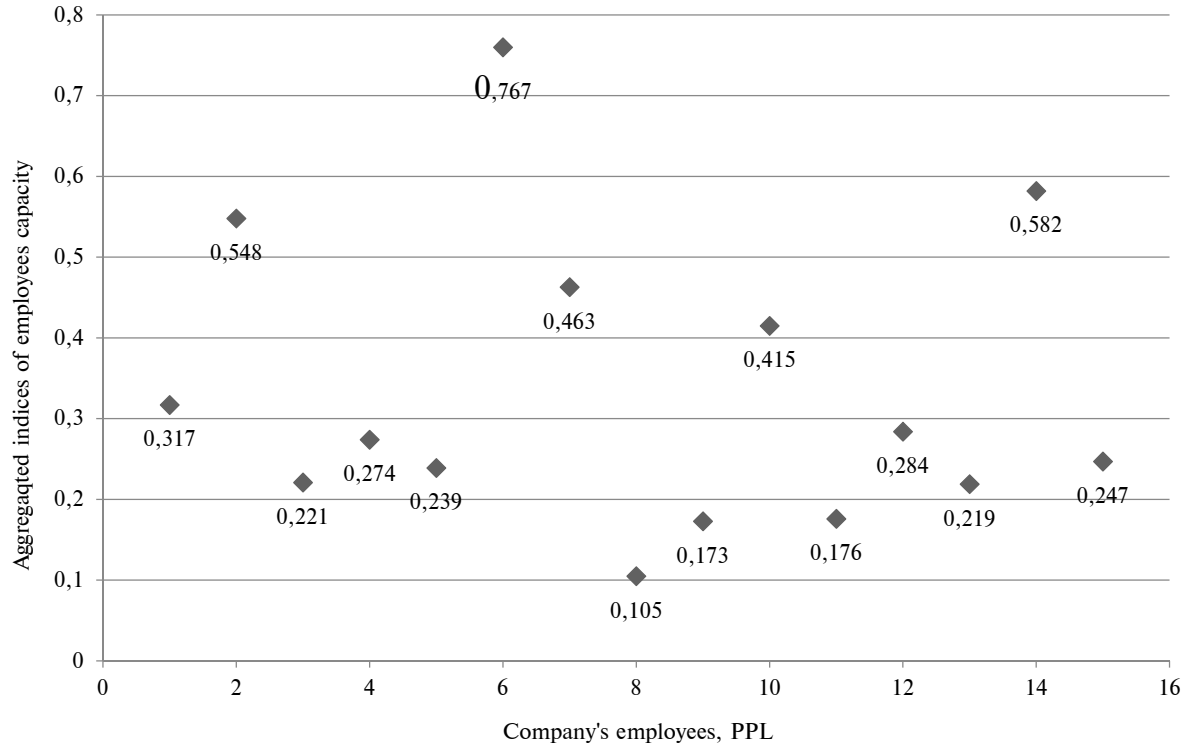

Fig. 2. Composite competence ratings of the IT company's employees

It was concluded on the basis of the presented diagram that the most competent employee is 6 (competence index is 0.767), followed by employees 14 and 2 (competence indices are 0.582 and 0,.548, respectively). However, this is just a small part of the evaluated employees who have a fairly high level of competence.

For more detailed analyses of the company, the authors propose segmentation, which consists of four groups (similar to the matrix of the Boston Consulting Group): «Stars», «Cash cows», «Dogs» and «Problem children».

The heads of the company's departments were involved in the evaluation as experts. The first group (8 people), «Stars», are the employees who have been working for the company for more than two years, thus repeatedly underwent education and training to improve their professional skills. As already mentioned, 8 people belong to «Stars», but according to the aggregated indices only one of them is on the 8th level of competence (10-point rating scale); 7 people occupy the 7th position. Although this group is the smallest in size, it is the one of the utmost value for the company.

The second group (43 people), «Problem children», is characterized by a high level of performance potential and requires a fairly significant investment in order to develop it. Among the employees belonging to the «Problem children» category, 7 persons occupy the 6th level of competence, 36 occupy the 5th level. Upon receiving sufficient knowledge and accumulating experience, a gradual transition to the «Stars» takes place.

The third group (19 people) is «Cash cows». This group is characterized by a high level of productivity. This is the least attractive group from the point of development, since the functionality performed by the employees in most cases does not require development of any additional skills in relation to the company. 6 people from the «Cash cows» occupy the 4th level, 13 people the 3rd level.

The fourth group (12 people) id «Dogs». Basically, these are the new employees who are being trained at the moment. They have a low level of competence and do not bring profits. Trainings and seminars which will identify potential employees and weed out the least qualified are required for transition to another group. In the «Dogs» category 9 people occupy the 2nd position, and 3 people have shown a very low level of competence, so the company decided to dismiss these trainees, without waiting for the end of the probationary period.

Taking the profit index for 100%, an average profit of «Stars» is 42%, 37% for «Problem children», 18% for «Cash cows», and 3% for «Dogs». Thus, a «Star» brings 5,02% of the profits for the studied IT companies, a «Problem Child» brings 0.96%, a «Cash Cow» brings 0.64%, and a «Dog» brings 0.32%. Thereafter, it is urgent to create a staff development program, aimed at increasing the number of «earning» employees.

The evaluation of human capital of the employees of IT company identified the need for the development of innovation and social competences. Accordingly, the company needs to develop a set of measures aimed at matching the real situation with the desired profile according to the developed competence profile. The purpose of the proposed activities is to reduce the difference between the existing and the required level of competence and, as a consequence, facilitate the development of the intellectual capital of the company, as human capital is the basis of its structure.

It should be borne in mind that investment in staff will be economically viable if it provides a high level of income to the company. The human capital evaluation requires an economic assessment of the knowledge acquired through education and experience, not only in terms of the accumulation of past investments in human capital accumulated in the reserve, but also in terms of the opportunity to acquire new knowledge in the future [7].

It is worth pointing out that human capital, as a form of intangible capital, cannot be separated from those to whom it belongs, and cannot be copied or reproduced in any other organization. Managers of domestic enterprises need to pay greater attention to the formation, accumulation and development of human capital using the most appropriate and effective tools, such as: the development of the strategy of selecting new recruits, the creation of a system for evaluation and continuous training of personnel, the implementation of a set of material and moral incentives for employees.

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