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# Fuzzy Optimization Model Of Human Capital Development Of The University's Department

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**Abstract:** Under the conditions of stiff competition and limited resources, the University management in the implementation of the strategic development program faces with the problem of forming the optimal portfolio of investment projects, taking into account existing project risks. One of the priority areas of investment is human capital of the organization, and its increase is an important condition for sustainable development and achieving the university's strategic goals. This paper describes the design of the fuzzy dynamic model of optimal distribution of investments in human capital of a university's business-unit between employees, in the areas of investment and years, for possible promotion to achieve the strategic goals of the business-unit. To estimate uncertainties in the calculation of numbers of the objective function, part of the model's input parameters is given in the form of term-sets of linguistic variables, which are moved into fuzzy numbers. As an example, we consider the problem of forming the optimal structure of distribution of investments in the department's human capital of Russian and Chinese universities. Comparative analysis of the obtained results has been done.

**Keywords:** University's human capital, economic-mathematical model, optimization structure of investments, the strategic management of the university, fuzzy-set approach.

## Introduction

In a post-industrial society and transition to the sixth technology revolution, human capital becomes essential factor for sustainable development of any socioeconomic system. It is one of the main factors of formation and development of economy of knowledge, and the theory that humans are the main feature for the successful functioning of any complicated in its structure organization, including university, has become one of the basic foundation of modern management.

Modern models of management of sustainable development of the university are aimed at achieving strategic goals, which is possible only with proper and substantiated investment of the available financial resources. One of the priority areas of investment is the human capital of the university, defining the impact on the implementation of the university's development strategy. The complex organizational structure of the University leads to the necessity of formation of the investment strategy and the optimal plan of measures, to the maximum extent to achieve the target values of the strategic tasks, defined under the strategic goals of the university.

This work is of interest for top management and heads of business-units of universities and provides them with the tools, which allow them to allocate optimally investments in human capital, depending on initial parameters of the business-unit, taking into account existing economic uncertainties, thus, to achieve its strategic goals to the maximum extent. Moreover, for modeling the uncertainty of parameters of internal and external environment, the mathematical apparatus of theory of fuzzy sets is used.

The work is based on human capital theory developed by T. Schultz and G. Becker [8, 16]. A significant contribution to the development of instrumental means of assessment of the value of human capital and the impact of investments for human capital development was made by such scholars as A. Dobrynin, S. Dyatlov, J. Kendrick, M. Critsky, J. Mincer, L. Torow, M. Friedman and others. Among modern authors is worth to mention the work of C. Carraro, E. De Sian M. Tavoni [9], where integrated assessment model of human capital and its relationship with innovation, climate change, and policies in education was proposed. D. Faulds proposed conceptual model of evaluating the composite factors of human capital, subdivided into subjective well-being and living standards, which, in turn, affect the overall political climate and economic climate [10]. In his study, H Gong proposed a model of estimation of the impact of inequality of human capital on total factor of productivity in China, built using dynamic panels over the period of time of 18 years for 29 provinces [12].

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In their work, J. Su and Z. Liu conducted a study on the impact of direct foreign investment and human capital on various determinants of economic growth using the extended model of Solow [17]. S. Vaitkevičius, E. Meulen and A. Savanevich, to identify the typology of the countries of the European Union in the development of human capital, have developed an index of development of human capital, consisting of three sub-indices: social progress of human capital, level of innovation development of human capital and potential of the development of human capital [18]. In N. Vargas, M. Loria and S. Rodg Dobon's work [19], a conceptual model for assessing the relationship between system of knowledge support (system of education) and human capital, direct and indirect effect on the use of human capital and the impact of educational streams on the efficiency of the organization was proposed.

However, existing tools are aimed at modeling of the development of human capital at the mega and meso levels and it is impossible to transfer them to the micro level (the level of the organization and its business-units) for the majority of positions. Among other drawbacks it can be noted that existing tools do not take into account the following: multi-periodicity of process of investing in human capital; uncertainties and risks when making decisions about investing in human capital; the specificity of the object (in certain work of the university).

Previously, the authors developed the following tools, which promote the development of optimal investment strategy and implementation plan for the business-unit, in the field of human capital management:

1) a method to quantify the level of university's human capital, taking into account a variety of characteristics that describe human capital;

2) elements of conceptual change model of human capital of the university's business-unit as a result of investing in its development of funds, that take into account the mutual influence of human capital and additional financial income to the university, while improving the level of human capital;

3) dynamic economic-mathematical model of distribution of investments in human capital of the university's business-unit, determining the optimal structure of investments to employees and areas of investment, depending on the target function; two objective functions were considered: the total human capital level of the business-unit and additional financial contributions by increasing the level of human capital [3, 5].

We should note, that some parameters of the dynamic model are determined on the basis of expert assessments, and, therefore, there is a considerable uncertainty in them, that must be considered taken into account. For modeling uncertainties, it is proposed to use fuzzy sets approach in estimation of initial values of characteristics of human capital of the department, the coefficients of importance of the characteristics and strategic goals. The problems of using of fuzzy sets theory to the portfolio investment was considered in the works [1, 13, 20].

Thus, the aim of this study is to develop an economic-mathematical model, which would allow us to allocate optimally the investments in human capital of the university's department, for the maximum possible progress in achieving its strategic goals and taking into account existing uncertainty in strategic decision-making, arising from subjectivity in the research of some initial parameters of the model.

**The conceptual model of the development of human capital of a university's business-unit by investing in it the financial funds**

To assess the impact of investments, contributed to in different areas of investment, for a human capital of a university's business-unit, it must be an understanding of the process of this unit's human capital development, as a result of investments of financial funds, including reinvested funds raised by employees of the unit in the previous period, and the necessary tools to quantify this development. In this regard, there is a need to develop a conceptual model, that will take into account all of the above.

Human capital of an employee of a university's business-unit will be understood as the combination of inborn abilities and acquired knowledge, abilities and skills of the employee, ensuring his effective and rational functioning as a productive factor of development [8].

Meanwhile human capital of employee is described by a certain set of characteristics, depending on the specifics of his job. As the result of the analysis of works [11, 14, 21, etc.] and the results of the studies of the authors, five integrated groups of characteristics of human capital are identified: personal, intellectual, professional, experience in the professional field and the image in a certain area.

For each of the characteristics of human capital the concept of level is introduced, showing the quantitative assessment of the level of ownership by the employee of a business-unit of a particular characteristic. The vector-function is assigned for each employee:

$$X_i(t) = \left(x_{i1}(t), x_{i2}(t), ..., x_{ij}(t)\right),\ i = 1, ..., N,\ j = 1, ..., M, \quad (1)$$

where $x_{ij}(t)$ is the value of *j-th* characteristics of human capital of the *i-th* employee of university's business-unit at the time moment *t*, $x_{ij}(t) \in [0; 100]$; *N* is the number of employees of a university's business-unit; *M* is the number of characteristics that describe the human capital of the employee of a university's business-unit.

Under the human capital level of a university's business-unit of *S(t)* will be understood the average quantification of inborn abilities and acquired knowledge, abilities and skills of all employees of a university's business-unit:

$$S(t) = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M} \alpha_j \cdot x_{ij}(t)}{N}, \quad (2)$$

where $\alpha_j$ is a weighting factor characterizing the importance of the *j-th* characteristics of human capital, $\alpha_j \in [0; 1]$ and $\sum_{j=1}^{M} \alpha_j = 1$.

The weighting factors are determined on the basis of assumptions of Russian and foreign psychologists on the importance of a particular ability [2, 6, 7, 11, 21 etc.] and the results of expert evaluation of competent senior managers of universities, resulting from the processing of the author's questionnaire.

Competent management of the university means having a program of its strategic development. Strategic development program of the university has a complex character, aimed, primarily, at meeting the needs of all stakeholders. One of the priority directions of the university development program is the accumulation and preservation of human capital. One of the ideas of the program is that investments in human capital should lead to the One of the ideas of the program is that investments in human capital should lead to the achievement of the strategic goals of the university, including facilitation of the implementation of the key indicators of assessment of the university activity's efficiency.

This paper considers the task with the given planning horizon *T*. At each time *t*, where *t* = 0, 1, ..., *T*–1, the university invests financial resources in the human capital of its business-units in the framework of the program of strategic development.

The investments in human capital are denoted as all the costs, aimed at improving of labour productivity [15]. In this work, the authors consider four areas of investment, namely education, health, reproduction and image.

Each direction of investments to the employee of a business-unit, in one way or another, leads to the growth of its human capital due to the changes in the characteristics, describing this capital. The authors highlighted the channels of influence of investments to human capital on its characteristics, given in the article [3].

Each employee, depending on his level of human capital, is able to attract a certain amount of financial resources. For a university's business-unit it's possible to allocate the following basic sources of attraction of financial resources by the employees: basic and additional educational programs; research grants and funds; contractual research work; consulting and support of the activities of other organizations (e.g., the provision of interpreter services).

The part of the funds, involved by the employee of the university, next year may be directed at increasing the level of human capital of the business-unit, in which the employee works, one more time. Thus, in the framework of the problem under consideration, investments to human capital of a business-unit consist of two components: financial resources for investment to human capital, planned for a business-unit under the program of strategic development of the university at the moment of time *t*; the part of the funds, involved by a business-unit during the time interval [*t*-1, *t*], is aimed at increasing of human capital.

As a result, the relationship of human capital of a business-units and additional resource incomes into it appears, emerging with the development of human capital. A graphical representation of the dynamic description of this effect is shown in figure 1.

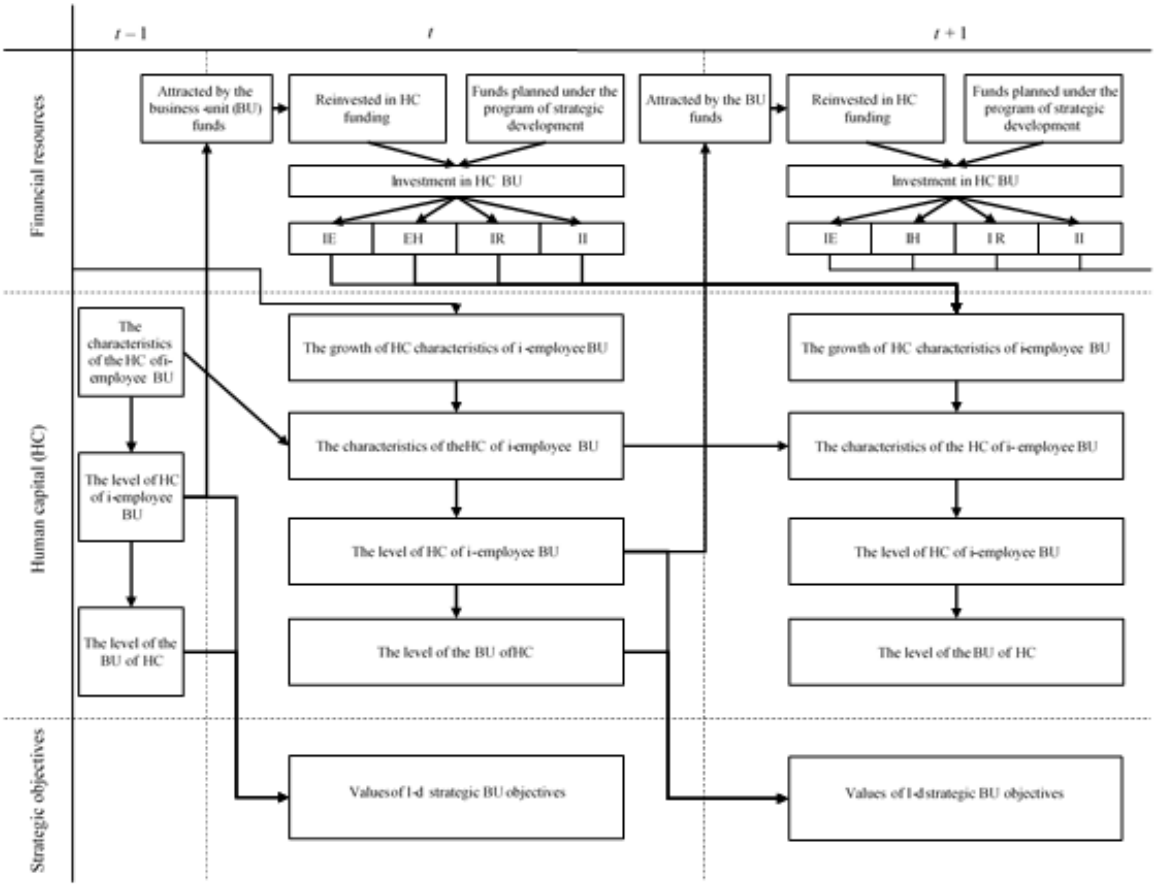


Figure 1 – Interference of the human capital of the business-unit and additional financial income

**Optimization model of distribution of investments in human capital business-unit of the university**

In the framework of the program of strategic development, of the university directs a portion of the funding for the development of the existing potential of the human capital of employees of business-units. There is a need for the leadership of the business-unit of optimal distribution of funds between staff according to areas of investment. In this regard, the problem of choosing the optimal structure of distribution of investments to human capital between employees in the areas of investment and years with a planning horizon *T* is considered, for maximum progress towards the strategic tasks of a university's business-unit. The optimization model is suggested for its solution.

To build the model, it's necessary to have the functional description of the change of meanings of characteristics of human capital of the employee, depending on the volume and structure of financial resources, invested in it. While looking for this dependence, the following should be considered:

– investment at the *r-th* direction affect the characteristics according to the channels of influence with regard to the degree of influence, which can be interpreted as the absorption of investment for the given characteristic;

– the increase in the age of an employee leads to the obsolescence of skills, knowledge and abilities, which, in turn, is the cause of lowering of the absorption of investment funds and increases the difficulty of increasing its level;

– to enhance the human capital of an employee with lower level, less investment are needed, than to improve the human capital of an employee with a higher level;

– it is advisable to use a selection function, showing how much investment you need to invest in a certain investment direction, in order to increase the value of human capital characteristics of the employee with level 10, up to 10 points, assuming complete absorption and regardless to age.

Based on the above considerations, the increase in the value of the human capital characteristics of the employee, as a result of investments of financial assets to him, is offered to find according to the following formula:

$$\Delta x_{ij}^{r}(t+1)=\lambda_j^r\cdot Z(\tau_i)\cdot\frac{\left(\beta(t)\cdot\sum_{i=1}^{N}B_i(t)+\hat{B}(t)\right)\cdot\gamma_i^r(t)}{B^{r\ норм}\cdot(1+d)^t}\cdot 10\cdot\left[1-\left(\frac{x_{ij}(t)-10}{90}\right)^s\right], \quad (3)$$

where $\lambda_j^r$ is the coefficient of absorption of investment at the *r-th* direction for *j-th* characteristics of human capital, $\lambda_j^r\in[0;1]$; $Z(\tau_i)$ is the function of absorption of the investment depending on the age of the employee, $Z(\tau_i)\in[0;1]$; $\tau_i$ is the age of the *i-th* employee; $\beta(t)$ is the coefficient of withdrawal at time, $\beta(t)\in[0;1]$; $B_i(t)$ is the function of the funds, attracted by the *i-th* employee during the time interval [*t*-1, *t*]; $\hat{B}(t)$ is financial resources for investment to human capital, planned for a business-unit under the university's program of strategic development at the moment of time *t*; $\gamma_i^r(t)$ is the share of investment funds, allocated for the *i-th* employee at the *r-th* direction at time *t*, $\gamma_i^r(t)\in[0;1]$, $\sum_{r=1}^{4}\sum_{i=1}^{N}\gamma_i^r(t)=1$; $B^{r\ норм}$ is selection function of *r-th* direction of investment; *d* is the discount rate; *r* is the direction of investment, where investment to education *r* = 1, investments to health *r* = 2, the investment to reproduction *r* = 3, investment to the image r = 4; *s* is saturation coefficient.

A detailed description of all the elements of function (3) is presented in the works [3, 5].

The change in human capital of employee of a business-unit is determined by the following formula:

$$\Delta K_i(t+1)=\sum_{j=1}^{M}\left(\sum_{r=1}^{4}\Delta x_{ij}^r(t+1)\right)\cdot\alpha_j, \quad (4)$$

Taking into account formulas (2) and (4), the assess of accumulated human capital of a business-unit is given by the formula:

$$S(t+1)=S(t)+\frac{\sum_{i=1}^{N}\Delta K_i(t+1)}{N}, \quad (5)$$

Let's move to constructing the objective function, taking into account a set of strategic challenges, facing the business-unit and are derived from the strategic goals of the university. Let each strategic objective is assigned by the indicator. There is a target value for the indicator on the considered planning horizon. Depending on the level of human capital of a business-unit at time *t*, certain results on the indicators are achieved. As objective function we introduce the following integral indicator:

$$I(t)=\sum_{l=1}^{L}\frac{P_l(t)}{\overline{P_l}}\cdot\zeta_l, \quad (6)$$

where $P_l(t)$ is the value of the index of *l-th* strategic task of a business unit in time *t*; $\overline{P_l}$ is the target value of indicator *l-y* strategic task; $\zeta_l$ is the coefficient of importance of *l-th* strategic task of a business-unit, represented by the heads of the business-units of the university and heads of the university, $\zeta_l\in[0;1]$, $\sum_{l=1}^{L}\zeta_l=1$; *L* is the number of strategic objectives.

To find out the value of the integral indicator, functional dependences are built, that allow to find out the values of indicators of the strategic tasks for the structure and level of human capital of a university's business-unit. These dependencies are constructed by regression analysis method, based on some assumptions and statistic data. In this case, the function of the indicator value is as follows:

$$P_l(t)=f_l(K_1(t), K_2(t), ..., K_N(t)), \ l=1, 2, ..., L. \quad (7)$$

Examples of construction of the following functional dependencies are given below.

We should note, that to build the optimization model, it is necessary to make several important assumptions:

– for the characteristics of human capital of group "job experience in a particular sphere of professional activity" the annual increase in value, regardless of the volume and directions, is 10 points;

– if a single time period in the model is equal to 1 year, then changing of the value of the *j-th* characteristic of human capital of the *i-th* employee $\Delta x_{ij}$ does not exceed 10;

– the annual investment in the human capital of a university's business-unit is limited with the amount of funds $B_{бюджет}$, allocated to a business-unit under the program of strategic development of the university.

Using the above mentioned assumptions, correlations, and notations, it is proposed to implement the formation of the optimal structure of investment to human capital of a business-unit, using the following model:

$$
\begin{cases}
I(T)=\sum\limits_{i=1}^{L}\dfrac{P_l(T)}{\overline{P}_l}\cdot\zeta_l\to\max,\\
K_i(0)=\sum\limits_{j=1}^{M}\alpha_j\cdot x_{ij}(0),\ \sum\limits_{j=1}^{M}\alpha_j=1,\\
K_i(t+1)=K_i(t)+\sum\limits_{j=1}^{M}\left(\sum\limits_{r=1}^{4}\Delta x_{ij}^{r}(t+1)\right)\cdot\alpha_j,\ t=0,1,...,T-1,\\
\Delta x_{ij}^{r}(t+1)=\lambda_{ij}^{r}\cdot Z(\tau_i)\cdot\dfrac{\left(\beta(t)\cdot\sum\limits_{i=1}^{N}B_i(t)+\hat{B}(t)\right)\cdot\gamma_i^{r}(t)}{B^{r\,нор.м}\left(x_{ij}(t)\right)\cdot(1+d)^{t}}\cdot10\cdot\left[1-\left(\dfrac{x_{ij}(t)-10}{90}\right)^{1,64}\right],\ r=1,4,\\
\Delta x_{ij}^{r}(t+1)=\lambda_{ij}^{r}\cdot Z(\tau_i)\cdot\dfrac{\left(\beta(t)\cdot\sum\limits_{i=1}^{N}B_i(t)+\hat{B}(t)\right)\cdot\gamma_i^{r}(t)}{B^{r\,нор.м}\left(K_i(t)\right)\cdot(1+d)^{t}}\cdot10\cdot\left[1-\left(\dfrac{x_{ij}(t)-10}{90}\right)^{1,64}\right],\ r=2,3,\\
B_i(t)=f(K_i(t)),\ \ t=0,1,...,T-1,\\
\sum\limits_{r=1}^{4}\sum\limits_{i=1}^{N}\gamma_i^{r}(t)=1,\ t=1,2,...,T-1,\\
\Delta K_i(t)\le10,\ \hat{B}(t)\le B_{бюджет}(t),\ t=1,2,...,T.
\end{cases}
$$

**The method of determining the objective function value for a certain period of planning in fuzzy logic**

A part of the model input parameters is determined on the basis of expert assessments of heads of business-units of universities. Meanwhile, it is quite difficult to give these parameters in the form of crisp numbers, and it is much easier for the expert to formulate them in the form of verbal evaluations based on subjective perceptions and feelings. One way to model the uncertainty of the views of experts is the use of fuzzy-sets approach. In this work, we use the following estimation methods of input parameters in fuzzy logic.

1. To determine the level of human capital of the *i*-employee of the business-unit at time $t = 0$ we use the verbal evaluation of his characteristics, transformed into a fuzzy number. So, for the linguistic variable $Y$ = <the level of employee's human capital characteristics> the term set can be written as $V(y)$ = {absence; an extremely low value; a very low value; low value; value is below average; above average value; high value; extremely high value; extremely high value; the maximum value}. Language evaluation is subjective and approximate, so to describe them we use a trapezoidal membership function to which it is convenient to perform all the necessary operations. The membership function are trapezoidal fuzzy numbers as follows:

- *W*(absence) = {0; 0; 0; 20};
- *W*(extremely low value) = {0; 0; 10; 30};
- *W*(very low value) = {0; 10; 20; 40};
- *W*(low value) = {0; 20; 30; 50};
- *W*(below average) = {10; 30; 40; 60};
- *W*(average) = {20; 40; 50; 70};
- *W*(above average) = {30; 50; 60; 80};
- *W*(high value) = {40; 60; 70; 90};
- *W*(extremely high value) = {50; 70; 80; 100};
- *W*(extremely high value) = {60; 80; 90; 100};
- *W*(the maximum possible value) = {70; 90; 100; 100}.

2. For determining the weights characterizing the importance of the *j-th* characteristics of human capital, and factors of importance of *l*-strategic objectives of the business-unit the verbal estimation of experts where each expert has a certain level of competence on this issue, determined verbally are used.

Thus, there are two linguistic variables $Y_1$ = <the importance of the human capital characteristics (or the importance of the strategic objectives of the business-unit)> and $Y_2$ = <the level of competence of the respondent on this issue>, term which can be written as $V(y_1)$ = {absent; minimal; low; medium; high; highest}, and $V(y_2)$ = {level does not allow to answer; an intuitive idea; the level of logical justification; the level of practical or theoretical knowledge; practical and theoretical knowledge; the Respondent is the expert}. The membership function are trapezoidal fuzzy numbers as follows:

- for $Y_1$: $W$(no) = {0; 0; 0; 2}; $W$(min) = {0; 0; 1; 3}; $W$(low) = {0; 2; 3; 5}; $W$(average) = {2; 4; 5; 7}; $W$(high) = {4; 6; 7; 9}; $W$(maximum) = {7; 9; 9; 9};
- for $Y_2$: $W$(level does not allow to answer) = {0; 0; 0; 2}; $W$(level intuitive representation) = {0; 0; 1; 3}; $W$(rational level) = {0; 2; 3; 5}; $W$(the level of practical or theoretical knowledge) = {2; 4; 5; 7}; $W$(the level of practical and theoretical knowledge) = {4; 6; 7; 9}; $W$(the Respondent is an expert) = {7; 9; 9; 9}.

Taking into consideration the given above fuzzy numbers, the formula for the consolidation of opinions of different experts in response to the *p-th* question is the following:

$$a_p = \sum_{q=1}^{Q} \frac{a_p^q \cdot c_p^q}{\sum_{q=1}^{Q} c_p^q}, \quad (8)$$

where $a_p^q$ is the evaluation of the *q-th* respondent when responding to the *p-th* question, the fuzzy number; $c_p^q$ is the assessment of level of competence of the *q-th* respondent when responding to the *p-th* question, the fuzzy number; $Q$ is the number of respondents.

To determine the weights of importance consolidated ratings need to be normalized. In case when the task has a clear statement, the values of the median of trapezoidal fuzzy numbers are taken as consolidated values.

Next, we consider the following problem: the determination of the degree of achievement of the strategic objectives of the business-unit at time $T$ if some input parameters are represented by fuzzy numbers and the investment in human capital is carried out both at the expense of the funds planned under the program of strategic development of the university, and by parts brought by the employees from the funds directed at increasing the level of human capital the next year.

To solve this problem we use the following algorithm:

1) following the method presented in studies [1, 13], for given levels of confidence a fuzzy constraint is converted to a clear mind;

2) the optimal structure of distribution of investment funds in human capital between employees in the areas of investment and time for the model in a clear formulation, where the initial values of the input parameters are the median of fuzzy numbers is found.

3) using the optimal structure of investment allocation found in paragraph 2, the objective function in the form of fuzzy numbers after $T$ years is determined with the help of the recursive dependencies of a dynamic model by the direct counting and the degree of risk of not achieving the target values of the integral indicator is determined.

**An example of formation of investment strategies for human capital development at the departments of Russian and Chinese universities**

As an example, we consider the problem of determining the optimal structure of distribution of investments in human capital between members of the department in the areas of investment and years to achieve the maximum value of the integral indicator that takes into account the degree of achievement of the strategic objectives of the department of Russian and Chinese universities. In [4] it was shown that some of the input parameters of the model depend on national and cultural specificities of the country. In this regard, the idea of the analysis of the results obtained in the process of using the model on the example of not only Russian universities, but also universities in other countries arose. Note that the choice of China as a site for comparative analysis is due to significant differences in the outlook of the European people, including Russians, and Asian people.

In the study [4] the following model parameters whose values differ in Russian and Chinese universities have been allocated:

- the weights of importance of the characteristics of human capital;
- function coefficients of absorption of the investment depending on the age of the employee;
- the coefficients of the selection functions for areas of investment;
- function coefficients of the funds brought by the employee.

Note that some of the assumptions and quantitative estimates necessary to construct the set of functional dependencies for the model and selection functions for the areas of investment, the function of assimilation of investments depending on the age and function of the funds brought by employee for Chinese university are presented in the study [4].

Then, taking into consideration the verbal assessment of the importance of human capital obtained from various respondents, and using the formula (8), the values of weighting coefficients presented in table 1 were obtained.

Table 1 – The importance of weighting factors of human capital characteristics

| Name of characteristics | Value of the coefficient of importance in the form of a fuzzy number | |
|---|---|---|
| | Russian University | Chinese University |
| Thinking | {0,032; 0,041; 0,044; 0,045} | {0,029; 0,032; 0,035; 0,036} |
| Speech | {0,021; 0,032; 0,036; 0,039} | {0,051; 0,051; 0,051; 0,051} |
| Reflective | {0 ; 0 ; 0,007; 0,016} | {0 ; 0,006; 0,015; 0,02 } |
| Emotionally-sensitive | {0,056; 0,059; 0,062; 0,063} | {0,029; 0,035; 0,038; 0,041} |
| Behavioral | {0,032; 0,039; 0,041; 0,042} | {0,062; 0,064; 0,066; 0,072} |
| Creative | {0,049; 0,051; 0,053; 0,053} | {0,007; 0,01 ; 0,016; 0,021} |
| Linguistic | {0,035; 0,036; 0,037; 0,042} | {0 ; 0,011; 0,018; 0,023} |
| Logical-mathematical | {0,084; 0,1 ; 0,114; 0,126} | {0,007; 0,016; 0,022; 0,026} |
| Spatial | {0 ; 0,016; 0,024; 0,029} | {0,014; 0,019; 0,025; 0,03 } |
| Bodily-kinetic | {0,021; 0,021;0,027 ; 0,03 } | {0,029; 0,032; 0,035; 0,036} |
| Interpersonally | {0 ; 0 ; 0 ; 0,01 } | {0 ; 0,005; 0,013; 0,018} |
| Interpersonal | {0 ; 0,007; 0,01 ; 0,017} | {0 ; 0 ; 0,009; 0,015} |
| Naturalistic | {0,01 ; 0,014; 0,022; 0,026} | {0,022; 0,027; 0,031; 0,034} |
| Communication | {0,077; 0,083; 0,091; 0,095} | {0,055; 0,056; 0,06 ; 0,065} |
| Multitasking | {0,087; 0,109; 0,128; 0,147} | {0,05 ; 0,051; 0,053; 0,058} |
| Decision-making | {0,075; 0,088; 0,101; 0,116} | {0,007; 0,016; 0,022; 0,026} |
| Organization | {0,055; 0,056; 0,057; 0,153} | {0,059; 0,060; 0,063; 0,065} |
| Proactivity | {0,037 0,037; 0,037; 0,042} | {0,069; 0,082; 0,101; 0,116} |
| Learning | {0,087; 0,102 ;0,119; 0,137} | {0,066; 0,075; 0,08 ; 0,087} |
| Experience of pedagogical activity | {0,01 ; 0,014; 0,022; 0,026} | {0,064; 0,071; 0,082; 0,094} |
| Academic experience | {0 ; 0 ; 0 ; 0,01 } | {0,014; 0,021; 0,025; 0,029} |
| The image in the region | {0 ; 0 ; 0,005; 0,013} | {0,036; 0,037; 0,038; 0,039} |
| The image in the country | {0 ; 0,007; 0,017; 0,023} | {0,069; 0,082; 0,095; 0,109} |
| Image in the world | {0 ; 0,016; 0,024; 0,029} | {0,059; 0,065; 0,076; 0,087} |

As part of this work another important difference between the systems of goal-setting in Russian and Chinese universities, generating a difference in the strategic goals and objectives, their indicators and the factors of importance, and, consequently, in the objective function may be noted.

Next, we consider the problem of maximization of an integral indicator with a planning period of 5 years, taking into account the degree of achievement of the strategic objectives of the department. Strategic objectives, their indicators and the targets for the department of Russian and Chinese universities presented in table 2.

Table 2 – Strategic objectives

| Country | Strategic objective | Indicator | The objective value |
|---|---|---|---|
| Russia | increase the publication activity of the staff of the department ($l$ = 1) | number of publications indexed in the citation systems, on average, for one member of staff of the department in a year | 3 |
| | improving of the qualification of teaching staff of the department ($l$ = 2) | the proportion of teaching staff of the department, having a degree of candidate or doctor of sciences in the total number of staff of the department | 0,8 |
| | increasing in the amount of funds raised by the staff of the department in the research work ($l$ = 3) | the amount of funds attracted for the implementation of projects in the form of grants and research on one member of staff of the department for 1 year | 7,7 thousand dollars |
| | the increase in the number of competitions and contests won by the students of the department ($l$ = 4) | number of achievements (1st, 2nd and 3rd places) in contests for 1 year | 4 |
| | improving of the effectiveness of training graduate students ($l$ = 5) | the proportion of post-graduate students of the department, who passed the theses defense in time | 0.5 |
| | improving of the quality of the students accepted on the 1 course ($l$ = 6) | the average score on the exam of students accepted to the internal form | 72 points |
| | improving of the quality of the students accepted on the 1 course of ($l$ = 7) | average score of the undergraduate diploma of the students who were enrolled at the master's degree programs of the department | 85 points |
| China | Growth of the academic reputation of the department ($m$ = 1) | average expert assessment of the academic reputation of the department by representatives of the academic community from 0 to 100 | 80 |
| | increasing citation of scientific publications of the teaching staff of the department ($m$ = 2) | number of citations per one member of the teaching staff of the department a year | 10 |
| | increase of the publication activity of the teaching staff ($m$ = 3) | the number of scientific publications on average per a member of the teaching staff of the department a year | 2 |
| | the increase in funding of the research activities of the department by third party companies ($m$ = 4) | funding of the research activities of the department by the third parties on average per one member of the teaching staff of the department a year | 9.2 thousand dollars |
| | the development of international activities of the department ($m$ = 5) | the share of foreign students in the total number of students of the department | 0,4 |
| | improving the qualification of teaching staff of the department ($m$ = 6) | the proportion of defended dissertations in the total number of staff of the department | 0,9 |
| | the improvement of working conditions of full-time faculty of the department ($m$ = 7) | remuneration attributable on average one member of staff of the department a year | 17 thousand dollars |

Considering verbal assessment of the importance of strategic tasks received from various respondents, and using the formula (8), the values of weighting coefficients presented in table 3 were obtained.

Table 3 – Weights of the importance of strategic objectives

| Strategic objective | The value of the coefficient of importance in a form of a fuzzy number | Strategic objective | The value of the coefficient of importance in a form of a fuzzy number |
|---|---|---|---|
| $l = 1$ | {0,143; 0,146; 0,146; 0,155} | $m = 1$ | {0,236; 0,269; 0,319; 0,367} |
| $l = 2$ | {0,143; 0,146; 0,146; 0,155} | $m = 2$ | {0,293; 0,338; 0,397; 0,433} |
| $l = 3$ | {0,172; 0,208; 0,22 ; 0,25 } | $m = 3$ | {0,067; 0,068; 0,085; 0,098} |
| $l = 4$ | {0 ; 0,024; 0,042; 0,069} | $m = 4$ | {0 ; 0,042; 0,077; 0,095} |
| $l = 5$ | {0,107; 0,122; 0,125; 0,138} | $m = 5$ | {0,1 ; 0,1 ; 0,1 ; 0,109} |
| $l = 6$ | {0,172; 0,208; 0,22 ; 0,25 } | $m = 6$ | {0 ; 0,029; 0,062; 0,083} |
| $l = 7$ | {0,107; 0,122; 0,125; 0,138} | $m = 7$ | {0,033; 0,045; 0,069; 0,086} |

In this work, the proposed model is updated by the functions of the value of the indicator of *m* strategic objectives of the department in time *t*. Note that for the department of the Russian university the data of the dependencies were previously constructed in study [4]. For each indicator of the strategic objectives of the department of Chinese university, functional dependence is described by the methods of regression analysis using some assumptions and statistical data of Heilongjiang University (table 4).

Table 4 – Function values of the index objectives of the department in time *t*

| Index of tasks | Function of the value of the indicator |
|---|---|
| Average expert evaluation of the academic reputation of the department by the representatives of the academic community from 0 to 100 | $P_1(t) = S(t)$ |
| The average number of citations per one member staff of the department a year | $P_2(t) = \frac{16 \cdot \sum_{i=1}^{N} V_i^1(t)}{N}$, $V_i^1(t) = \begin{cases} 0, K_i(t) \in [0; 30); \\ 0{,}2, K_i(t) \in [30; 50); \\ 0{,}4, K_i(t) \in [50; 70); \\ 1, K_i(t) \in [70; 100] \end{cases}$ |
| The average number of scientific publications per one member of staff of the department a year | $P_3(t) = \frac{\sum_{i=1}^{N} V_i^2(t)}{N}$, $V_i^2(t) = \begin{cases} 0, K_i(t) \in [0; 30); \\ 0{,}0006 \cdot K_i^2(t) - 0{,}0077 \cdot K_i(t), K_i(t) \in [30; 100] \end{cases}$ |
| The average funding of the research activities of the department by the third-party companies per one member of staff of the department a year, thousand dollars | $P_4(t) = \frac{\sum_{i=1}^{N} V_i^3(t)}{N}$, $V_i^3(t) = \begin{cases} 0, K_i(t) \in [0; 50); \\ 0{,}385 \cdot e^{0{,}044 K_i(t)}, K_i(t) \in [50; 100] \end{cases}$ |
| The share of foreign students in the total number of students of the department | $P_5(t) = \begin{cases} 0, S(t) \in [0; 50); \\ 0{,}016 \cdot S^2(t) - 1{,}039 \cdot S(t) + 22{,}857, S(t) \in [50; 100] \end{cases}$ |
| The proportion of defended dissertations in the total number of full-time faculty teaching staff of the department | $P_6(t) = \frac{\sum_{i=1}^{N} V_i^4(t)}{N}$, $V_i^4(t) = \begin{cases} 0, K_i(t) \in [0; 30); \\ 0{,}3, K_i(t) \in [30; 50); \\ 0{,}8, K_i(t) \in [50; 70); \\ 1, K_i(t) \in [70; 100] \end{cases}$ |
| The amount of average remuneration per one member full-time faculty of the department a year, thousand dollars | $P_7(t) = \frac{30{,}77 \cdot \sum_{i=1}^{N} V_i^5(t)}{N}$, $V_i^5(t) = \begin{cases} 0, K_i(t) \in [0; 20); \\ 0{,}2, K_i(t) \in [20; 50); \\ 0{,}6, K_i(t) \in [50; 70); \\ 1, K_i(t) \in [70; 100] \end{cases}$ |

As an example, consider the departments of Russian and Chinese universities with the same input parameters. Let the department consists of 10 people, whose fragment of the verbal estimates of the values of the characteristics in the initial moment of time is presented in table 5. The initial planned investments for the strategic development program is $15.4 thousand annually and the rate of withdrawal for borrowed funds is equal to 0,1 throughout the planning horizon. Variables subject to optimization are the share of investments in employees in the areas of investment and the years $\gamma_i^1(t)$, …, $\gamma_i^4(t)$, где $i$ = 1, …,10, $t$ = 1, …,5.

Table 5 – A fragment of the values of the characteristics of members of the department

| Feature | Employee number | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | … | 4 | … | 7 | … | 10 |
| $x_{i1}$ | low | … | below average | … | high | … | very high |
| … | … | … | … | … | … | … | … |
| $x_{i24}$ | very low | … | average | … | average | … | extremely high |

Received verbal values of the characteristics are translated into trapezoidal fuzzy number, and then the levels of human capital of each employee in the form of fuzzy numbers are found (the values of importance weights of characteristics are shown in table 1). The data obtained are presented in table 6.

Table 6 – Initial levels of human capital department

| The employee number | Level of human capital | | Age |
|---|---|---|---|
| | Russian University | Chinese University | |
| 1 | {10; 14; 24; 49} | {10; 16; 26; 46} | 25 |
| 2 | {10; 14; 25; 48} | {10; 13; 22; 41} | 26 |
| 3 | {10; 16; 26; 49} | {10; 15; 24; 44} | 27 |
| 4 | {29; 49; 59; 84} | {27; 47; 57; 77} | 31 |
| 5 | {27; 47; 56; 85} | {28; 49; 58; 79} | 36 |
| 6 | {27; 47; 58; 85} | {26; 46; 56; 76} | 37 |
| 7 | {22; 41; 51; 78} | {25; 45; 55; 76} | 38 |
| 8 | {50; 70; 80; 100} | {49; 69; 79; 97} | 44 |
| 9 | {50; 70; 81; 100} | {48; 68; 77; 95} | 51 |
| 10 | {49; 69; 80; 100} | {49; 69; 79; 97} | 55 |

In the first phase of the method of determining the values of the objective function over the planning period in fuzzy logic the fuzzy goals are translated into clear ones, and in the second stage the optimal allocation of investment funds between the members of the department in the areas of investment and years to achieve the maximum value of the integral indicator for 5 years for the described example is determined in a clear statement. The structure of distribution of investment funds is presented in figure 2

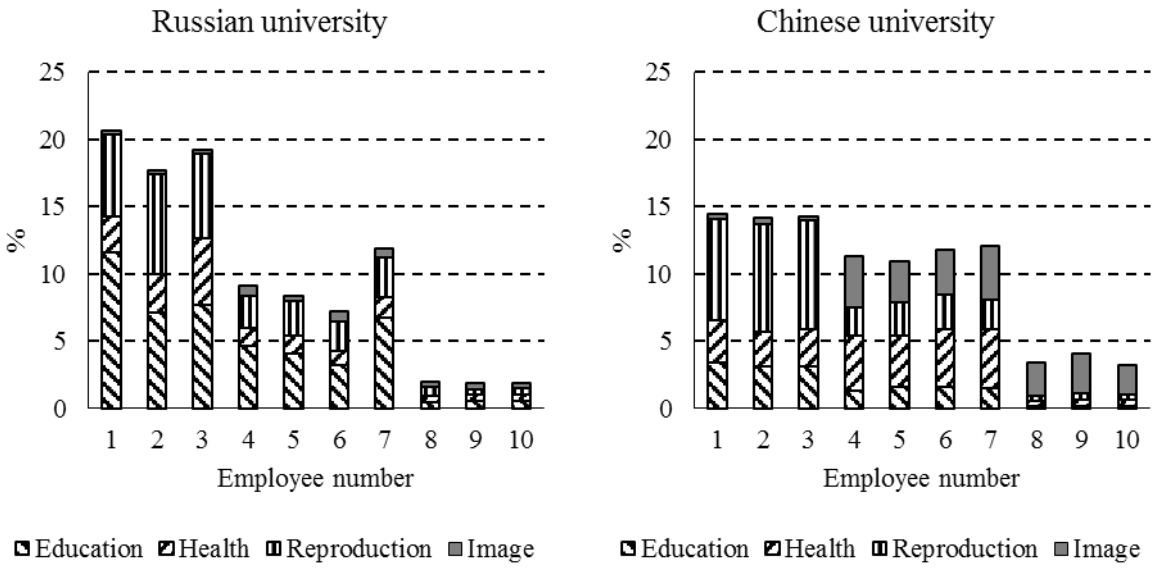


Figure 2 – The structure of distribution of investment funds

An increase in the level of human capital of the department of the Russian university in 5 years will be about 10 units with a total investment cost of 187,7 thousand dollars (of which 77 thousand dollars are the planned investments under the program of strategic development of the university and 110,7 thousand dollars are the reinvestment of additional funds), the increase in the level of human capital of the Chinese university is about 13 units with a total investment cost 231,5 thousand dollars (of which 77 thousand dollars come from the program of strategic development of the university and 154.5 thousand dollars from the reinvested funds).

Using the found percentage of the distribution of investment and setting the initial values of human capital, their weights of importance (table 1) and the coefficients of the importance of strategic objectives (table 3) in the form of fuzzy numbers for the account of the uncertainty in the recursive dependencies of the model we find the values of indicators of the strategic objectives and the integrated indicator by years with the help of the direct counting. Some values are presented in table 7.

Table 7 – Values of indicators of the strategic objectives in a form of fuzzy numbers in 5 years

| Strategic objective | The value of the indicator of the strategic objective | Strategic objective | The value of the indicator of the strategic objective |
|---|---|---|---|
| $l = 1$ | {0,77; 2,01; 2,56; 3,85} | $m = 1$ | {49; 64; 72; 86} |
| $l = 2$ | {0,21; 0,58; 0,87; 1} | $m = 2$ | {4; 9; 13; 16} |
| $l = 3$ | {2; 5,6; 10,3; 33,3} | $m = 3$ | {1,07; 1,08; 2,61; 3,85} |
| $l = 4$ | {1; 3; 4; 7} | $m = 4$ | {1,4; 6,5; 9,2; 17,1} |
| $l = 5$ | {0,1; 0,3; 0,4; 0,6} | $m = 5$ | {0; 0,22; 0,31; 0,52} |
| $l = 6$ | {0; 74; 79; 91} | $m = 6$ | {0,45; 0,81; 0,89; 0,93} |
| $l = 7$ | {54; 64; 70; 82} | $m = 7$ | {9,8; 22,2; 27,1; 30,8} |
| $I$ | {0,26; 0,77; 1,04; 1,99} | $I$ | {0,42; 0,82; 1,11; 1,41} |

Considering the results presented in table 7, it is possible to evaluate the degree of risk of not achieving the target value of, for example, an integral indicator. The degree of risk will be assessed according to the following formula:

$$R = \sum_{l=1}^{L} \frac{S^l_{риска}}{S^l_{общая}} \cdot \zeta_l , \quad (9)$$

where $S^l_{риска}$ is the area of the figure located to the left of the target values for the $l$ strategic objective; $S^l_{общая}$ is the total figure for the $l$ strategic objective.

Using the formula (9) the risks of not achieving the strategic objectives of the departments of Russian and Chinese universities were found. The obtained values are summarized in table 8.

Table 8 – The risks of not achieving strategic objectives

| Objective | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $I$ |
|---|---|---|---|---|---|---|---|---|
| Russian university | 0,85 | 0,75 | 0,22 | 0,57 | 0,92 | 0,73 | 1,00 | {0,598; 0,679; 0,706; 0,789} |
| Chinese university | 0,75 | 0,44 | 0,43 | 0,58 | 0,89 | 0,96 | 0,16 | {0,429; 0,528; 0,655; 0,753} |

Analyzing the data of table 8, we can say that for the department of Russian and Chinese universities, risks of not achieving the strategic goals are above average (for the Russian university it is about 0,692, for the Chinese University – 0,612), indicating a probable failure to reach the majority of the strategic objectives.

The values allow us to formulate the following investment strategies for human capital development of a business unit of the university, depending on the country in which it is located:

- for the department of the Russian university: if the department is dominated by employees with an initial level of human capital, corresponding to the average level, and maximizing of the integral index is implemented, taking into account the degree of achievement of the set of strategic objectives of the business-unit in a long-term strategy ($T$ = 5), the maximum portion of the investment (50-60%) goes to employees with the level of human capital [45; 55], and the main areas of investment are education (45-50%) and reproduction (30-35%). The degree of risk of failing to deliver the strategic goals under this funding, amounts to 0,7;
- for the department of the Chinese university: if the department is dominated by employees with an initial level of human capital, corresponding to the average level, and maximizing of the integral index is implemented, taking into account the degree of achievement of the set strategic objectives of the business-unit in a long-term strategy ($T$ = 5), investments are distributed among the employees equally with a slight bias in favor of employees with low levels of human capital, and the main areas of investment are reproduction (30-35%) and health care (25-30%). The degree of risk of failing to deliver the strategic objectives of this funding is 0,6.

A significant difference in the distribution of investments to human capital for the departments of Russian and Chinese universities is a hierarchy of areas of investment for Chinese university: priority is given to reproduction and health, further image and education, while for the department of the Russian university there is the following hierarchy: education, reproduction, health and image. For the department of the Russian university, clearly outliered (less than 5%) is the direction of image, and for the Department of the Chinese university it is not in such a way. This structure is due to the fact, that while the implementation of the strategic tasks, the important role is played by the individual himself, who is able, due to his high level of human capital, to make a significant contribution to the achievement of target values of indicators of the strategic tasks of the department.

A distinctive feature of the distribution of investments to human capital of the department of the Chinese university between the staff, is smoother gap between maximum investment amount and minimum one. For the department of the Chinese university, the difference is about 10%, while for the Russian department, it is more than 15%. The strategy of the department of the Russian university is pulling the weak links (employees with low levels of human capital) to the average level of the Department, while investment in the department of the Chinese university are spread more evenly between employees, which indicates the satisfaction of the interests of all employees.

**Conclusion**

A fuzzy sets model for optimal allocation of investment to human capital of a business-unit of the university is proposed in the paper. The objective function of the model is the integrated indicator, characterizing the degree of achievement of the strategic tasks, set for a business unit by the university. The optimization variables are the percentage distribution of investments to human capital of a business-unit of the university among its employees in the areas of investment the model (education, health, reproduction and image) and periods. In this case, part of the model input parameters (initial values of human capital of employees of a business-unit set of the university, the weights factors of importance of the characteristics and strategic goals) is in the form of term-sets of linguistic variables, that are further translated into fuzzy non-distinct trapezoidal numbers. This allows you to simplify the task of determining data parameters of the model, within the blurring of the information and subjective perceptions and feelings of respondents (experts) and to estimate the uncertainty in the calculations of forecast values of the integral indicator. For the solution of fuzzy tasks, the method of determining the objective function value for a certain period of planning in fuzzy logic is proposed.

An example for achieving the strategic objectives by the departments of Russian and Chinese universities has been analyzed. A comparative analysis of patterns of investment to human capital departments of Russian and Chinese universities has been done. The results of model calculations allow us to create an investment strategy of human capital development of a business-unit of the university, taking into account currently available time of human capital and funding.

The proposed model is an effective tool for management of the middle and upper units of the university, which allows to find the optimal quantitative structure of distribution of financial resources, aimed to human capital. At the same time, not only the department can be considered as a business-unit, but other departments: academic, scientific, providing, or manufacturing. The optimal structure of investment to human capital provides an opportunity to assess their contribution to the achievement of target values of indicators and to build "a road map" of accomplishing strategic goals within the restrictions of financial resources.

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