Methods and Results of Forecasting the Rating Indicators at the University

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Abstract. The paper deals with the problem of constructing a system of rating indicators to stimulate the work of the teaching staff of a higher educational institution. To predict the total amount of incentives, a comprehensive methodology has been proposed that contains four modules: modeling the values within the existing range in the previous period; modeling the values of a new indicator based on the assumptions entered using the generator of a random number; excluding the range of values of remote indicators; modeling new values on the basis of studying a modern trend of indicators. The presence of a flexible information structure in the form of a hypercube and a complex mathematical model has made it possible to carry out a computational experiment for predicting the values of group and individual indicators. In the course of the experiment, the structural stability of the values has been revealed, which has not lead to a great change in the quantitative ratio between the groups of indicators.

Introduction

The development of a modern system of higher education requires a change in the strategic approach in the system of managing the activities of faculty. In this regard, the personnel administration of Russian universities introduces new forms of management, among which the popular and scientifically justified is the introduction of the rating system. The rating system of assessment of the activities of the teaching staff is one of the tools for managing the activities in the system of higher education. The choice of the structure of indicators included in the rating system determines the strategy and intensification of the priority areas of development.

The analysis of the structure of the indices of this system for the Russian and leading foreign higher educational institutions, cited in [1], has proved that the set of main groups is invariant and determines the main types of activity of the teaching staff. Among the main groups in the leading Russian higher educational institutions are: educational activities, research work, international activities. As part of the research activity, the publication activity of scientists is singled out separately, which is registered and evaluated on the basis of indicators of scientometric systems of the international and Russian level. The advantages and disadvantages of using scientometric indicators in the management and evaluation systems of the teaching staff activity are the subject of scientific discussion, but, nevertheless, they remain the only tool for evaluating the effectiveness and relevance of the results of intellectual work [2, 3].

Mathematical Model of the Rating System

Description of the rating system for managing the activities of the faculty of the university is carried out using a mathematical dynamic model with drifting parameters, which has the form:

$$R = \alpha \sum_{i=1}^{n_r} K_i + \beta \sum_{i=1}^{n_s} A_i,$$

(1)
where \( \alpha, \beta \) are weighting coefficients, taking the value of 0.3 and 0.7, and allowing to perform the strengthening intensification of the indicators of one of the groups; \( K_i \) are the group-functions that characterize the qualifications of the teaching staff members (qualification group); \( A_i \) are the group-functions characterizing the activity of the teaching staff (activity group); \( n_K, n_A \) are the numbers of indicators in the qualification and activity groups in the reporting period, respectively.

As a rule, several subgroups associated with main activities are defined in an activity group of an educational institution: educational, research, international, etc. The set of subgroups is unique for each institution and is determined by the goals achieved.

Each of the indicators of the groups - functions is determined by:
- drift, that is by the entry of the indicator in the rating system and belonging to the group;
- the number of parameters, their type and form of dependence;
- the value of the parameters corresponding to each of the indicators within the group.

The initial data for determining the value of a function in a given period is a two-dimensional array of records that are structured and each entry includes the fields:

\[
R_i = (Id_i, Name_i, E_i(n_K + n_A)), i = 1, n_{year},
\]

where \( R_i \) is a record of the data array corresponding to the employee with the number \( i \); \( Id_i \) is the identification number of the employee; \( Name_i \) is an array of rows for storing information about the \( i \)-th employee (first name, patronymic, last name, academic degree, position, subdivision, enlarged subdivision); \( E_i(n_K + n_A) \) is an array of ratings of a \( i \)-th staff member; \( n_{year} \) is the number of participants in the rating in a given reporting period year. The dimension of one hypercube layer is a variable in each reporting period.

Preservation of several layers of input data for the reporting periods of a functioning rating system allows keeping the history of development and changes in the values of the rating system indicators in a dynamic. A complete structure of the initial data forms a hypercube. The section headings are in boldface capital and lowercase letters. Second level headings are typed as part of the succeeding paragraph (like the subsection heading of this paragraph).

Each indicator of the rating system for assessing the performance of the teaching staff is functionally dependent on the level of achievement of the required values. Linear dependencies on one or more variables are defined for all the indicators. For example, for the indicator:
- the availability of a scholar degree: \( K_{i1} = 3 \cdot n_{kand} + 50 \cdot n_{doct} \) where \( n_{kand} \) is the number of candidates of science; \( n_{doct} \) is the number of doctors of sciences; 30 and 50 are the assigned parameters; \( n_{kand} + n_{doct} \) is the number of project participants by the indicator;
- the values of the author's Hirsch index according to the Russian Scientific Citation Index data:

\[
A_{i2} = \sum_{i=1}^{n} (h_i - h_{i1}) + 3h_{i2},
\]

where \( h_i \) is the value of the Hirsch index of the \( i \)-th employee; \( h_{i1} \) is the value of the Hirsch index of the \( i \)-th employee without taking into account self-citation; \( h_i \) is the number of the members of the teaching staff with non-zero value of the indicator in the current period which is the number of the project participants by indicator; 1 and 3 are the assigned parameters.

**Methods and Results of Forecasting**

Taking into account the pointed characteristics of the drift of the indicators and their sensitivity to the variable arguments, two hyper-cubes of the initial data are constructed: the hypercube of the original data with the number of participants in each indicator, with the exception of the indicator \( A_{13} \); the hyper-cube of the initial data with the number of participants in the project after staff optimization.

The following procedure is proposed for predicting the values of the parameter \( A_{13} \):
1) To generate a random number $\omega$ in the range $[0;1]$ for each project participant, by the indicator $A_{13}$;
2) To introduce a hypothesis about the successful mastering of on-line courses depending on the position: "The probability of successful mastering of on-line courses by the teaching staff of their own will is: 20% for the position of a professor; 35% is for an assistant professor and 50% is for an assistant and a senior teacher";
3) To form the corresponding field in the hypercube of the original data (2) in accordance with the hypothesis by the formula:

$$A_{13} = 40 \cdot \begin{cases} 1, & \text{if } Cond = true; \\ 0, & \text{if } Cond = false; \end{cases}$$

where $Cond$ is the condition defined by the hypothesis and formally has the form:

$$Cond = (pos = 1 \land \omega < 0.2) \lor (pos = 2 \land \omega < 0.35) \lor ((pos = 3) \lor (pos = 4) \land \omega < 0.50),$$

where $pos$ is the designation of the post of the teaching staff: 1 is a professor, head of the department, director of the Institute, dean of the faculty; 2 is an assistant professor; 3 is a senior teacher; 4 is an assistant;
4) To calculate the indicator for the group $A_{13}$:

$$A_{13} = \sum_{i=1}^{n_{A_{13}}} A_{13i},$$

where $n_{A_{13}}$ is the number of project participants with non-zero indicators.

The reliability of the hypothesis can be established after the analysis based on the results at the end of the forecasted reporting period. Under these simulation conditions, we obtain the following statistical characteristics for the indicator $A_{13}$:
- the average number of participants is 200 people (20.3%);
- the total score is 7800;
- the average number of points per participant is 40.

To predict the values of publication activity, a methodology based on the change in the summary indicators with correction factors and the forecasted increase in indicators for the previous reporting periods is proposed. Correction of indicators is made by the formulas:

$$A_{31} = 0.7 \left(3(n_{2016} - n_{2015}) + 15n_{2016}\right),$$

where 0.7 is the weight coefficient of the group; 3 and 15 are the assigned coefficients of the indicator; $n_{2016}$ and $n_{2015}$ are the projected numbers of publications in 2016 by the university staff; $n$ is an index denoting a special publication status, for example, an article in the journal Supreme Certifying Commission or a book and is determined by the relation:

$$n_{2016} = n_{2015} + \Delta; \Delta = n_{2015} - n_{2014},$$

where $n_{2015}$ and $n_{2014}$ are the corresponding quantitative indicators of the institution in 2015 and 2014 reporting periods;

$$A_{32} = 0.7 \left(k_h \left(1(h - h_1) + 4h_1\right)\right),$$

where $h$ is the value of the total Hirsch index of project participants in 2015; $h_1$ is the value of the total Hirsch index without self-quoting of the project participants in 2015; 1 and 4 are the assigned parameters of the indicator; $k_h$ is a correction factor for the growth of the Hirsch index of the institution, defined by the ratio:
where \( h_{\text{org}2015} \) and \( h_{\text{org}2014} \) are the values of the Hirsch index of the institution corresponding to the years 2015 and 2014 and on July 27, 2016 the value of the correction factor is 1.049;

\[
A_{33} = 0.7P_{IF}IF_{2015}k_{IF}n_{ja2016},
\]

where \( P_{IF} \) is an assigned parameter; \( IF_{2015} \) is a weighted average impact-factor of the journals in which articles are published in 2015; \( k_{IF} \) is a correction coefficient characterizing a uniform increase in the impact factors of the journals and is determined by formula (10); \( n_{ja2016} \) is a predicted number of journal articles in 2016, determined by the ratio (11):

\[
k_{IF} = \frac{IF_{2015}}{IF_{2014}}, IF_{2015} = 0.355; IF_{2014} = 0.191;
\]

\[
n_{ja2016} = n_{ja2015} + \Delta; \Delta = n_{ja2015} - n_{ja2014},
\]

where \( IF_{2015} \) and \( IF_{2014} \) are the average values of the impact factors of the journals in which the articles were published in 2015 and 2014; \( n_{ja2015} \) and \( n_{ja2014} \) are the numbers of journal articles published in 2015 and 2014 and the value of the correction factor is 1.86 on July 27, 2016 [4,5].

The assignment of the parameter \( P_{IF} \) is an unpredictable process. Still the rate of growth in relative indicators is random and unpredictable.

Therefore, predicting the indicator of the impact factor for its intended assignment \( P_{IF} \) is a useless fortunetelling. That is why, we adopt a balanced constraint technique for the assignment \( P_{IF} \). According to this methodology, a balance must be maintained between the indicators of the publication activity group. For example, by setting a limit from 25 to 50% of the total indicators amount of group \( A_{3} \):

\[
\frac{1}{4} \sum_{i=1}^{3} A_{i1} \leq A_{33} \leq \frac{1}{2} \sum_{i=1}^{3} A_{i3}.
\]

Restrictions on the values of the parameter \( P_{IF} \) is obtained with the help of simple analytic transformations:

\[
\frac{1}{3} A_{31} + A_{32} \leq P_{IF} \leq \frac{A_{31} + A_{32}}{M},
\]

where \( M = 0,7IF_{2015}k_{IF}n_{ja2016} \).

Thus, the forecasting by the group of indicators \( A_{3} \) becomes balanced.

The initial data for predicting the values of indicators of group \( A_{3} \) are given in Table 1.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>2014</th>
<th>2015</th>
<th>Forecasting for 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n_{\text{Year}} )</td>
<td>2668</td>
<td>3883</td>
<td>5098</td>
</tr>
<tr>
<td>( n_{\text{Year}} )</td>
<td>608 +161</td>
<td>626 +277</td>
<td>644 +393</td>
</tr>
<tr>
<td>( h )</td>
<td>–</td>
<td>3391</td>
<td>–</td>
</tr>
<tr>
<td>( h )</td>
<td>–</td>
<td>2601</td>
<td>–</td>
</tr>
<tr>
<td>( h_{\text{orgYear}} )</td>
<td>41</td>
<td>43</td>
<td>–</td>
</tr>
<tr>
<td>( n_{\text{jaYear}} )</td>
<td>1750</td>
<td>2112</td>
<td>2474</td>
</tr>
</tbody>
</table>

The total score is: 19416 + 8219 + 11470; 34412 = [39106; 66742].

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On average, from 40 to 69 points are for one project participant. The results of the change in the structure of group estimates in the forecast 2016 and the reporting year 2015 at $P_{IF} = 1$ are shown in Figure 1.

![Figure 1](image)

Figure 1. Structure of group assessments: a is distribution of points in groups and subgroups; b is the ratio of the average score in the group and in subgroups.

In Figure 1, the outer ring corresponds to the data of the year 2015, the inner ring corresponds to the data of 2016.

**Summary**

When forecasting the results, it is necessary to take into account the characteristics of the indicators, such as the drift of the indicators, the variability of the form of dependence and the values of the parameters. The type of drift determines the forecasting strategy and the change in the structure of the hypercube of the original data.

The forecasting method should be chosen for newly introduced indicators. It is determined by the indicators meaning and dynamics over time. The main methods are recommended: the method of generating values for random processes that are limited by the hypotheses being introduced, and the balance-interval method that allows assigning the parameters after the expiration of the reporting period to maintain a balance between the indicators within the group.

**References**


[4] O.S. Logunova, A.V. Lednov, V.V. Korol’ova The analysis results of the publication activity of the faculty of the Nosov Magnitogorsk State Technical University, Vestnik of Nosov Magnitogorsk State Technical University, 3 (47) (2014) 78-87.