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METHODOLOGICAL APPROACHES TO DETERMINING THE LEVEL OF DEVELOPMENT OF GREEN INTELLECTUAL CAPITAL OF A HIGHER EDUCATION INSTITUTION

Taking into account the main shortcomings of the existing integral methods of evaluating green intellectual capital (GIC), namely: the subjectivity of the results of the use of the expert evaluation method, calculation based on a limited number of factors, as well as the presentation of factors in different units of measurement, it was proposed to use the method of multifactor analysis - the method of principal components, which allows eliminate the above-mentioned shortcomings in the assessment and analysis of the factors of development and increase of green intellectual capital of higher education institutions (HEIs).

The method of assessing the development of green intellectual capital was developed using the recommendations of E. Pedro [1], existing approaches to its assessment for industrial enterprises by O. Kozhushko [2] and approaches to the assessment of human development by O. Tutova [3]. As a result of the fact that the values of the input i-indicators of a certain component of the (GIC), of a separate HEIs could fluctuate in relatively large intervals and have different units of measurement, they were linearly normalized by A. Hervier [4] within [-1, 1]:

for stimulating factors: $\tilde{x}_{ia} = 2 \times \frac{x_{ia} - x_i^{min}}{x_i^{max} - x_i^{min}} - 1$ (1)

and for disincentive factors: $\tilde{x}_{ia} = 2 \times \frac{x_i^{max} - x_{ia}}{x_i^{max} - x_i^{min}} - 1,$ (2)

where $\tilde{x}_{ia}$ – the normalized value of the input i-indicator for the *a*-observation period; x_{ia} – the basic value of the input i-indicator for the *a*-period of observation; x_i^{max}, x_i^{min} – respectively, the maximum and minimum value of the *i*-th indicator for all observation periods.

Further, using the statistical software product Statistica, a factor analysis using the method of principal components is performed. According to its results, the input *i*-indicators are transformed into new *iy*-indicators with different factor loadings according to the *y*-factors. Within the framework of a certain *m*-component of the GIC, on the basis of the maximum factor loadings, its weighting factor was calculated for each *iy*-indicator:

$$d_{iym} = \frac{f_{iym} \times Var_{iym}}{\sum f_{iym} \times Var_{iym}} \quad (3)$$

where d_{iym} – the weight coefficient of the *i*-th input indicator with the maximum value of the factor load, which was included in the *y*-factor (main component) of the *m*-component of the GIC, $i = \overline{1,n}$, $\sum d_{iym}$ =1, where *n* – input *i*-indicators of the *m*-component of the GIC; f_{iy} – the maximum value of the factor load of the input *i*-indicator that entered the *y*-factor (the main component); Var_{iy} – share of the total variance of the *y*-factor (the main component), which grouped the input and indicators of the *m*-component of the GIC with factor loadings greater than 0.7 (with a strong correlation according to the Pearson test).

The annual values of the integral indicator of the development of a separate *m*-component of GIC HEIs provide for the determination of indicators for *y*-indicators (for input *y*-indicators grouped by *y*-factors with factor loadings greater than 0,7):

$$d_{iyH} \times H_{\text{i } norm} \quad (4)$$

$$d_{iyR} \times R_{\text{i } norm} \quad (5)$$

$$d_{iyO} \times \text{O}_{\text{i } norm}\,, \quad (6)$$

where d_{iyY}, d_{iyR}, d_{iyO} – respectively, the weight of the *iy*-indicator of the client, human and innovative m-component of GIC, $i = \overline{1,n}$, where *n* – the number of *i*-indicators used to estimate the *m*-component of the GIC ($\sum d_{iy} = 1$); $H_{\text{i } norm}$, $R_{\text{i } norm}$, $\text{O}_{\text{i } norm}$ – normalized values of input i-indicators, respectively, of green human capital, green relationship capital and green organizational capital (informational, innovative, process) within [-1, 1].

During the normalization of the input i-indicators, some of them acquired a zero value, therefore, in order to prevent zero values of the integral indicators of the *iy*-indicators and, as a consequence, the integral indicator of the development and protection of a separate *m*-component of the GIC itself, a normalized additive convolution was used for their calculations. Taking into account the above, the annual assessment of the integral indicator for a separate *m*-component of the GIC of a certain HEIs was carried out within [-1,1] according to the formulas:

$$\text{I}_{\text{Л}} = \sum_{i=1}^{n} d_{iyH} \times \text{H}_{\text{i } norm} \quad (7)$$

$$\text{I}_{\text{B}} = \sum_{i=1}^{n} d_{iyR} \times R_{\text{i } norm} \quad (8)$$

$$\text{I}_{\text{O}} = \sum_{i=1}^{n} d_{iyO} \times \text{O}_{\text{i } norm}\,, \quad (9)$$

where $\text{I}_{\text{Л}}$, I_{B}, I_{O} – espectively, integral indicators of the development of the GIC component for a certain period for a separate HEIs ($-1 \le \text{I}_{\text{m}} \le 1$).

In order to determine the integral indicators of the development of GIC as a whole over the years of observation, the obtained data on the level of development of the components of GIC (integral indicators without normalization) are subject to factor analysis by the method of principal components and are transformed into new *mz*-indicators. For each mz-indicator I_{H}, I_{R} and I_{O}, grouped by *z*-components with factor loadings greater than 0.7), its weighting factor is calculated:

$$d_{zm} = \frac{f_{zm} \times Var_{zm}}{\sum f_{zm} \times Var_{zm}} \quad (10)$$

where d_{zm} – the weight of the integral indicator of the *m*-component of GIC with the maximum value of the factor load, which was included in the *z*-factor (the main component), where $m = \overline{1,3}$ – the index of the component of GIC ($\sum d_{zm} = 1$); f_{zm} – the maximum value of the factor load of the integral indicator of the *m*-component of the GIC, which was included in the *z*-factor (the main component); Var_{zm} – shares of the total variance of the *z*-factor (principal component), which grouped the integral indicators of the *m*-component of the GIC with factor loadings greater than 0,7.

The calculation of the annual values of the integral indicator of GIC for each HEIs provided for the determination of indicators for the corresponding period of observation:

$$d_{zЛ} \times I_H \quad (11)$$
$$d_{zB} \times I_R \quad (12)$$
$$d_{zO} \times I_O, \quad (13)$$

where d_{zH}, d_{zR}, d_{zO} – respectively, the weighting factor of the *mz*-indicator or the integral indicator of the *m*-component of the GIC ($\sum d_{zm} = 1$); I_H, I_R , I_O – integrated indicators of green human capital, green relational capital and green organizational capital, respectively, by years of observation ($-1 \leq I_m \leq= 1$).

Taking into account the annual values of the indicators for the components of the GIC, the annual assessment of its integral indicator for a certain HEIs (I_{GIC}) was carried out within [-1,1] according to the normalized additive convolution:

$$\mathrm{I}_{GIC} = d_{zH} \times \mathrm{I}_H + d_{zR} \times \mathrm{I}_R + d_{zO} \times \mathrm{I}_O = \sum d_{zm} \times \mathrm{I}_m \qquad (14).$$

The use of additive convolution is based on the results of numerical modeling of output effects, according to which the similarity of additive and multiplicative convolutions is manifested when it becomes impossible to change the output effect instantaneously according to the change of input resources, that is, when the integration step becomes smaller than the time required to change the output effect according to input resource [5]. Such trends characterize the influence of factors on the level of development of GIC.

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