Materials of Conferences

MODEL AND ANALYSIS OF FACULTY STAFF AGE STRUCTURE DYNAMICS AT UNIVERSITIES

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Age dynamics of faculty staff at universities on the basis of cellular automata model was investigated. Quality analysis of number of professors according to their age was performed, the most active age groups were detected.

In the article the social system (faculty staff) is investigated with nonlinear dynamics methods. Research objective is to analyze and forecast the state of the system. Faculty staff current state and progress trends, as well as development of universities scientific potential is analyzed by applying mathematical modeling.

Let us consider mathematical model of the one-dimensional cellular automata class, which allows analyzing age structure dynamics of faculty staff. We are going to model each faculty staff age category of the same kind with one element of the cellular automata, value of which characterizes number in this category. Model, which was the basis for staff analysis, was designed for age groups with 10 years gap: 25–29 years, 30–39 years, …, above 60 years.

Transition from one age group to another takes one discrete time step corresponding to time interval $\Delta t = 1$ year. This transition goes with shift along the space of cellular automata. The element, whose age is at the boundary of the group 29, 39, 49, 59 years, should be transferred to the next age group.

The following factors were taking into account in modeling:

– ageing of each professor with the course of time (transition into next age group of each element of the model);

– retirement of professors who reached corresponding age;

– change of activity by ambitious employees;

– employment of newcomers recently graduated from the university;

– defense of Ph.D. and doctoral thesis with the succeeding professors' transition to the new category.

Let us describe these factors using cellular automata rule.

Cell dynamics (one year ageing of the employees in one group and of the same age) in each step at a time is computed using the following formula

$$X_j^{i+1} = X_{j-1}^i \quad (j = 2,\ldots,N-1), \qquad (1)$$

with using at the boundary of the cellular automata space ($j = 0$) the boundary condition

$$X_0^{i+1} = X^0, \qquad (2)$$

where the value X^0 characterizes the number of young employees annually joining the faculty staff.

Change of activity by ambitious employees is described by the formula

$$X_j^{i+1} = X_{j-1}^i - G(i,j) \quad (j = 2,\ldots,N-1). \qquad (3)$$

In the simplest variant the function G is as follows

$$G(i,j) = kX_j^{i+1}, \qquad (4)$$

where the coefficient $0 < k \le 1$.

Equation corresponding to one-dimensional cellular automata is the equation of continuity – conservation law of staff number taking into account their leave of university system:

$$\frac{\partial x}{\partial v} + \frac{\partial x}{\partial t} - G(x,v) = 0, \qquad (5)$$

where $x(v, t)$ is the university staff number aged v at a time t. G is the function of skilled workers drain, it is characterized by staff number aged v, who leave the university system for other activities. In the simplest variant the function G can be described by the linear relationship

$$G(x) = kx, \qquad (6)$$

where $0 < k \le 1$.

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UNIVERSITY OPERATION MODEL

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Findings obtained in the article prove the need of maintaining the high level of faculty staff activity at the universities.

The problem of loss of universities operating effect is associated with the level decline of scientific research conducted by the employees, and with decline of high skilled staff training quality through postgraduate and doctoral training systems.

To provide further insight into existing tendencies of level dynamics of human resources at the university a phenomenological model was worked out which allows to analyze tendencies and influence at the potential of development of different factors typical to the modern university system [1–2].

Let us develop and research a mathematical model which allows studying at qualitative level possible variants of university development taking into account its operating effect and change in accumulated academic and faculty staff.

Assume each faculty staff age category $N(T)$ is characterized by some functions $\varphi(T, t)$ and $a(T)$, where T is an age value of a considered faculty staff category, $N(T)$ is a number in this category. Write $a(T)$ for activity of this age category. Assume activity is a value ranging from 0 to 1. Zero means that a given age category is out of university activities, one means that a given category works with total efficiency. Activity can be assessed by holding faculty staff ranking at the university. Write $\varphi(T, t)$ for potential of the faculty staff age category. Potential shall be understood to mean a combination of knowledge, skills and abilities which are possessed by representatives of the corresponding age group at a time t. Contribution of a given age category to the university work is

$$\Phi(T, t) = a(T)\ \varphi(T, t). \qquad (1)$$

Measuring of value $\Phi(T, t)$ concerns quantity and quality of scientific paper issued by employees in a given age category, their training development papers, study guides, contribution to conference management, number of grants. System of faculty staff ranking introduced at the universities in some way reflects scope of their contribution.

Integral result of university activity at a time t is determined from the formula

$$\Phi(t) = \sum_{T} N(t)\, a(T) \varphi(T, t). \qquad (2)$$

Potential $\varphi(T, t)$ of each age group changes with time. In a year age group potential will be defined by the formula

$$\varphi(T,t) = \varphi(N-1, t-1) + ka(T-1)\Phi(t-1) - r\varphi(N-1, t-1), \qquad (3)$$

where k and r are constants of proportionality. Value $N(T)$ is determined from the formula

$$N(T, t) = N(T-1, t-1), \qquad (4)$$

with neglect of staff flow from the university.

When reaching the maximum age T_{max} the employees are no more considered, and the new vacancies are occupied by newcomers aged T_{min}:

$$N(T_{min}, t) = N_0. \qquad (5)$$

Flow of faculty staff from each age group happens constantly, but at a first approximation this fact can be neglected, it does not affect quality results. Graduates join faculty staff, their initial potential is $\varphi(T_{min}, t)$ determined by general condition of the university $\Phi(t)$. University graduates potential is determined by the following expression

$$\varphi(T_{min}, t) = c\Phi(t), \qquad (6)$$

where the coefficient $c < 1$.

After performing certain calculations we need to use the formulas of dynamics potential (3), of number in each age group (4), graduates potential (6) and university general level (2).

Studies showed that the value $\Phi(t)$ characteriing university condition rises in time. This corresponds to normal university development, growth of its scientific, methodical and teaching potentials. At the same time university graduates potential also grows, some of which later become university employees.

Assume what happens if faculty staff activity coefficient $a(T)$ is less than 1. Analyze how half decrease in faculty staff activity coefficient will result. Calculations performed within the model present that in 25 years after half decrease in activity coefficient, university development level will decrease five times.

The developed model of university operating efficiency and quality analysis proved that it is important to consider in estimating state of university such factors as activity and accumulated potential of faculty staff.

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