

# Development of a Method for Forming an Optimal Portfolio of Regional Projects to Achieve Strategic Regional Development Targets

Lev S. Mazelis<sup>1</sup>, Kirill I. Lavrenyuk<sup>2</sup>, Andrey A. Krasko<sup>3</sup>, Elena V. Krasova<sup>4</sup>

<sup>1</sup>Doctor of Economic Sciences, Head of department, Department of Mathematics and Modeling, Vladivostok State University of Economics and Service, Vladivostok, Primorsky Krai, Russia,  
ORCID: <https://orcid.org/0000-0001-7346-3960>, ResearchGate: [https://www.researchgate.net/profile/Lev\\_Mazelis](https://www.researchgate.net/profile/Lev_Mazelis)

<sup>2</sup>Director, Human Resources Directorate, RT-Techpriemka, Electric lane 1/12, Moscow 123557, Russia,  
ORCID: <https://orcid.org/0000-0002-9092-3196>

<sup>3</sup>Postgraduate student, Department of Mathematics and Modeling, Vladivostok State University of Economics and Service, Vladivostok, Primorsky Krai, Russia,

<sup>4</sup>PhD in economics, Associate professor, Department of Economics and management, Vladivostok State University of Economics and Service, Vladivostok, Primorsky Krai, Russia,  
ORCID: <https://orcid.org/0000-0001-7847-0385>

## Abstract

The article focuses on the topical problem of accumulation and development of regional human capital. Given the limited resources (e.g., financial and human), the regional leadership faces the task of their optimal distribution between strategic projects that directly or indirectly affect the development of regional human capital. This study aims to develop and test the economic and mathematical method of forming the optimal portfolio of strategic regional projects to maximize progress towards achieving the targets of social and economic development of the region. The article proposes a dynamic model, the objective function of which is an integrated index that takes into account the degrees of achievement of targets of the social and economic development of the region. The model is based on updated functional interrelations of investments that directly or indirectly affect the development of regional human capital → targets of regional human capital → targets of the social and economic development of the region. The variables used for optimization are the Boolean variables of the inclusion of a project in a particular investment area at a certain point in time in a project portfolio. For the Primorsky Region, an example of the formation of an optimal portfolio of strategic projects is considered by years for a given planning period, which allows to achieve the maximum progress towards targets of the social and economic development of the region. A comparative analysis of the project portfolios obtained under two scenarios was performed. In the first scenario, the investment structure was taken from the draft regional budget. In the second scenario, the investment structure was calculated according to the model.

**Keywords:** social and economic development of the region, regional human capital, project portfolio optimization, dynamic economic and mathematical model

## I. INTRODUCTION

Currently, the regions are facing new challenges associated with the digital transformation of the economy and social

environment. This considerably increases the importance of such a resource as human capital. Therefore, from the point of view of regional authorities, there is a need to implement measures aimed at creating the most favorable conditions to attract highly trained professionals and talented youth and to retain them and fully develop their human potential.

However, despite the priority of these tasks, the region, like any system, operates under conditions of limited resources, which necessitates a reasonable and effective utilization of available resources to achieve the development goals of the region. At the same time, companies and people in the region are also directly or indirectly involved in the development of the regional human capital. Because the region is a complex system in which some ongoing processes cannot be controlled, there is a need to use tools that would allow:

First, to identify strengths and weaknesses of human capital development within the framework of achieving the strategic priorities of the region,

Second, to determine resource requirements for rectifying weaknesses and improving strengths with high accuracy,

Third, to assess the effects of the implementation of activities at the regional level and form an optimal portfolio of these activities as part of the implementation of the regional development strategy that is subject to the “rectifying” or “improving” priority.

The abovementioned requirements suggest the high urgency of the issue of creating economic and mathematical methods and models for forming a portfolio of regional projects for the fastest possible achievement of the development goals of the region.

## II. ANALYSIS OF LITERATURE DATA AND SETTING THE GOAL OF THE STUDY

Modern research in the field of human capital is conceptually based on the classical provisions of the human capital theory, the underlying hypothesis of which consists of a significant

positive relation between investments in various areas of human capital and sustainable economic development. At the regional level, this relation is properly implemented through a project and investment mechanism that ensures high target efficiency of measures by optimizing costs and improving performance in a specific segment of economic activity related to human capital. Many theoretical and empirical studies are dedicated to the problems of optimizing the allocation of funds and rationalizing the formation of project portfolios, and one of the overriding priorities is the improvement of methods and tools as part of the project approach to regional management.

A global trend in addressing optimization issues as part of strategic economic research is to follow the trajectory of sustainable growth of countries and their territories in the context of given priorities. At the same time, a pattern of breakthrough scientific, technological, and socio-economic development is assumed for the Russian territories to ensure a sustainable growth in prosperity and competitiveness of every person, every family, and the entire society [7]. Reference [22], using best practices, theoretically substantiates an increase in the efficiency of territory management through the rational utilization of limited resources of the public and private sectors and project management achieved as part of the practice. Reference [17] describes a wide range of methods for creating regional development strategies, including simulation models, which can serve as a basis for the formation of regional development projects in the medium term, leading to a change in the socio-economic situation in the right direction. The implementation of methods for optimizing regional development in Russia is shown using the example of the SIRENA scientific project, the Prognoz analytical complex, the territorial automated information system (TAIS), and other tools [23]. The advantages of these methods are the toolkit flexibility, comprehensiveness of approaches to strategic planning, ability to address issues specific to the region, and coordination of actions of various authorities. However, several shortcomings can be distinguished such as high cost, considerable requirements for information support and hardware, and the complexity of practical implementation in the current activities of authorities. Thus far, the abovementioned restrictions limit the scope of application of these methods.

Noteworthy are studies related to simulation of the strategic development of the region with an emphasis on rationalizing investments made both in traditionally problematic areas of management and in promising projects. Reference [27] focuses on simulating a structural and investment policy of the Russian territories, which would provide the potential for the country's GDP growth until 2035 in the amount of at least 3.5% per year and overcome the disproportionate distribution of resources. Reference [13] developed an information and analytical model for the development of a regional economic system, which allows to determine means of achieving promising goals that bring this system from the reference point of competitiveness to the one required by the objective conditions of competitive interaction. Reference [18] proposes to solve the problem of ensuring the strategic development of regions using an optimization model for the distribution of flows of regional investment resources from the perspective of territorial entities,

which maximizes the total gross value added of the region as one of the resulting indicators of its functioning and development. A set of restrictions of this model respects the interests of various stakeholders - the state, business, and households. Increased capabilities of modern simulation (forecasting) tools for the strategic development of regions are demonstrated by the interregional "payments-income" model, which allows to balance the budgetary support of the regional economy by industry and region [5]. The presented models have several positive aspects. Specifically, they are capable of solving strategic tasks to a certain extent, accommodate the interests of institutionally different subjects, and take into account the priorities of national development. However, they have several drawbacks. Specifically, there are no clear criteria for optimizing strategic development, and an essential component of regional development (i.e., human capital) is not fully taken into account.

At the same time, in a wide range of works dedicated to the economic development of territories, human capital acts as a platform for strategic breakthrough. The analysis of findings of many studies conducted in different periods of time reflects an increasingly close correlation between one of the forms of human capital (i.e., intellectual capital) and sustainable economic development in both private and public sectors [9]. On the basis of the analysis of multidirectional factors affecting the social, ecological, and economic security of the region, reference [26] highlights human capital as a factor in the vital capacity of the problem region. A case study using the example of African countries has shown that the development of human capital and an increase in labor productivity based on it is a critical factor in the convergence of African countries by 2060 [11]. On the basis of the findings of empirical research conducted in China, human capital is regarded as the core of the regional economy in the country. According to Chinese scientists, the development of provinces with a low level of human capital is possible only through the implementation of social projects [28]. Study [3], using the example of China, also shows that social capital, which is similar in nature to the category of human capital, makes a tangible contribution to the restructuring of the country's rural regions and determines the current level of economic security of the rural population. In general, having studied the research findings on Chinese provinces for different periods of the 20th and 21st centuries, it is clear that the less developed is the territory, the stronger is the impact of investment in human capital on the social and economic development of the region [2; 10]. Nevertheless, the variety of data and research methods used, the difference in the initial socio-economic and historical conditions, and the rate of innovation processes in countries yield heterogeneous and occasionally contradictory conclusions about the impact of investments on the given targets of regional development.

Most scientists associate the impact of the implementation of projects related to the development of human capital with education and healthcare, the growth of which in the total investment expenditures of regions is quite reasonable and expected, especially in developing countries. Reference [6] reveals the mechanism of interaction between human capital and regional development through the implementation of investment projects in the education and health sectors of

underdeveloped countries. The study empirically confirms that the effective reproduction of human capital essentially depends on the supply of services in those sectors, the activity of which, in turn, depends on the macroeconomic policy of the state. A comprehensive study into measuring human capital in 195 countries and territories for 1990–2016 is based on the indicators of life expectancy, education level, and health status (i.e., the classical realms of human capital) [24]. However, a number of authors reasonably believe that mere investment in education and healthcare is not sufficient and propose to expand the areas of investment in culture, welfare (infrastructure provision), R&D, recreation, entertainment, sports activities, and environment. Specifically, reference [4] proposes a new comprehensive measure of investment in human capital as an alternative to the traditional education-based assessment system. Study [21] divides human capital into social and commercial components and specifies each of them in terms of entrepreneurship. At the same time, scientific literature still lacks experience in researching the impact of the entire complex of different investments in human capital depending on their synergistic effect.

Of note, modern scientific literature develops areas that explore the correlation between human capital and the implementation of projects in certain industries. Thus, the findings of study [1] show a significant positive correlation between the growth of investment in human capital and the effectiveness of projects in the US construction sector. The knowledge and expertise of managers directly affect labor productivity in construction, which is also confirmed by the findings of another study that intellectual capital acts as an optimizing factor in Polish construction teams [20]. The study also shows that the development of intellectual capital helps to mitigate risks in construction and increases the quality of performance. These studies are specific because they reflect the peculiarities and industries of a particular country. However, the findings of those studies can serve as the underlying hypothesis for further research of the role of human capital in the strategic development of regions.

Thus, studies of methods for optimizing the development of regions based on the implementation of projects in the field of human capital cover broad areas of theoretical knowledge and practical application. An abundance of concepts, methods, and models account for various and sometimes contradictory research findings, as well as for the impossibility to determine with great accuracy the optimal range of specific projects and measures for regional development. The authors adhere to the position of an active scientific inquiry and further development of approaches to the methodology of regional development by accounting for the factor of human capital to provide modern society with effective tools for addressing multiple social and economic issues.

### III. PURPOSE AND OBJECTIVES OF RESEARCH

This study aims to develop the economic and mathematical method of forming the optimal portfolio of strategic regional projects to maximize progress towards achieving the targets of the social and economic development of the region.

To achieve this goal, the following objectives were set:

- to develop a dynamic model for the formation of an optimal portfolio of regional projects to maximize the integrated index of the social and economic development of the region;
- to update the functional dependencies of the influence of volume and composition of investments in the regional human capital by area to change the indicators of its social and economic development;
- to examine the computation aspects of the model application under the conditions of real development of regions.

### IV. DYNAMIC MODEL FOR THE FORMATION OF AN OPTIMAL PORTFOLIO OF REGIONAL PROJECTS SUBJECT TO THE DEVELOPMENT OF HUMAN CAPITAL

Reference [16] describes a conceptual model for the development of regional human capital. Reference [17] proposes a formalization of the main part of the conceptual model in the form of a mathematical programming problem in a crisp setting. The models are based on chains of influence channels: regional investments that directly or indirectly affect the development of regional human capital → targets of regional human capital → targets of the social and economic development of the region.

In this study, we will examine the problem of forming an optimal portfolio of regional projects that directly or indirectly affect the development of regional human capital in terms of investment areas and years, where  $T$  is the planning period. The determination of the optimal project portfolio will result in the maximum possible progress towards achieving the targets of the social and economic development of the region. This study deals with a multi-period dynamic process, with time  $t = 0, 1, \dots, T - 1$ . At each point in time  $t$ , financial resources are invested in various projects that directly or indirectly affect the development of regional human capital.

All expenditures that directly or indirectly affect the development of human capital in a particular region are viewed as investments in human capital. These expenditures can be divided into 12 groups corresponding to the classification of Russian budgetary expenditures [8] (hereinafter referred to as the areas of investment in human capital): national issues ( $r = 1$ ), national defense ( $r = 2$ ), national security and law enforcement ( $r = 3$ ), national economy ( $r = 4$ ), housing and utilities ( $r = 5$ ), environmental protection ( $r = 6$ ), culture and cinematography ( $r = 7$ ), social policy ( $r = 8$ ), mass media ( $r = 9$ ), education ( $r = 10$ ), healthcare ( $r = 11$ ), and physical education and sport ( $r = 12$ ). In turn, investments in human capital can be classified as follows:

– by purpose:

- a) process investments - financial resources allocated to maintain the functioning of the region's existing infrastructure (e.g., payroll costs of the head of a constituent entity of the Russian Federation and expenditure for the judiciary);
- b) project investments - financial resources allocated for the

creation of new infrastructure or modernization of the region's existing infrastructure (e.g., subsidies to small and medium-sized businesses for business expansion and road construction);

- by source:

a) federal budget - financial resources of the federal budget allocated for the implementation of national projects, the major purpose of which is to improve the quality of life of the population of the regions;

b) regional budget - financial resources of the regional budget allocated for the social and economic development of the region;

c) company budgets - financial resources of a company (organization, enterprise) allocated for the development of personal and professional skills (both direct and through the implementation of projects) of its own personnel and improving their quality of life;

d) population income - financial resources of people allocated for self-development and improving the quality of life of the population.

Of note, some projects are implemented on terms of co-financing. For example, all national projects are financed from two sources (federal and regional budgets), with certain regional projects being implemented on the basis of a public-private partnership (i.e., financed from the regional budget and the company's budget).

Therefore, the total amount of financial resources allocated to the  $r$ -th investment area in the  $n$ -th region at time  $t$  ( $z_{rm}(t)$ ) is calculated using the following formula:

$$z_{rm}(t) = z_{rm}^{1.0}(t) + z_{rm}^{2.0}(t) + z_{rm}^{3.0}(t) + z_{rm}^{4.0}(t), \quad (1)$$

where:

$z_{rm}^{1.0}(t)$  is the amount of federal budget funds allocated to the  $r$ -th investment area in the  $n$ -th region at time  $t$ . Retrospective and forecast data  $z_{rm}^{1.0}(t)$  are determined on the basis of information on supported projects as part of national projects presented on the website [12];

$z_{rm}^{2.0}(t)$  is the amount of budget funds of the  $n$ -th region allocated to the  $r$ -th investment area at time  $t$ . Retrospective data  $z_{rm}^{2.0}(t)$  are determined on the basis of information provided in the law of a constituent entity of the Russian Federation "On the Regional Budget" (e.g., [25]). Forecast data are determined using the following formula:

$$z_{rm}^{2.0}(t+1) = \alpha_{rm} \cdot \beta_{rm} \cdot z_{rm}^{2.0}(t) + \sum_{i=1}^{I_r} (y_{irm}(t+1) \cdot C_{irm}^{2.0}(t+1)), \quad (2)$$

where  $\alpha_{rm}$  is the coefficient of change in the amount of budget funds of the  $n$ -th region allocated to the  $r$ -th investment area,  $\alpha_{rm} \geq 0$  (determined by experts);  $\beta_{rm}$  is the share of process

investments in the total amount of budget funds of the  $n$ -th region allocated to the  $r$ -th investment area,  $0 \leq \beta_{rm} \leq 1$  (determined by the results of the regional budget analysis for previous years);  $y_{irm}(t+1)$  is the coefficient of inclusion of the  $i$ -th project implemented as part of the  $r$ -th investment area of the  $n$ -th region at time  $(t+1)$  in the regional project portfolio; assumes the value of 0 if the project is not included in the portfolio or 1 if the project is included in the portfolio (hereinafter, optimization variable);  $C_{irm}^{2.0}(t+1)$  is the amount of budget funds of the  $n$ -th region allocated for the implementation of the  $i$ -th regional project as part of the  $r$ -th investment area at time  $(t+1)$ ;  $i$  is the number of the regional project,  $i = 1, 2, \dots, I_r$ ;  $n$  is the number of the region of interest,  $n = 1, 2, \dots, N$ .

Of note, all projects can be divided into two types: cyclic (e.g., subsidies to companies) and one-time (e.g., road construction). Moreover, investments in one-time projects can be made within several years in addition to being made at once (in one year). Of note, if a decision is made to include a one-time project in the portfolio at time  $t$  and if the investments of this project are recurring (e.g.,  $t$ ,  $t+1$ , and  $t+2$ ), the project's investments for subsequent years are also reflected in the portfolio.

$z_{rm}^{3.0}(t)$  is the total amount of budget funds of the companies operating on the territory of the  $n$ -th region allocated to the  $r$ -th investment area at time  $t$ . Retrospective data  $z_{rm}^{3.0}(t)$  are determined on the basis of the results of surveys of companies on the volumes and composition of investments allocated for the development of human capital in terms of own employees. Forecast data are determined using the following formula:

$$z_{rm}^{3.0}(t+1) = \varphi_{rm} \cdot \gamma_{rm} \cdot z_{rm}^{3.0}(t) + \sum_{i=1}^{I_r} (y_{irm}(t+1) \cdot C_{irm}^{3.1}(t+1)) + \sum_{j=1}^{J_r} C_{jrm}^{3.2}(t+1), \quad (3)$$

where  $\varphi_{rm}$  is the coefficient of change in the total amount of budget funds of the companies operating on the territory of the  $n$ -th region allocated to the  $r$ -th investment area,  $\varphi_{rm} \geq 0$  (determined by experts);  $\gamma_{rm}$  is the share of process investments in the total amount of budget funds of the companies operating on the territory of the  $n$ -th region allocated to the  $r$ -th investment area,  $0 \leq \gamma_{rm} \leq 1$  (determined by experts based on a company survey);  $C_{irm}^{3.1}(t+1)$  is the total amount of budget funds of the companies operating on the territory of the  $n$ -th region allocated to the implementation of the  $i$ -th regional project as part of the  $r$ -th investment area at time  $(t+1)$ ;  $C_{jrm}^{3.2}(t+1)$  is the total amount of budget funds of the companies operating on the territory of the  $n$ -th region allocated to implementation of the  $j$ -th private project (i.e., without co-financing) as part of the  $r$ -th investment area at time  $(t+1)$ ;  $j$  is the number of the private project,  $j = 1, 2, \dots, J_r$ .

Of note, if the  $i$ -th project is implemented using only the budget funds of the  $n$ -th region (i.e., without attracting the company's investments), then  $C_{in}^{2.0}(t+1) = 0$ ;

$z_{rn}^{4.0}(t)$  is the amount of funds from the cash income of the population of the  $n$ -th region allocated to the  $r$ -th investment area at time  $t$ . To determine the forecast values  $z_{rn}^{4.0}(t+1)$ , the following analysis is performed: 1) statistical data on consumer expenditures in the areas of investment "education", "healthcare", and "physical culture and sports"; 2) the results of a survey of the population on the amount and structure of costs allocated to the development of own human capital. The forecast data are determined by the formula:

$$z_{rn}^{4.0}(t+1) = D_n(t+1) \cdot H_{rn}(t+1), \quad (4)$$

where  $D_n(t)$  is the size of the population of the  $n$ -region employed in the economy at time  $t$ ,  $H_{rn}(t)$  is the amount of costs (for the  $r$ -th investment area) on average per person employed in the economy of the  $n$ -th region at time  $t$  ("average bill"). To determine the forecast values  $D_n(t+1)$  and  $H_{rn}(t+1)$ , time-series models are built based on the available historical data for previous points in time.

Of note, investments in human capital at the regional level that can be managed to maximize their effect are financial resources allocated from the regional budget for the implementation of strategic regional projects.

Regional human capital consists of certain components (a description of the components and indicators for assessing regional human capital is given in [16]). The vector function for a specific region is as follows:

$$X_n(t) = (x_{1n}(t), x_{2n}(t), \dots, x_{Mn}(t)), \quad (5)$$

where  $x_{mn}(t)$  is the value of the  $m$ -th indicator of human capital of the  $n$ -th region at time  $t$ ;  $m$  is the number of the indicator of regional human capital,  $m = 1, 2, \dots, M$ .

This study examines the effect of indicators of regional human capital on the basic indicators of its social and economic development (a description of indicators of the social and economic development of the region is given in [14]). The vector function for a specific region is as follows:

$$W_n(t) = (w_{1n}(t), w_{2n}(t), \dots, w_{Pn}(t)), \quad (6)$$

where  $w_{pn}(t)$  is the value of the  $p$ -th indicator of social and economic development of the  $n$ -th region at time  $t$ ;  $p$  is the number of the indicator describing the social and economic development of the region,  $p = 1, 2, \dots, P$ .

For the functional description of chains of influence channels, we will build a two-level system of econometric dependencies.

When building the first level dependencies to eliminate multicollinearity and reduce the dimension of problem, the

principal components for the system of human capital indicators are built as the first step (the method is described in [15]), with econometric dependencies of the principal components upon investments being built as the second step. Of note, compared to reference [14], this study expands the database by adding values from the year of 2018.

Thus, the effect of the volume and composition of investment in regional human capital on the values of principal components is set by econometric models that are created on the basis of panel data:

$$RCX_{kn}(t) = g_k(RCX_{kn}(t-1), z_{1n}(t-1), \dots, z_{12n}(t-1), z_{1n}(t-2), \dots, z_{12n}(t-2), z_{1n}(t-3), \dots, z_{12n}(t-3)), \quad (7)$$

where  $RCX_{kn}(t)$  is the value of the  $k$ -th principal component of human capital of the  $n$ -th region at time  $t$ ;  $k$  is the number of the principal component,  $k = 1, 2, \dots, K$ .

At the second level, the effect of the values of principal components of regional human capital on the values of indicators of its social and economic development is set by econometric models that are created on the basis of panel data:

$$w_{pn}(t+1) = f_p(w_{pn}(t), RCX_{1n}(t), \dots, RCX_{Kn}(t)), \quad (8)$$

In the strategies and programs for the social and economic development of the region, the target values of the resulting indicators of social and economic development are set for the planning period of interest within the framework of strategic goals. Let us designate these values as  $\tilde{w}_{pn}$ .

Then, the integrated index of progress towards achieving the targets of social and economic development of the region will take the following form:

$$ISE_n(t) = \sum_{p=1}^P \frac{w_{pn}(t)}{\tilde{w}_{pn}} \cdot v_{pn}(t), \quad \sum_{p=1}^P v_{pn}(t) = 1, \quad (9)$$

where  $v_{pn}(t)$  is the weight coefficient characterizing the importance of the  $p$ -th indicator of social and economic development for the  $n$ -th region at time  $t$  (determined by experts).

To create the model, we will make a number of assumptions regarding the process of human capital development:

- the amount of budget funds of the region allocated for the direct or indirect development of regional human capital at time  $t$  is limited by the total amount of costs approved by public authorities as part of the regional budget  $R_n(t)$ :

$$\sum_{r=1}^{12} z_{rn}^{2.0}(t) \leq R_n(t); \quad (10)$$

- the annual growth rates of investments from the regional budget in each area of investment have lower limits  $\bar{a} = (a_1, \dots, a_{12})$  associated with the required minimum

amount of financial resources to maintain the environment created at the previous stage, as well as upper limits  $\bar{b} = (b_1, \dots, b_{12})$  associated with the maximum possible amount of financial resources for expenditure:

$$a_r \leq \frac{z_{rn}^{2.0}(t)}{z_{rn}^{2.0}(t-1)} \leq b_r; \quad (11)$$

- if one period in the model is equal to one year, most development indicators of regional human capital for a given period cannot considerably change, i.e., the relative gain of the principal components has lower  $\bar{c} = (c_1, \dots, c_K)$  and upper  $\bar{d} = (d_1, \dots, d_K)$  bounds:

$$c_k \leq \frac{RCX_{kn}(t+1) - RCX_{kn}(t)}{RCX_{kn}(t)} \leq d_k; \quad (12)$$

- the degrees of achievement of the target values at time  $T$  should not considerably differ from the target values, i.e., deviations in the values of social and economic development of the region from target values have lower  $\bar{e} = (e_1, \dots, e_p)$  and upper  $\bar{f} = (f_1, \dots, f_p)$  bounds:

$$e_p \leq \frac{w_{pn}(T)}{\tilde{w}_{pn}} \leq f_p. \quad (13)$$

Thus, it is proposed that the formation of an optimal portfolio of projects that affect the social and economic development of the region (through development of regional human capital) should be performed using the following optimization model:

$$\left\{ \begin{array}{l} ISE_n(T) = \sum_{p=1}^P \frac{w_{pn}(T)}{\tilde{w}_{pn}} \cdot v_{pn}(T) \rightarrow \max, \\ \sum_{p=1}^P v_{pn}(t) = 1, n = 1, \dots, N, t = 0, \dots, T, \\ w_{pn}(t+1) = f_p(w_{pn}(t), RCX_{1n}(t), \dots, RCX_{Kn}(t)), p = 1, \dots, P, \\ RCX_{kn}(t) = g_k(z_{1n}(t-1), z_{1n}(t-2), \dots, z_{12n}(t-1), z_{1n}(t-2), \dots, z_{12n}(t-2), z_{1n}(t-3), \dots, z_{12n}(t-3)), k = 1, \dots, K, \\ z_{rn}(t) = z_{rn}^{1.0}(t) + z_{rn}^{2.0}(t) + z_{rn}^{3.0}(t) + z_{rn}^{4.0}(t), r = 1, \dots, 12, \\ z_{rn}^{2.0}(t) = \alpha_{rn} \cdot \beta_{rn} \cdot z_{rn}^{2.0}(t-1) + \sum_{i=1}^{I_r} (y_{irn}(t) \cdot C_{irn}^{2.0}(t)), i = 1, \dots, I_r, \\ z_{rn}^{3.0}(t) = \varphi_{rn} \cdot \gamma_{rn} \cdot z_{rn}^{3.0}(t-1) + \sum_{i=1}^{I_r} (y_{irn}(t) \cdot C_{irn}^{3.1}(t)) + \sum_{j=1}^{J_r} C_{jrn}^{3.2}(t), j = 1, \dots, J_r, \\ z_{rn}^{4.0}(t) = D_n(t) \cdot H_m(t), \\ \sum_{r=1}^{12} z_{rn}^{2.0}(t) \leq R_n(t), a_r \leq \frac{z_{rn}^{2.0}(t)}{z_{rn}^{2.0}(t-1)} \leq b_r, \\ c_k \leq \frac{RCX_{kn}(t+1) - RCX_{kn}(t)}{RCX_{kn}(t)} \leq d_k, e_p \leq \frac{w_{pn}(T)}{\tilde{w}_{pn}} \leq f_p. \end{array} \right.$$

Boolean variables  $y_{irn}(t)$  are used as model variables. The solution to the model is found by a nonlinear least squares method with a boundary (Levenberg-Marquardt method) using the Global Optimization Toolbox for MatLab. The obtained solutions allow to form an optimal action plan ("road map") at the regional level to maximize progress towards achieving the target values of the key indicators of the social and economic development of the region.

## V. COMPUTATION ASPECTS OF THE MODEL APPLICATION UNDER THE CONDITIONS OF DEVELOPMENT OF REGIONS

The model for the formation of an optimal portfolio of projects that directly or indirectly affect the social and economic development of the region through the dynamic development of human capital described above can be applied to real conditions. As an example, let us consider the problem of forming an optimal portfolio of projects for the Primorsky Region using a given planning period. The solution to this problem will allow to maximize progress towards achieving the target values of the key indicators of the region's social and economic development.

Publicly available statistical data for 2011–2018 and data obtained as a result of remote surveys and interaction with experts were used as the reference data on the level of human capital and social and economic development of the regions.

Reference [16] describes the method of clustering regions by indicators of human capital development and conducts clustering of Russian regions. On the basis of the results of clustering, the Primorsky Region was included in the "small" cluster.

The principal components of indicators of human capital development were built for these clusters using the database supplemented with the 2018 data (the method is described in [15]). The number of principal components used is seven, which explains approximately 76% of the variance.

To obtain dependencies (7) and (8), which functionally describe investment influence channels, three types of models (i.e., end-to-end, deterministic, and spatial random effects models) were created by the Best Subject method on the basis of the database containing 2018 data. The best models were selected for each cluster using the Wald, Hausman, and Breusch-Pagan tests.

For the Primorsky Region, let us consider the formation of a project portfolio with a planning period of 3 years ( $T = 3$ ). The targets of the region's social and economic development, which are obtained from the budget law, are shown in Table 1.

**Table 1.** Targets for the Primorsky Region

<b>Indicator</b>	<b>Actual value (<math>t = 0</math>)</b>	<b>Target value (<math>t = 3</math>)</b>
(1) Share of employed population in labor force, %	0.94	0.98
(2) Per capita cash income correlated with the minimum subsistence level, times	2.60	2.95
(3) Amount of consumption expenditure per capita per month, RUB	22,385.20	26,822.27
(4) Share of consumption expenditure in the total income of the population, %	69.10	71.74
(5) Consumer price index, December to December of last year, %	106.44	104.00
(6) GRP per capita, RUB	382,586.90	457,452.95
(7) Fixed assets value at the end of the year at the gross book value per capita, RUB	1,620,423.00	1,863,486.40
(8) Fixed capital expenditures per capita at actual prices, RUB	64,120.00	76,362.09
(9) Industrial production index, in % to the previous year	97.80	104.90
(10) Volume of shipped locally produced goods, work performed, and services rendered using own resources by type of economic activity "Extraction of minerals", at actual prices, per capita, RUB	8,909.30	10,245.35
(11) Volume of shipped locally produced goods, work performed, and services rendered using own resources by type of economic activity "Manufacturing activity", at actual prices, per capita, RUB	98,321.93	113,069.15
(12) Volume of shipped locally produced goods, work performed, and services rendered using own resources by type of economic activity "Production and distribution of electricity, gas, and water", at actual prices, per capita, RUB	31,753.20	36,515.95
(13) Agricultural products in farms of all categories at actual prices, per capita, RUB	21,963.20	34,465.37
(14) Commissioning of residential and non-residential buildings (gross floor area) per capita, sq.m. per person	0.37	0.55
(15) Aggregate turnover of retail trade, catering, and paid services per capita, RUB	260,688.44	301,133.36
(16) Proportion of break-even (including profit-making) organizations, as a percentage of the total number of organizations	69.20	79.30
(17) Consolidated budget revenues of the Primorsky Region per capita, RUB	58,512.03	67,288.80

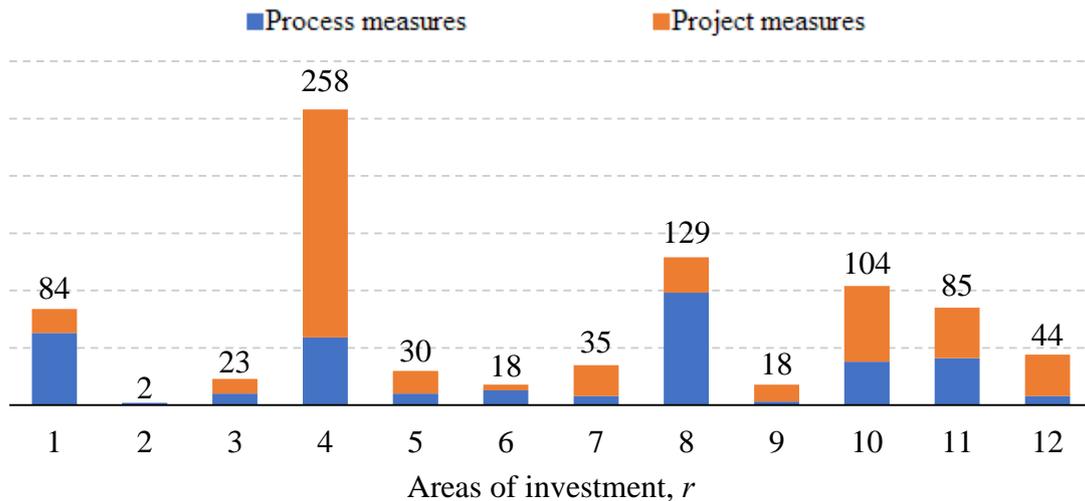
The principal input parameters of the model are the volume and composition of investments in the region's human capital. The following is a brief analysis of the current financial situation in the Primorsky Region. As noted earlier, investments in the region's human capital are made up of 4 sources: federal and regional budgets, company budgets, and population income. Let us consider each source separately.

#### 1. Federal budget

The primary financial resources of the federal budget are currently going to regional budgets through the implementation of national projects. Over the next 5 years, the Primorsky Region plans to implement 557 projects as part of 13 national projects (79 federal projects) for a total amount of 202.7 BRUB, of which 188.5 BRUB from the federal budget.

#### 2. Regional budget

Currently, regional budget is the principal public source of direct or indirect development of regional human capital. However, only part of the regional budget funds can be invested in the region's development because a considerable amount of funds is allocated to the functioning of the existing infrastructure. For example, let us consider the results of the analysis of the regional budget of the Primorsky Region for 2020 [25]. In 2020, it was planned to implement 830 projects, of which 477 were projects aimed at regional development. The quantitative structure of regional budget projects by areas is shown in Figure 1.

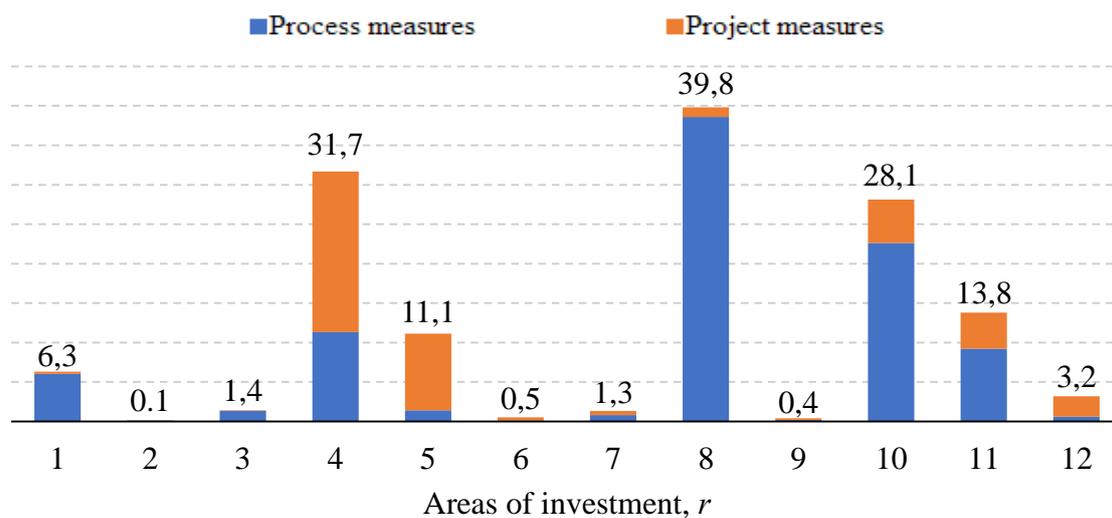


**Figure 1.** Quantitative structure of regional budget projects by areas, ea.

The areas with the largest number of implemented projects include “national economy” (199 project activities), “social policy” (31), and “education” (66).

In total, it is planned to invest 137.7 BRUB in the implementation of 830 projects, of which 45.5 BRUB

(approximately 33%) will be invested in the implementation of project activities. Of note, the anticipated volumes of investment in project activities for 2021 and 2022 are considerably lower: 31.9 and 28.7 BRUB, respectively. The financial structure of regional projects by areas is shown in Figure 2.



**Figure 2.** Financial structure of regional projects by areas in 2020, BRUB

“Social policy” is one of the most cost-intensive areas in the region (39.8 BRUB), whereas investments in project activities amount to only 1.2 BRUB. The “national economy” area ranks second in terms of total investment (31.7 BRUB) and first in terms of the volume of investment in project activities (20.4 BRUB). Thus, according to the regional authorities, the region's development is based on the development of transport infrastructure and the formation of conditions for business development.

Of note, model restrictions  $R_n(t)$  are the size of the budget of

the Primorsky Region and are equal to 108.9 BRUB at the time  $t = 1$ , 103.5 BRUB at time  $t = 2$ , and 112.3 BRUB at time  $t = 3$ .

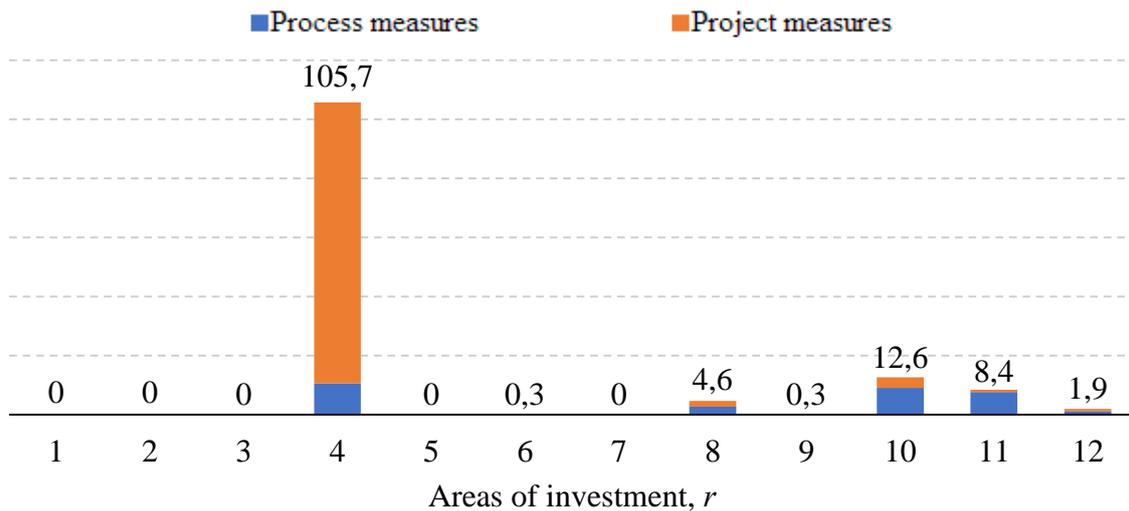
### 3. Company budget

Currently, one can hardly imagine a modern company without a developed human resources management system. Training/development and motivation of staff are considered two of the most important functions of human resources management. Of note, many companies are implementing numerous projects aimed at staff development such as the

creation of training centers and corporate universities. Such projects are implemented both using their own funds and under the terms of co-financing (in association with the regional government).

In 2019, the consolidated revenue of companies that are based in the Primorsky Region amounted to 2,267.6 BRUB

(according to [19]). However, the aggregate costs of companies for the development of their own human capital amounted to 126.5 BRUB in 2019, of which 102.2 BRUB was allocated for the implementation of projects (according to the survey). The structure of expenditures for the development of human capital by areas is shown in Figure 3.

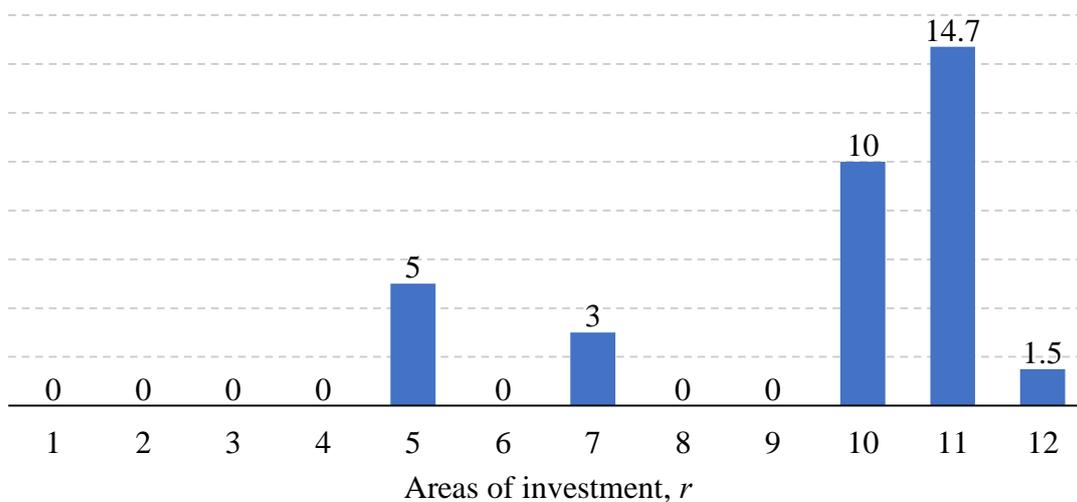


**Figure 3.** Structure of company expenditures for the development of human capital by areas, BRUB

The largest volume of investments (105.7 BRUB) is allocated to the “national economy”, of which 95.1 BRUB account for the implementation of project activities. According to company representatives, these investments are allocated for the development of companies, and, consequently, for the generation of employment and development of labor productivity. Of note, companies' investments in education amount to approximately 12.6 BRUB.

#### 4. Population income

Most people spend part of their cash income on their personal development and improvement of the quality of life. The amount of cash income of the population of the Primorsky Region was estimated to be 853.2 BRUB in 2019, of which approximately 34.4 BRUB was invested in the development of their own human capital. The financial structure of private investments in the development of human capital by areas is shown in Figure 4.



**Figure 4.** Financial structure of private investments in the development of human capital by areas, BRUB

The largest volume of private investment accounts for “healthcare” (14.7 BRUB) and “education” (10 BRUB). Residents of the Primorsky Region invest approximately 5 BRUB annually to improve their living conditions, which is

reflected in the area of “housing and utilities”.

Other input parameters of the model are shown in Table 2.

**Table 2.** Model input parameters

Investment area	Name of parameter			
	$\alpha_{rn}$	$\beta_{rn}$	$\varphi_{rn}$	$\gamma_{rn}$
National issues	1.07	0.94	–	–
National defense	1.03	1.00	–	–
National security and law enforcement	0.97	0.93	–	–
National economy	1.01	0.36	1.05	0.10
Housing and utilities	1.06	0.13	–	–
Environmental protection	1.54	0.25	1.05	0.80
Culture and cinematography	1.04	0.62	–	–
Social policy	1.11	0.97	1.05	0.30
Mass media	1.05	0.57	1.05	0.40
Education	1.13	0.81	1.09	0.60
Healthcare	1.03	0.67	1.14	0.90
Physical education and sport	1.06	0.18	1.15	0.40

Now, we consider two scenarios:

- 1) optimization scenario, in which the composition of investments allocated for the implementation of projects is calculated according to the model;
- 2) inertial scenario, in which the composition of investments allocated for the implementation of regional projects is taken from the draft budget of the Primorsky Region.

However, both scenarios have the same total investment by year.

On the basis of the analysis of investments in the region's human capital, the authors proposed a number of projects to be implemented over the next 3 years, with the determination of their cost for the Primorsky Region. Examples of some projects are shown in Table 3.

**Table 3.** Examples of projects for the Primorsky Region

Project	Type	Investment source	Investment volume by points in time, MRUB	
			1	2
Social policy				
Construction of a boarding house for the elderly and disabled	One-time	Regional budget	20.0	20.0
		Company budget	20.0	20.0
...	...	...	...	...
Physical education and sport				
Construction of a sports and recreation complex	One-time	Regional budget	120.0	0.0
		Company budget	20.0	0.0
...	...	...	...	...

National economy				
Crop business development subsidies	Cyclic	Regional budget	880.0	0.0
		Company budget	3000.0	0.0
Grants for the development of family livestock farms	Cyclic	Regional budget	120.0	0.0
		Company budget	120.0	0.0
Road construction	One-time	Regional budget	300.0	120.0
		Company budget	0.0	0.0
Development of the concept of digital transformation	One-time	Regional budget	45.0	0.0
		Company budget	0.0	0.0
...	...	...	...	...

The total number of projects under consideration, which can be implemented within 3 years, is 364. Of note, the abovementioned list of projects was expanded by the authors (more than 150 projects were added). The total investment from the regional budget, which is necessary for the implementation of all projects within the 1st year, is 130.81 BRUB (the required total investment for 3 years is 266.36 BRUB).

However, the restrictions on the amount of investment of budgetary funds of the Primorsky Region by year are as follows: in the 1st year - 45 BRUB; in the 2nd year - 32 BRUB; in the 3rd year - 29 BRUB.

Next, let us set the model restrictions. The constraint vectors used in model relations (11) – (13) are specified as follows:

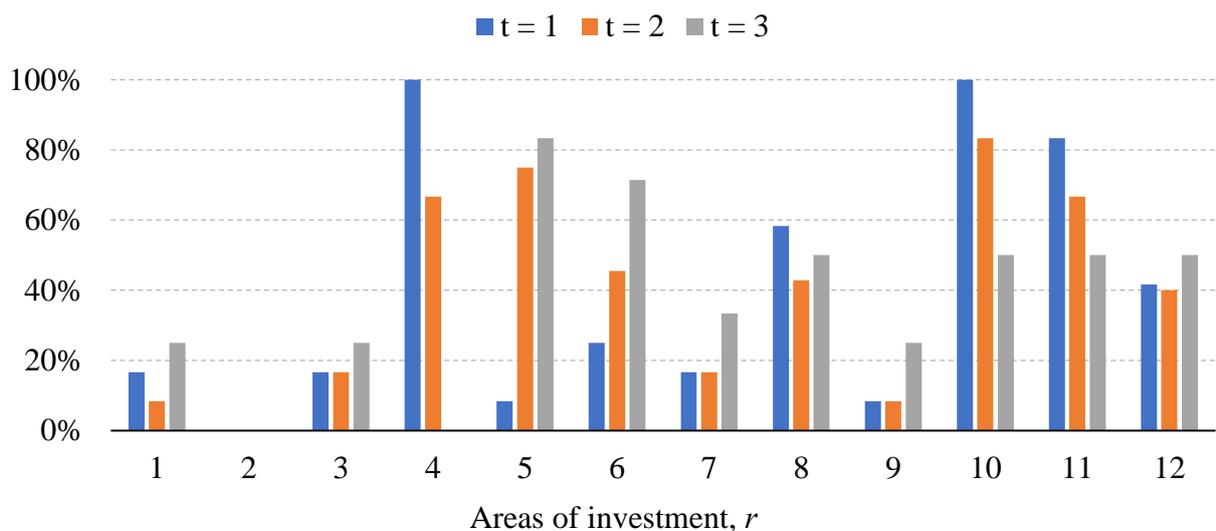
1) the lower and upper limits of the growth rates of the volumes of investments allocated from the regional budget for the development of human capital at one point in time for this

example are as follows:  $\bar{a} = (0,5, \dots, 0,5)$ ,  $\bar{b} = (2, \dots, 2)$ ;

2) the lower and upper limits of the relative changes in the principal components of indicators of the development of regional human capital at one point in time for this example are as follows:  $\bar{c} = (0, \dots, 0)$ ,  $\bar{d} = (1, \dots, 1)$ ;

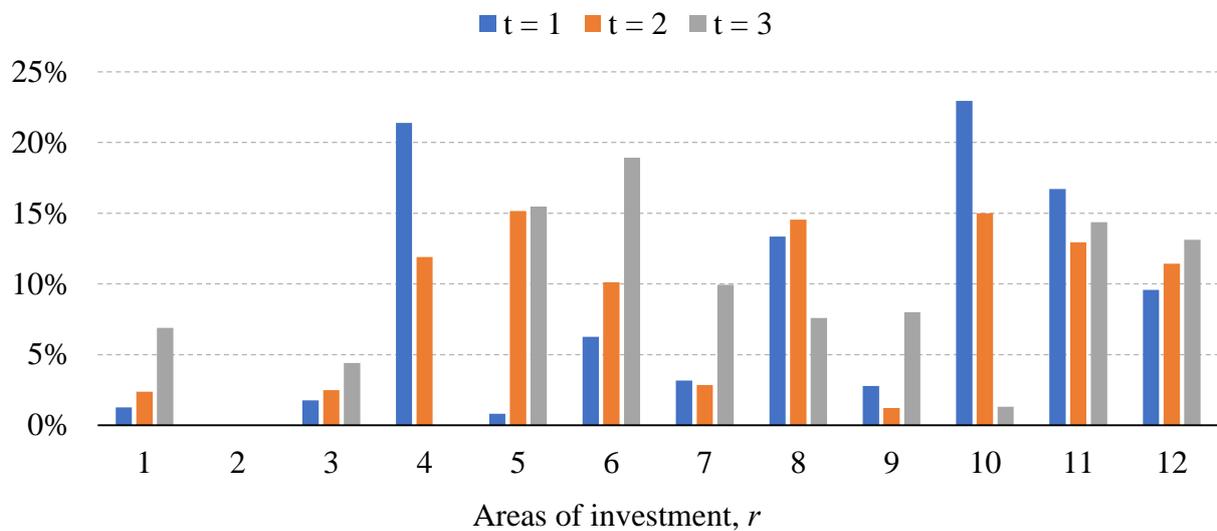
3) the lower and upper limits of the degrees of achievement of the target of the social and economic development of the region at time  $T$  for this example are as follows:  $\bar{e} = (0,75, \dots, 0,75)$ ,  $\bar{f} = (1,5, \dots, 1,5)$ .

The result of optimization is the definition of a list of projects by areas of investment in human capital and by years, which should be included in the overall portfolio of regional projects. Figure 5 shows information about the percentage of projects accepted by areas of investment over time.



**Figure 5.** Percentage of projects included in the overall portfolio of regional projects

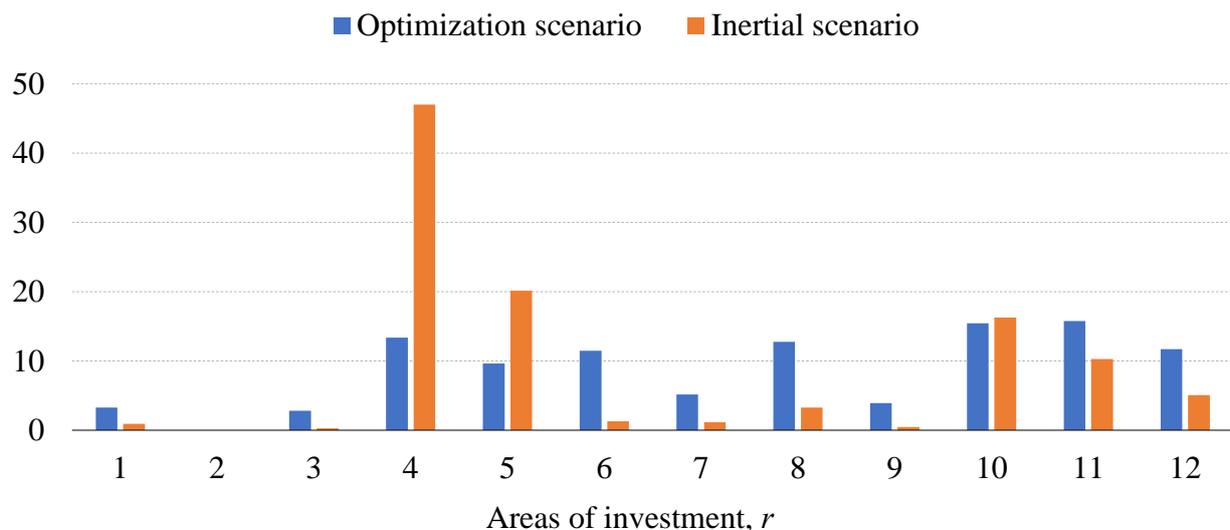
Of note, at least 99% of regional budget funds was developed in each of the 3 years. On the basis of the obtained solution, Figure 6 shows the composition of investments allocated from the regional budget to project activities, by areas of investment and by years.



**Figure 6.** Composition of investments from the regional budget in project activities by areas of investment and by years

Thus, it is recommended that during the 1st year of project implementation, the largest amount of investment from the regional budget is allocated for education (23% of the total investment or about 10 BRUB) and national economy (21% of the total investment 9.5 BRUB); during the 2nd year, investments will be allocated more evenly among projects: it is recommended that 5 BRUB (or 15%) is to allocated to housing and utilities; approximately 5 BRUB (or 15%) to education; 4.5 BRUB (or 14.5%) for social policy; approximately 4 BRUB

(or 14%) to healthcare; a uniform distribution structure is also maintained during the 3rd year. Of note, investments in the national economy are performed only during the first two years. In the future, it is no longer expedient to invest in the national economy in terms of impact on indicators of social and economic development. A similar situation exists for investing in education. Figure 7 shows a comparative graph of the investment structure over 3 years by two scenarios.

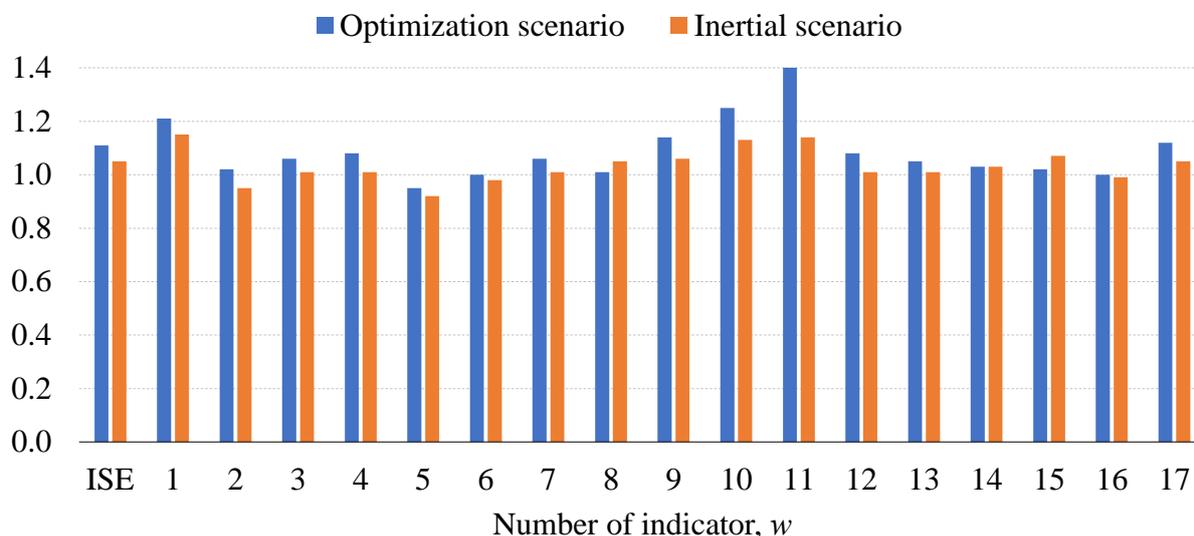


**Figure 7.** Comparative graph of investment volumes under inertial and optimization scenarios, BRUB

By analyzing the data shown in Figure 7, it is observed that the optimization scenario offers a more uniform investment structure. However, in the inertial scenario, the priority investment area is the national economy, to which it is planned to allocate more than 45% of the total regional budget investments over 3 years.

Of note, the comparative analysis of portfolios by two scenarios showed 49% coincidence for the projects included in them.

Figure 8 shows the result of achieving the targets of social and economic development of the Primorsky Region for both optimization and inertial scenarios.



**Figure 8.** Degrees of achievement of indicators of social and economic development of the Primorsky Region under optimization and inertial scenarios

At the final point in time  $t = 3$ , the value of the integrated index in the optimization scenario will be 1.11 (with the initial value of 0.87) and 1.05 in the inertial scenario. Consequently, the target values of the integrated index are achieved in both scenarios; however, the final result is 6 percentage points better in the optimization scenario. Of note, the optimization scenario does not achieve the target value of the social and economic development of the region, specifically in terms of the “consumer price index” (the degree of achievement is 0.95).

In general, it can be concluded that the proposed model is effective. It will improve the targets of the social and economic development by an average of 5% over three years, which is higher than the current dynamics.

## VI. DISCUSSION OF THE RESEARCH FINDINGS ON THE FORMATION OF A REGIONAL PROJECT PORTFOLIO TO ACHIEVE THE TARGETS OF THE REGION'S DEVELOPMENT

The article addresses the issue of the social and economic development of the region owing to the rapid development of the regional human capital. The dynamic model was developed for the formation of an optimal portfolio of regional strategic projects that directly or indirectly affect the development of regional human capital and thus maximize progress towards achieving the strategic targets of the social and economic development of the region.

The model is mainly distinguished by the following:

- 1) consideration of financial resources from federal (as part of implementation of national projects) and regional budgets, company budgets, and part of the population income as investments that directly or indirectly affect the development of regional human capital;

- 2) formation of an optimal portfolio of strategic regional projects that directly or indirectly affect the development of human capital, for which the regional budget serves as the source of funding.

To build functional dependencies (7) and (8), a database was formed that comprised the indicators for the Russian regions for 2011–2018 and expert estimates for the Primorsky Region.

The comparative analysis of the inertial scenario (which used the investment structure reflected in the draft regional budget) and the optimization scenario (in which the investment structure was calculated according to the model) shows that:

- 1) the base vector of redistribution of public resources is the reduction of investments in the “national economy” and “housing and utilities” and a smoother alignment between other investment areas, as shown in Figure 7;

- 2) the optimization scenario demonstrates a more effective progress towards achieving the targets of social and economic development. Of note, in the optimization scenario, the targets of the social and economic development of the region over 3 years are on average 5% higher than those in the inertial scenario.

We should also emphasize the practical relevance of this study

expressed in the formation of an applied tool, which will allow to improve the efficiency of decision-making by regional authorities in terms of inclusion in the regional budget of costs for the implementation of certain strategic projects by taking into account their scarcity and set tasks.

## VII. CONCLUSION

The dynamic model has been developed, which allows to form an optimal portfolio of regional strategic projects that directly or indirectly affect the development of regional human capital. The objective function of the model is an integrated index that takes into account the degrees of achievement of the targets of social and economic development of the region for a given planning period. The model is based on updated functional interrelations of investments that directly or indirectly affect the development of regional human capital → targets of regional human capital → targets of the social and economic development of the region. Optimization is performed using the Boolean variables of the inclusion of a project in a particular investment area at a certain point in time in a project portfolio.

The formation of the optimal portfolio of strategic projects for the Primorsky Region considers the computation aspects of the proposed model. The resulting structure of regional budget investments by investment areas is formed on the basis of a pool of strategic projects. The comparative analysis of the investment structure resulting from the use of the model and reflected in the draft regional budget was performed. The analysis showed a higher efficiency of financial resources expressed in a greater degree of achieving the integrated index and targets of social and economic development for the regional project portfolio formed on the basis of the proposed model.

## ACKNOWLEDGEMENTS

The study was sponsored by the Russian Foundation for Basic Research (RFBR) as part of research project No. 18-010-01010.

## REFERENCES

- [1] Brown AW, Adams JD, Amjad AA. The relationship between human capital and time performance in project management: A path analysis. *International Journal of Project Management*. 2007 Jan 1;25(1):77-89.
- [2] Fleisher B, Li H, Zhao MQ. Human capital, economic growth, and regional inequality in China. *Journal of development economics*. 2010 Jul 1;92(2):215-31.
- [3] Wu B, Liu L. Social capital for rural revitalization in China: A critical evaluation on the government's new countryside programme in Chengdu. *Land Use Policy*. 2020 Feb 1;91:104268.
- [4] Fraumeni BM, He J, Li H, Liu Q. Regional distribution and dynamics of human capital in China 1985–2014. *Journal of Comparative Economics*. 2019 Dec 1;47(4):853-66.
- [5] Melentev BV. Forecasting cash flows based on the inter-regional cross-sectoral models. *Economics and mathematical methods*. 2016;52(3):50-64.
- [6] Kaufmann D, Wang Y. Macroeconomic policies and project performance in the social sectors: A model of human capital production and evidence from LDCs. *World Development*. 1995 May 1;23(5):751-65.
- [7] Medvedev DA. Russia-2024: the strategy of social and economic development. *VOPROSY ECONOMIKI*. 2018;10.
- [8] Federal Law of July 31, 1998 N 145-Ф3 "Budget Code of the Russian Federation" (as amended on April 7, 2020). ATP Consultant Plus. URL: [http://www.consultant.ru/document/cons\\_doc\\_LAW\\_19702/](http://www.consultant.ru/document/cons_doc_LAW_19702/)
- [9] Secundo G, Ndou V, Del Vecchio P, De Pascale G. Sustainable development, intellectual capital and technology policies: A structured literature review and future research agenda. *Technological Forecasting and Social Change*. 2020 Apr 1;153:119917.
- [10] Zhou G, Gong K, Luo S, Xu G. Inclusive finance, human capital and regional economic growth in China. *Sustainability*. 2018 Apr;10(4):1194.
- [11] Das GG, Drine I. Distance from the technology frontier: How could Africa catch-up via socio-institutional factors and human capital?. *Technological Forecasting and Social Change*. 2020 Jan 1;150:119755.
- [12] Government spending: Accounts Chamber of the Russian Federation. 2019. URL: <https://spending.gov.ru/np/>
- [13] Konstantinidi KA. Strategic development of the regional economic system in the context of accelerating post-industrial transformations. Moscow: Sputnik + Publishing House. 2015:247 p.
- [14] Mazelis L, Lavrenyuk K, Krasko A, Krasova E, Emtseva E. Devising a Method to Optimize the Investment Structure Aimed to Achieve Strategic Targets in the Socio-Economic Development of Regions. *Eastern-European Journal of Enterprise Technologies*. 2020 Feb 24;1(3):103.
- [15] Mazelis LS, Emtseva ED, Lavrenyuk KI, Krasko AA. Analysis of regional human capital's development because of investment process. *Azimuth of scientific research: economics and administration*. 2018;3(24):180-184.
- [16] Mazelis LS, Lavrenyuk KI, Krasko AA, Zagudaeva ON. A conceptual model of the regional human capital development. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*. 2018 Nov 14;9(4):477-494.
- [17] Nizamutdinov MM, Oreshnikov VV. Modeling the development of the regional economy. Moscow: Economy. 2017:304 p.
- [18] Klimova NI, Bukharbaeva LY, Franz MV, Shmakova MV. Economic mathematical model for regional development strategy financial support. *Fundamental'nye issledovaniya= Fundamental*

- Research. 2015(10-2):378-83.
- [19] Network publication Information resource SPARK: News agency Interfax. 2020. URL: <http://www.spark-interfax.ru/>
- [20] Łataś R, Walasek D. Intellectual capital within the project management. *Procedia Engineering*. 2016 Jan 1;153:384-91.
- [21] Estrin S, Mickiewicz T, Stephan U. Human capital in social and commercial entrepreneurship. *Journal of Business Venturing*. 2016 Jul 1;31(4):449-67.
- [22] Kozhevnikov SA. Project management as a tool for enhancing the performance of government executive bodies. *Territorial development issues*. 2016;5(35). URL: [http://vtr.vscc.ac.ru/article/2037/full?\\_lang=ru](http://vtr.vscc.ac.ru/article/2037/full?_lang=ru)
- [23] Suspitsyn SA. Proekt SIRENA: ot kontseptsii do tekhnologii [Project SIRENA: From Concept to Technology]. *Region: Ekonomika i Sociologiya*. 2017:25-61.
- [24] Lim SS, Updike RL, Kaldjian AS, Barber RM, Cowling K, York H, Friedman J, Xu R, Whisnant JL, Taylor HJ, Leever AT. Measuring human capital: a systematic analysis of 195 countries and territories, 1990–2016. *The Lancet*. 2018 Oct 6;392(10154):1217-34.
- [25] The Law of the Primorsky Region dated December 19, 2019 No. 666-RL “On the Regional Budget for 2020 and the Planning Period 2021 and 2022” (as amended on March 17, 2020 No. 757-RL). Official website of the Government of the Primorsky Region and executive authorities Primorsky Region. URL: <https://www.primorsky.ru/authorities/executive-agencies/departments/finance/laws.php>
- [26] Misakov VS, Kuyantsev IA, etc. Prediction and assessment of sustainable development opportunities for problem regions. Nalchik: IIPRU of the Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences. 2015:116 p.
- [27] Ivanter VV, Belousov DR, etc. Structural and investment policy as an instrument for modernizing the Russian economy. *Problemy Prognozirovaniya*. 2017;4(163):3-16.
- [28] Xu Y, Li A. The relationship between innovative human capital and interprovincial economic growth based on panel data model and spatial econometrics. *Journal of Computational and Applied Mathematics*. 2020 Feb 1;365:112381.