# PUBLIC MANAGEMENT OF REGIONAL DEVELOPMENT IN THE CONDITIONS OF THE INCLUSIVE ECONOMY FORMATION

**Olha Popelo, Chernihiv Polytechnic National University**
**Svitlana Tulchynska, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"**
**Viktoriia Marhasova, Chernihiv Polytechnic National University**
**Olga Garafonova, Kyiv National Economic University named after Vadym Hetman**
**Yuliia Kharchenko, Chernihiv Polytechnic National University**

## ABSTRACT

*Within the study, it is proposed to determine the impact of public administration of regional development in the inclusive economy formation using the L. Pontryagin maximum principle. To assess the impact of public administration on regional development in the formation of inclusive economy, it is proposed to use the L. Pontryagin maximum principle, as this approach allows to optimize the target function, and at the same time to find optimal functions of regional development management abandon complex methods of solving the problem; to ensure the proof of the dynamic programming method through linear approximation of optimal management of regional development.*

*It is proposed to visualize optimal values of the integral indices of the modules functioning using attractors. Optimal values of socio-economic development of regions are the position of entering the attractor trajectory in a closed cycle in a certain period, which is considered from the standpoint of the at-tractor stabilization from the variant set of phase trajectories of socio-economic development of the region. The proposed use of the L. Pontryagin maximum principle on the example of the regions of Ukraine has been tested.*

**Keywords:** Public administration; Management; Region, Regional development, Inclusive economy.

## INTRODUCTION

Public management of regional development, as evidenced by the practice of many countries, is now viewed from the perspective of inclusive development and economic growth. The inclusive direction of regional development is aimed at:

- Involvement in the economic reproduction of regional economic systems of each of its subjects with non-discrimination;
- Humanization of regional economic growth processes due to the cohesion of everyone in the direction of solving regional development problems;

- Investing in human potential and ensuring social protection of all segments of population;
- Fair distribution and redistribution of economic development results between regional actors;
- Ensuring productive employment in the regions;
- Intensification of public participation and consideration in management decisions at the regional and local levels;
- Development and implementation of strategic multi-channel, multi-vector directions to ensure effective public administration of inclusive development.

It should be noted that despite the fact that there are many different methodological approaches to assessing the inclusion of economic development, today there are insufficiently developed approaches to determining the impact of public administration of regional development in the inclusive economy formation.

## LITERATURE REVIEW

Foreign and domestic scholars have devoted a lot of research to the study of the mechanisms of public administration in various spheres of activity, features of management of regional development and issues of inclusive economy, among which it should be noted (Ljungholm, 2017; Salbaroli, 2018; Skica, 2018; Wu, 2018; Yin, 2018; Becerra, 2019; De Leon, 2019; Krasniqi, 2019; Kraynyuk, 2020; Shkarlet, 2020; Shynkaruk, 2020; Dergaliuk, 2021).

According to the results (Kraynyuk et al., 2020) the analysis conducted among the world's leading countries on the statistics of tourist visits, the main approaches to building public administration systems for the tourism industry development in the regions were identified. The document (Bouckaert, 2019) is devoted to the organization of knowledge about the public sector functioning. This knowledge is accumulated and scientifically organized in the public administration field. The article (Wu, 2018) outlines the functional mechanism of participation of government microblogs in public administration.The article by Romanian scholar (Ljungholm, 2017) is based on research on the transnational mechanisms development for the establishment of policy and administrative procedures, institutional interests of public sector actors, and mechanisms for the development and change of transnational governments.

The aim of the study (Krasnigi, 2019) is to develop a strategic model of regional economic development in Kosovo, which will have a positive impact on both business environment and overall development of the country through coordinated project management and synergies between communities, business and local authorities. The author (Yin, 2020) used the spatial econometric modeling to optimize nonlinear characteristics that affect economic development of regions to further obtain the initial data for the management of regional economic development. The scientist (De Leon, 2019) argues that public administration systematically monitors and improves public capacity and practice to make policies, decisions and to implement them, and to ensure the desired results. Spanish researchers (Salbaroli, 2018) note that a few years ago, the Emilia-Romagna region launched three regional data centers to provide services to local public administrations for reuse and cost-effectiveness. The authors (Becerra et al., 2020) from Argentina argue that the circular has great potential both in terms of its contribution to the creation of new interpretation systems and in terms of developing local and

inclusive development strategies when integrated with joint activities, bottom and innovative dynamics.

## MATERIALS AND METHODS

Since one of the directions of inclusive development is to increase living standards of population, including by reducing the asymmetry of regional development, in the opinion of the authors, the basis for assessing public administration of regional development in inclusive economy should be socio-economic development.

To assess the impact of public administration on regional development in the inclusive economy formation, in the opinion of the authors, it is appropriate to use the L. Pontryagin maximum principle, as this approach allows:

- To ensure the optimization of the target function and at the same time to find optimal functions of regional development management in the inclusive economy formation;
- To abandon complex methods of solving the problem;
- To ensure the proof of the dynamic programming method through linear approximation of optimal management of regional development.

In the public administration model of regional development within the inclusive economy formation there are common goals, which are reproduced in the presence of phase variables of the form $x(t) = (x1, \ldots, xn)$ and the functional L (x, u), which must be minimized.

The phase variables in differential equations of the model of the regional development management in the conditions of the inclusive economy formation are normalized partial indicators, which change over time.

Functionality L - is the minimization of the difference in the values of integrated indicators of the modules of reproduction, distribution and social functions, as well as the complex integrated index of the module of functions of socio-economic development of the region as a whole.

In the model of determining the impact of public administration of regional development in the inclusive economy formation, a subject to minimization is:

- Crisis state of regions in the conditions of the inclusive economy formation;
- State of centralized regional management;
- Imbalance in economy and management of regional economic entities;
- Negative impact on the ecosystem and in particular, environmental pollution.

In the model of determining the impact of public administration of regional development in the inclusive economy formation, these functions form a vector parameter of regional development management $u = (u1, \ldots, ur)$ from a given set of variable management functions U socio-economic development of regions in the inclusive economy formation.

Suppose that there is a macroeconomic model of regional development management in the inclusive economy formation, the model - socio-economic development of regions in the inclusive economy formation in the form of a differential equations system:

$$\begin{pmatrix} \frac{d_{X_1}}{d_t} = f_1(x_1, \dots x_n; u_1, \dots u_r, t) \\ \frac{d_{X_n}}{d_t} = f_n(x_1, \dots x_n; u_1, \dots u_r, t) \\ x_1(t_0) = x_1^0, \dots x_n(t_0) = x_n^0 \end{pmatrix} \qquad (1)$$

Where $\frac{d_{X_i}}{d_t}$ $i = 1, \dots, n$ - derivatives of the components of the phase variables (normalized partial indicators of socio-economic development of regional economic systems) model $x(t) = (x1, \dots, xn)$ by time t in the first system (see formula 1);

$fi\ (x,\ u,\ t), i = 1, \dots, n$ – continuously differentiated functions by phase variables are constructed $x = (x1, \dots, xn)$ and by the vector-parameter of state management of regional development $u = (u1, \dots, ur)$ from a given set of variable control functions U (integrated indices of modules of reproductive, distributive and social functions and complex integrated index of the functional module of socio-economic development of regions in the inclusive economy formation.

As a result of solving the differential equations system, we obtain optimal values of indicators of indices of functional modules and a complex integrated index of a functional module of regional state administration in the inclusive economy formation, which can predict partial indicators of socio-economic development of regions under the influence of public administration.

Under these conditions of the problem for modeling the impact it is necessary to translate the first system of differential equations, which is presented in the form of a formula (1) for a fixed time T from the initial state $x0 = (x10, \dots, xn0)$ to such a state $x(T) = (x1(T), \dots, xn(T))$, in which the functional has the following form:

$$L = c_1 x_1(T) + c_2 x_2(T) + \cdots + c_n x_n(T) + \int t_0 T f_0(x_1, x_2, \dots x_n; u_1, u_2, \dots, u_\tau, \tau) d\tau \quad (2)$$

Where $f0(x1, x2, \dots, xn;\ u1, u2, \dots, u\tau, \tau)$ - initial continuously differentiated function for selected phase variables $x = (x1, \dots, xn)$;

$u = (u1, \dots, u\tau)$ - function on the vector-parameter of management from a given set of variables U in the process of public administration of regional development in the inclusive economy formation;

t0 – T – limits of integration to find the optimal set of values of functionalities (integral indices of modules of reproductive, distributive and social functions and complex integral index of module of functionality of regions in the inclusive economy formation), at which the system enters the stabilization mode system of differential equations $((u0(t) = (u10(t), u20(t), \dots, u\tau0(\tau)),)$ from the set U and the corresponding optimal trajectory of socio-economic development of regions in the inclusive economy formation (input in this trajectory corresponds to the time of the stabilization regime of socio-economic development of the regions).

The attractor is a set of closed trajectories of integral indices of modules of regional development management functions in the conditions of the inclusive economy formation at bifurcation of solutions of the differential equations system.

The content of minimizing the functional L is to reduce the difference between the values of integrated indicators of modules of reproductive, distributive and social functions, as well as the complex integrated index of the module of socio-economic development of the region as a whole due to predicted phase variables.

In our case, the solution of the differential equations system by the L. Pontryagin's maximum principle is based on the application of the Hamilton function, namely: $\partial$

$$\frac{d\psi_i}{dt} = \frac{\partial H}{\partial x} = -grad_x H, i = 1, \dots n; \frac{d\psi_i}{dt}(T) = -c_i \qquad (3)$$

where H$= \Sigma \psi k\,(T)\,fk\,(x1, x2, \dots, xn;\ u1, u2, \dots, ur,$
t – Hamilton function, $k = 0, \dots, n,$
$\psi 0(t) = -1$. Time dependent functions x, u, ψ.

The authors propose to perform calculations of the model for determining the impact of public administration of regional development in the conditions of the inclusive economy formation using the Mathcad-15 software. To obtain high accuracy of solving the differential equations system, it is proposed to use the Runge-Kutta method of the 4th order, which allows to obtain the most accurate calculations, which is very important in determining the impact of regional development management in inclusive economy.

The model for determining the impact of public administration of regional development in the inclusive economy formations, which is presented in the form of formula (1), in this case, as a result of the substitution of specific functions have the following form:

$$F(t,f) = \begin{pmatrix} f_1 \left[ a - a(f_1 + f_2 + f_3 - k) - \frac{\sin(f_2)}{f_1 + b} \right] \\ (f_2) . \left( c + \frac{f_1}{f_1 + b} - \frac{f_3}{\sin(f_2) + b} \right) \\ f_3 \left( d + \frac{f_2}{\sin(f_2) + b} \right) \end{pmatrix} \qquad (4)$$

Where f1, f2, f3 - respectively, continuously differentiated functions by phase variables are constructed, namely reproductive, distributive and social functions;

k - complex integrated index of functionalities of state management of regional development in the conditions of the inclusive economy formation;

a, c, d – coefficients of differences of the values of integrated indices of modules of reproductive, distributive and social functions concerning values of indices of social and economic development of the region with the highest rank.

$$a = \frac{(I_{rf\,avg\,j} - I_{rf\,avg\,1})p}{l}, c = \frac{(I_{df\,avg\,j} - I_{df\,avg\,1})p}{l}, d = \frac{(I_{sfcp\,j} - I_{sfcp1})p}{l} \qquad (5)$$

Where Irf avg 1, Idfcp 1, Isf avg 1 – the average value of the integrated index of the module of reproductive, distributive and social functions of the region;

Irf avg j, Idf avg j, Isf avg j – the average value of the integral index of the module of reproductive, distributive and social functions of the studied j-th region;

l – rank of the region by the value of integrated indices;

p – step of integrating the optimization function over time;

$b = k \cdot p,$

α – step of integrating the values of the optimization function L.

Thus, the proposed methodological approach using the L. Pontryagin maximum principle on the basis of calculations of integrated indices of modules of functionalities of public administration of regional development in the inclusive economy formation to assess their impact on socio-economic development of regions is specified.

## RESULTS

By the approbation of the proposed approach to determine the impact of public administration of regional development in the inclusive economy formation, the authors selected the regions of Ukraine and carried it out through using the Mathcad-15 software. The basis for the calculations was a system of macroeconomic indicators, which were grouped in relation to the assessment of the module of social, reproductive and distributive functions of the impact of public administration of regional development in the inclusive economy formation.

By determining the impact of public administration on regional development in the inclusive economy formation using the L. Pontryagin maximum principle, which was tested by the authors in Chernihiv region, which ranks 17th in terms of the value of the complex integrated index of the module of public administration functions of regional development in inclusive economy. In Table 1, the results of solving the differential equations system on the L. Pontryagin maximum principle until 2034 for Chernihiv region are presented.
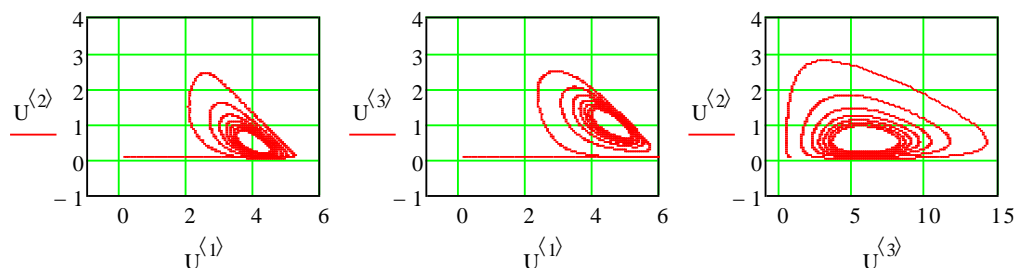
**TABLE 1**
**THE VALUE OF THE MODULE OF FUNCTIONALITIES OF STATE MANAGEMENT OF REGIONAL DEVELOPMENT IN THE CONDITIONS OF THE INCLUSIVE ECONOMY FORMATION FOR CHERNIHIV REGION ACCORDING TO THE SOLUTION OF THE DIFFERENTIAL EQUATIONS SYSTEM FOR 2021-2034**

| Years | The value of the functionalities module of state management of regional development in the conditions of the inclusive economy formation by solutions of the differential equations system under the L. Pontryagin maximum principle | | |
|---|---|---|---|
| | Reproductive function | Distribution function | Social function |
| 2021 | 0,129 | 0,156 | 0,102 |
| 2022 | 0,257 | 0,235 | 0,100 |
| 2023 | 0,385 | 0,353 | 0,099 |
| 2024 | 0,513 | 0,524 | 0,098 |
| 2025 | 0,642 | 0,765 | 0,096 |
| 2026 | 0,770 | 1,093 | 0,095 |
| 2027 | 0,898 | 1,517 | 0,095 |
| 2028 | 1,026 | 2,417 | 0,093 |
| 2029 | 1,155 | 2,596 | 0,092 |
| 2030 | 1,283 | 3,176 | 0,091 |
| 2031 | 1,411 | 3,715 | 0,090 |
| 2032 | 1,539 | 4,176 | 0,088 |
| 2033 | 1,668 | 4,541 | 0,087 |
| 2034 | 1,796 | 4,814 | 0,086 |

Source: calculated by the authors by formula (4).

The calculated values of integral modules of functions of state management of regional development in the conditions of the inclusive economy formation for Chernihiv region by solving the differential equations system under the L. Pontryagin maximum principle make it possible to determine optimal values of integral indices of function modules by visualizing their attractors.

The optimal values are the position of the trajectory of the attractor in a closed cycle in a certain period of time, which is considered the point of stabilization of the attractor from the variant set of phase trajectories of socio-economic development of the region. In Fig. 1, the attractors obtained as a result of solving the differential equations system according to the L. Pontryagin maximum principle for the integral indices of the modules of the reproduction (U⟨1⟩), distribution (U⟨2⟩) and social (U⟨3⟩) functions for public administration of regional development in the conditions of the inclusive economy formation are shown.

In Fig. 1 on the ordinate axis the values of the functionals of reproductive (U⟨1⟩), distributive (U⟨2⟩) and social (U⟨3⟩) functions of state management of regional development in the conditions of the inclusive economy formation are plotted, on the abscissa axis - time period, in our case - years, where 1 corresponds to 2021; 2 - 2022, and so on (a - attractor of reproductive (U⟨1⟩); b - distribution (U⟨2⟩); in - social (U⟨3⟩) functions of state management of regional development in the conditions of the inclusive economy formation).



**FIGURE 1**

**ATTRACTORS OF INTEGRATED INDICES OF MODULES OF FUNCTIONALITIES OF STATE MANAGEMENT OF REGIONAL DEVELOPMENT IN THE CONDITIONS OF THE INCLUSIVE ECONOMY FORMATION FOR CHERNIHIV REGION**

Visualization of attractors of modules of functions of state management of regional development in the conditions of the inclusive economy formation gives the chance to state that they do not contain gaps and have closed cycles that, in turn, gives the chance to define points of optimum values of modules of functionals of reproductive, distributive and social functions. According to the obtained attractors, the stabilization points for all functionals are different.

**CONCLUSIONS**

Public management of regional development in inclusive economy should be based on the fact that each entity must be able to fully meet their needs and is important, meaningful and

valuable to society. Inclusive development should help reduce the asymmetry of regional development and increase incomes of all segments of population.

The scientific novelty of this study is the rationale for using the L. Pontryagin maximum principle to determine the impact of public administration on regional development in inclusive economy, based on the application of Hamilton's function to simplify finding solutions of differential equations and simultaneous use of the Runge-Kutta 4 -th order method to obtain high accuracy of solutions, as well as to determine optimal values of the integrated indices of the modules of public administration functions by visualizing their attractors.

The use of the L. Pontryagin's maximum principle is of practical importance because it allows: first, to consider the objective functions taking into account the influence of control, in contrast to such methods as gradient methods, linear and nonlinear programming, methods with factors; secondly, to simplify the solution of the problem in contrast to such methods as integro-differential equations, nonlinear dynamics, generalization of functions from functional spaces, etc.; thirdly, it makes it possible to approximate optimal management of regional development.

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