Visualization of the regional migration dynamic and change of models of sustainable development

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Abstract. In the context of heterogeneous dynamics, the issues of spatial contraction or transformation of territories acquire special importance in solving regional problems of sustainable development. The construction of the models of transformation is considered on the example of studying migration dynamics and the specifics of the outflow of population from the Chelyabinsk region, one of the leading industrially developed territorial formations of the Urals. A multilevel analysis of the migration balance values is associated with updating a number of methodological foundations of the study of regional dynamics and the adaptation of visualization tools - the use of graphic information. Based on the results of the classification of the territories, along with the growth and contraction models, it is proposed to form a certain intermediate class of "spatial reconstruction" models.

1 Introduction

Recently, in the context of a variety of economic, social and environmental changes, the number of issues related to sustainable development is increasing significantly. The issue of sustainable development for socio-economic systems is traditionally associated with growth problems and is based on the obvious statement - a closed system with limited resources cannot grow indefinitely. The sustainability of the historically inherited development trajectory is traditionally associated with the limits of growth. The limits of the growth of systems are due to the limited main resources of the life support. (D. H. Meadows, D. L. Meadows et al. The Limiting to Growth N. Y. Potomac (1974)). Requirements to meet needs without compromising the ability of the future generations are also considered (Commission on Environment and Development (Our Common Future. UN, N.Y., (1987)).

However, at the regional level, despite the global problems of growth (extensive development), there are often problems of contraction - a heterogeneous spatial transformation. Spatial socio - economic contraction (hereinafter compression) for regional systems is seen as an opposite of the growth. In a heterogeneous space, the development trajectory of regional complex multi-level systems depends on two components. The first is a component of growth (multidirectional, predominantly extensive growth - expansion of

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the system). The second is the constituent of contraction (transformation - partial contraction and asymmetric growth).

Growth in socio-economic systems has traditionally been associated with an increase in population. It is within the framework of the concept of population growth that scenarios and trajectories of sustainable global development and conditions for balancing the main parameters are considered. For such growth scenarios, systems of indicators of the regional level, balanced in terms of the main parameters, are formed and further development forecasts [1], [2].

Recently, in a number of regions of Russia, local regional stable trends in population decline have been increasingly noticeable. These trends are largely determined not by demographic factors, factors of migration. Regardless of the reasons, such trends determine the development prospects of many territories. For such territories, scenarios of "partial contraction and asymmetric growth" are inevitable, with special requirements for development models.

Considering a region as a complex heterogeneous socio-economic system with an outflow of population, a number of foundations of the study of regional sustainable development inevitably change. In such conditions, a number of key methodological provisions and priorities of sustainable development models are inevitably updated. At the same time, the research instruments inevitably change. Such changes are considered in the article on the example of the study of the Chelyabinsk region, the leading industrially developed regional formation of the Urals with many heterogeneous urban districts and municipal districts.

2 Materials and Methods

Traditionally, solving problems of regional sustainable development is associated with considering various aspects of sustainability and the interaction of many, social, environmental and economic factors. For complex heterogeneous regional socio-economic systems with problematic population dynamics, key aspects of research on sustainable development are changing. A detailed study of the processes of limited spatial contraction becomes fundamental. This conceptual change means a transition from multidimensional models of general multidirectional development - growth to more complex models of limited asymmetric contraction - transformation.

With such a change in models, first of all, the system of restrictions and development priorities changes fundamentally. In contrast to the limits of the growth (restrictions on the growth of consumption of limited resources), *the limits of disproportionate contraction* are considered. They indicate the boundaries of the fall in *the values of the parameters before the transition of the system to the zone of loss of stability (bifurcation)*. In this case, bifurcation means the loss of proportions of balance between the main socio - economic parameters.

As we approach the limits of growth, socioeconomic dynamics inevitably slows down. Under the conditions of contraction, during the transition to the bifurcation zone with the destruction of socio - economic proportions, the dynamics of the fall can significantly accelerate. For example, in the event of a significant increase in migration and a rapid decline in the population, the problem of maintaining excess social facilities may sharply aggravate (up to their elimination with a sharp drop in the quality of life indicators).

In this case, it is inevitable to determine the limits of the fall (as opposed to the limit of growth) - the level of residual balanced functioning of the system. Such a development of systems is associated with the study of complex nonlinear dependencies and reaching some equilibrium states in the framework of the study of nonlinear dynamics [3]. In the study of such processes, the interdisciplinary foundations of the development of non-equilibrium

structures are important within the framework of the "philosophy of instability" by I.Prigogin (L.N. Vasil'eva Sociological Research, 6, 28-37 (2009)).

Models of sustainable development in relatively limited regions inevitably differ from models of larger-scale global systems. In turn, for a complex heterogeneous regional system, the development models of individual components of the territory will differ significantly. The change in dynamics from the inflow to the outflow of the population presupposes a change in sustainable development models. Different classes of models will differ significantly in terms of constraints, priorities, and requirements for balancing the main socio-economic parameters. The variety of possible spatial transformations increases with the use of several types of models.

The development models of individual territories of complex heterogeneous regional systems are fundamentally different. In the context of such a variety, the choice of a model is determined within the framework of *the classification of territories by the difference in key defining trends in regional dynamics*. The basis for the classification is associated with the adaptation of a number of aspects of the systemic for the analysis of the development of territories (with consideration of: the variability of trends in the outflow of the population, nonlinearity of patterns, lack of information, etc.).

Significant differences in trends of the population dynamics, and the conditions under consideration, predetermine the classification of territories. The nature of the dynamics of the inflow - outflow of the population is becoming one of the key features that determine the classification of territories. The difference between inflow and outflow (hereinafter the migration balance) considered below is one of the most significant factors determining the change in population size. Also, this indicator is the most striking indicator of the well-being and social attractiveness of the territory.

The considered operations of analysis and classification are associated with the adaptation of visualization tools and the expansion of the scope of information technology. Visualization involves the use of problem-oriented technologies for the formation of graphic information in special formats, based on the corresponding digital characteristics (estimates). Aggregation of heterogeneous information and visualization provide the formation of problem-oriented analytical graphic models (with a detailed examination of combined graphic-digital analytical models). Such graphic models at different levels of abstraction characterize the regional system as a set of territorial objects. Such models better than traditional digital models reflect not fully formalized patterns. A similar visualization of the characteristics of territories increases the information content of classical digital assessments.

For the considered transformation models, the emergence of trends of nonlinear recession and bifurcation presupposes a transition to a two-dimensional assessment of the migration balance. An estimate of the rate of change of the function itself (the derivative in the concept of differential calculus) is added to the usual estimate of the linear function of the dynamics of migration. The two levels of assessment are as follows:

• The first level is an assessment of the current migration of territories (characteristics of the functions of the dynamics of migration by territories), comparison of trends relative to each other and median values.

• The second level - assessment of the rate of change in migration of territories (characteristic of nonlinearity, variability of functions across territories: acceleration, deceleration), the rate of change in migration dynamics at a given point of the trajectory.

Such two groups of assessments are formed within the framework of the corresponding problem-oriented algorithms for ranking the entire aggregate of territories. The generalizing assessment of characteristics according to the two considered criteria is the basis for the classification of territories.

Carrying out a study on the classification of territories of a heterogeneous regional system imposes additional requirements for organizing a multi-stage analysis procedure. The organization of such a problem-oriented procedure presupposes a gradual update of the analysis procedure within the framework of the "soft systems" methodology - the application of systems thinking to non-systematic situations [5]. In this methodology, the specificity of the analysis procedure is largely determined both by the primary characteristics of the territories under consideration, and by intermediate results, which make it possible to promptly correct the subsequent stages of the study. The variety of options for the analysis and classification procedure for complex regional systems is great. However, they are similar in many ways. Below is the use of the considered foundations and the corresponding visualization tools on the example of studying the dynamics of population migration in a set of urban districts and municipal districts of the Chelyabinsk region.

3 Results

Studies of spatial socio - economic contraction on the dynamics of population migration are implemented in several successive stages. To classify the territories of the Chelyabinsk region, four main stages of analysis should be distinguished:

1. Determination of key characteristics of migration dynamics: identification of recession and turning points, assessment of trends along the trajectory of the most important territories.

2. Analysis of the current values of the balance of migration by territories.

3. Analysis of the variability (current increments) of the migration balance (rate of change across territories: acceleration, deceleration).

4. Generalizing classification of a heterogeneous set of territories based on a two-dimensional assessment of the dynamics (the value and variability of the migration balance).

Due to the heterogeneity of regional systems, the complexity of the main regularities, the most significant results for the stage are further presented in a graphical format.

Stage 1. Determination of the key characteristics of migration processes on the trajectory of the dynamics of migration of the largest cities in the region, identification of the dynamics of decline and turning points, assessment of trends.

The change in trends in the migration balance from growth to decline is largely individual for territories. Such changes are identified by the obvious signs of a "reversal" of trends when analyzing problem-oriented graphs of migration dynamics.

Such cities are traditional centers of "attraction" of the population. They largely determine regional dynamics.

Figure 1 shows the dynamics of the migration balance of the five largest cities of the Chelyabinsk region: Chelyabinsk, Magnitogorsk, Zlatoust, Miass, Kopeysk (as a percentage of their number, hereinafter Rosstat data). The thickness of the time series lines is proportional to the population of cities in 2018. Points of abrupt change (break) of trends in population outflow are highlighted. The emergence of negative migration trends in the leading territories is the first of the prerequisites for the transition to models of limited asymmetric compression - transformation.
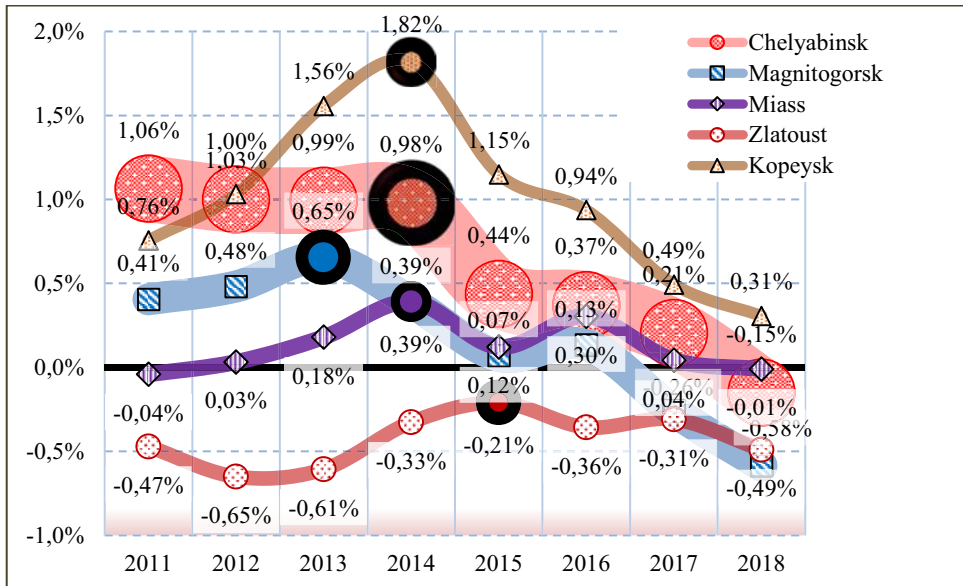
Fig. 1. Identification of turning points of the trajectory of migration dynamics: inflow (outflow) of the population of the largest cities of the Chelyabinsk region (% of the population).
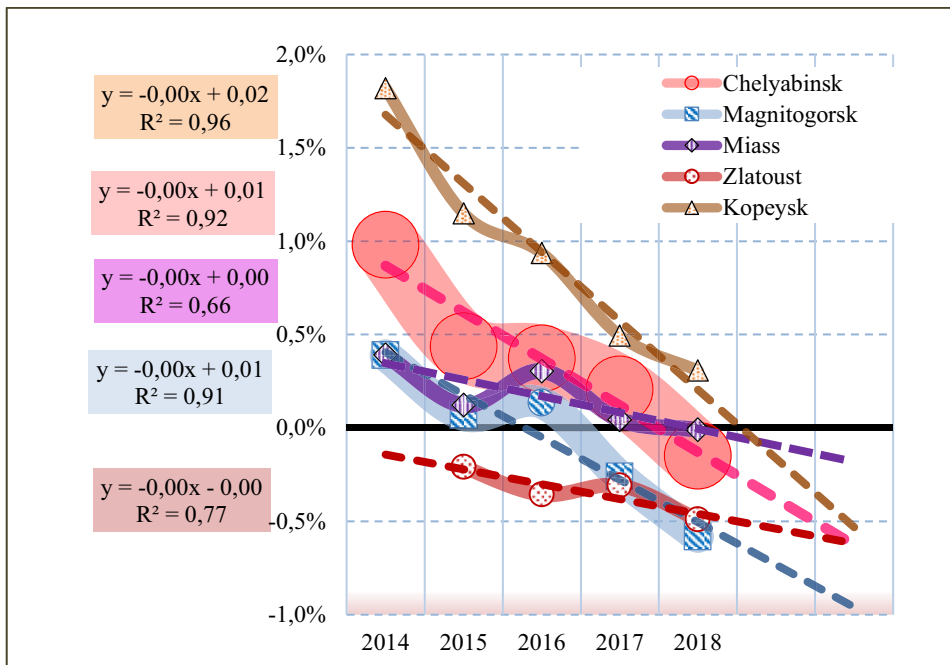

Fig. 2. Formation of negative trends in the dynamics of migration of the largest cities: migration balance (% of the population) and trends after the turn of the trajectory.

Stage 2. Analysis of the current values of the balance of migration by territories makes it possible to characterize the differences in the current dynamics of migration across the entire set of municipalities (based on the values of 2018). The distribution of territories after ranking according to the size of the migration balance is shown in the diagram (Fig. 3).
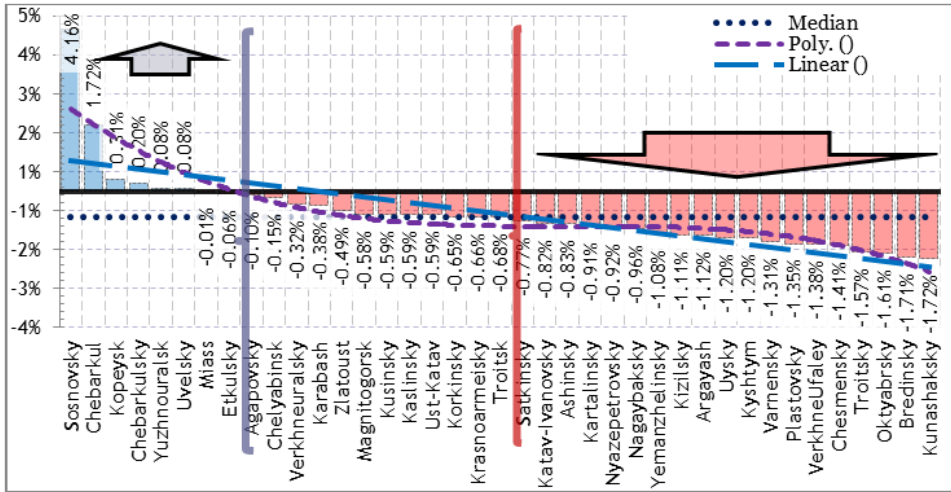
Fig. 3. The scale of migration: the distribution of territories by the criterion of the size of the current migration balance, approximation of the distribution (linear and polynomial 3 degrees), signs of classification of municipalities into three non-uniform groups.
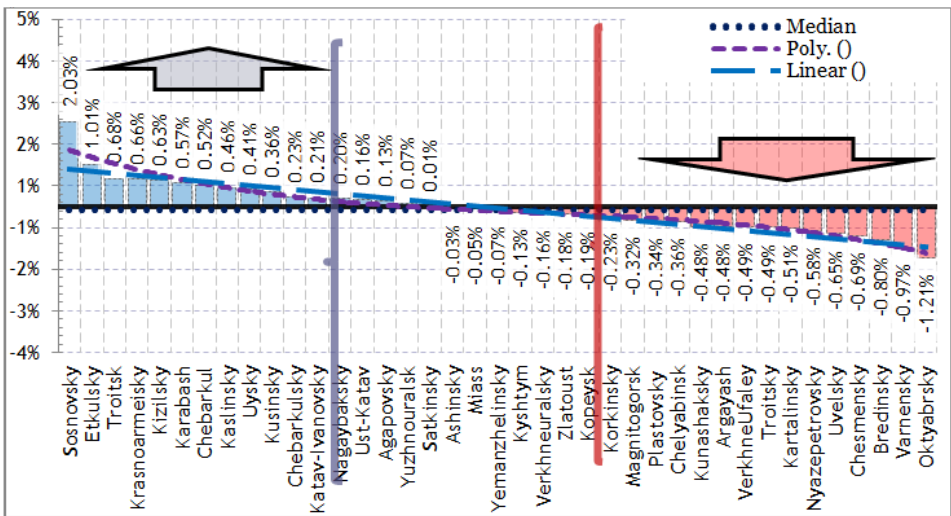

Fig. 4. Variability of migration: the distribution of territories according to the criterion of the increment of the balance of migration, linear approximation of the distribution, signs of classification of municipalities into three groups.

Most of the migration balance values are in the negative zone. Note the nonlinearity and asymmetry of the distribution of values (for analysis: the diagram shows approximations of the distribution: linear and polynomial 3 degrees). The division of territories into groups according to the criterion of inflow - outflow of the population is considered relative to the median ("middle" in the distribution). The noted specificity predetermines the basis for dividing many territories into three groups. Among them:

• Favorable group of territories (the balance is above or near zero with the growth or stabilization of the population size).

• A relatively neutral group of territories with limited negative consequences of migration (negative balance from zero to median with a limited decline in population).

• Problem group of territories with significant migration (negative balance below the median).

Obviously, with such a distribution, half of the territories are problematic. The group boundaries are marked on the diagram. Arrows indicate the direction of change. This distribution reflects the problems of the current regional situation.
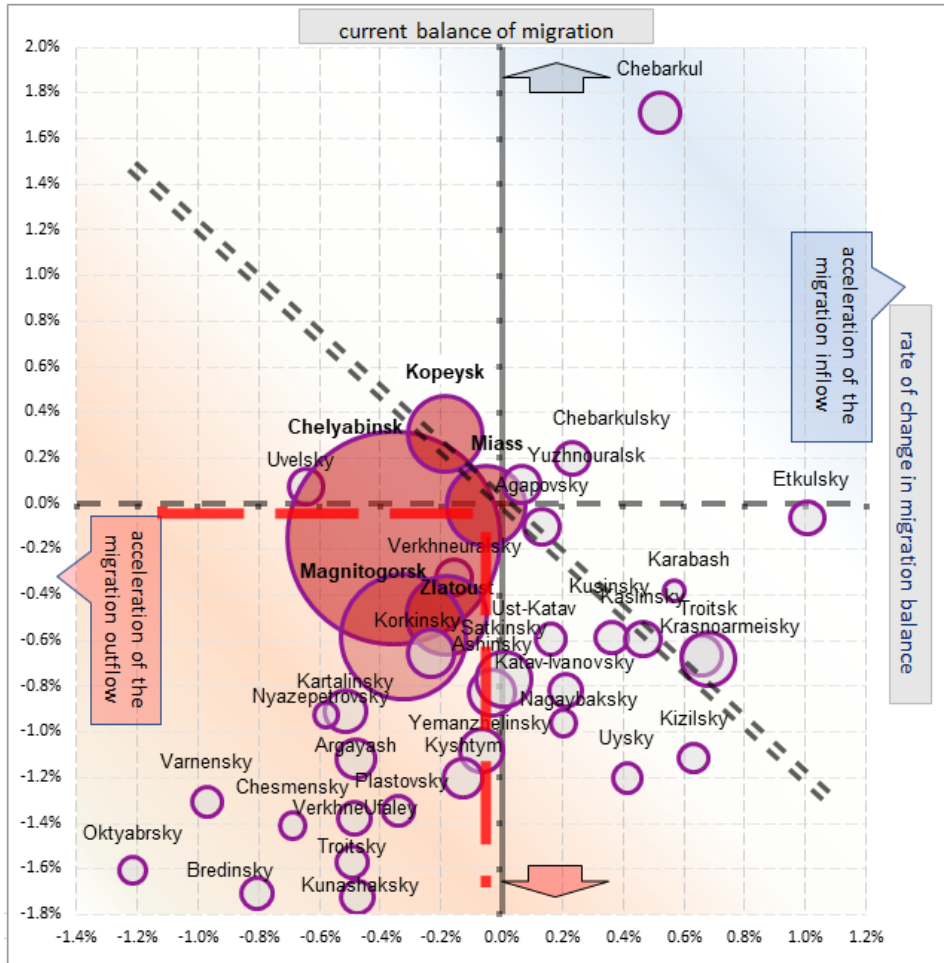

Fig. 5. Generalizing classification of territories by a two-dimensional assessment of migration dynamics (by the value and rate of change in the balance of migration) with the allocation of individual groups of territories.

Stage 3. Analysis of the variability (current increments) of the rate of change in the balance of migration (acceleration, deceleration) across territories provides a more accurate description of the observed processes. The ranking of all territories according to the criterion according to the rate of change (the increase in the migration balance in 2018) is shown in Fig. 4. An analysis of the distribution by the rate of change similar to the previous one allows us to distinguish three comparatively:

• areas for improving dynamics,

• maintaining current trends (near zero trends 0.1% -0.2%),

• areas of deterioration in dynamics

The presented distribution over the dynamics of changes is much more homogeneous than the previous one. However, significant negative migration trends indicate the trends of a rapid withdrawal of the territory into the "compression" zone. Further, there will be risks of irreversible social and economic consequences. Separately, it should be noted that none of the five largest cities under consideration fell into the group of territories with improving dynamics. This indicates significant latent regional problems.

Stage 4. Generalizing classification of a set of territories of various scales integrates the results of the previous stages. A two-dimensional assessment of the dynamics (by the value and rate of change in the migration balance) is shown in Fig. 5. The diagram shows the migration process in terms of "current state - nature of changes". The dynamics is presented in relation to the population size by territory. In a two-dimensional diagram, the area of the elements is proportional to the population. The position relative to the axes reflects the parameters of the dynamics of migration. Positive values of the parameters indicate that the territory belongs to the growth group. Negative negative values of the parameters indicate that the territory belongs to the group of spatial contraction.

The diagram highlights the problem area for the territory with negative values of the deteriorating balance of migration (lower left quadrant). Most of the territories of the Chelyabinsk Region, including the largest cities, fall into such a problem zone. The group of the largest cities is additionally highlighted with a fill. The neutral zone (in terms of two criteria) is placed relative to the diagonal.

The integration of the information in the diagram provides the basis for the subsequent multivariate analysis and classification of territories. This is followed by the choice of a particular model of sustainable development, determination of the necessary parameters and priorities.

4 Conclusion

The specificity of the development of the Chelyabinsk region largely determines both the problems of regional migration dynamics and the severity of contradictions. The results of the study of the characteristics of the heterogeneous dynamics of the inflow and outflow of the population of municipal districts and urban districts of the Chelyabinsk region make it possible to update the foundations of effective sustainable development for such regional systems.

According to the results of the generalizing classification, it is obvious that along with growth models and compression models for a significant number of territories, it is necessary to consider a certain intermediate class of models. These are to be defined as "spatial reconstruction" models. Scenarios of "spatial reconstruction" are obvious: both for the overwhelming number of small municipalities of the Chelyabinsk region and for the largest cities. All these territories, according to the results of the classification, turned out to be in a problem or border zone. Thus, sustainable development of regional systems with problematic dynamics must be considered within the framework of an interconnected system of three classes of spatial development models. Such differentiation opens up new opportunities for solving the problems of long-term spatial development.

The emergence of several classes of models makes it possible to expand the possibilities of studying the prospects for sustainable development. Within the framework of spatial reconstruction models (contradictory asymmetric transformations), there are more opportunities for a detailed study of many factors that were previously left out of consideration. Among them: the problems of path dependence [7] and changes in the previous trajectory [7], changes in territorial relationships in the center-periphery format

[8], changes in the spatial structure with the growth of mobility and agglomeration processes [9].

Further, the possibilities of practical use of the research results are related to the detailing of the spatial development priorities and the goals of transforming the urban environment. The adjustment of the priorities and goals of sustainable development is inevitably reflected in many aspects of further zoning. Additional prospects are associated with resolving the issues of synergy of design solutions (primarily infrastructural) and an increase in the quality of life of the population.

The main regularities of spatial transformation and elements of the tools used, considered in the study, are in many respects universal. They are easily adaptable for the study of many heterogeneous regional systems with a complex structure and contradictory internal dynamics of the components. Testing the new toolkit further contributes to expanding the boundaries of research. This adds qualitatively new directions in the study of the dynamics and stability of interrelated processes (social, environmental and economic). Such applied research is associated with the further development of proven technologies for multivariate analysis using visualization tools.

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References

1. B.N. Porfiryev, S.N. Bobylev, Studies on Russian Economic Development **2**, 116-123 (2018) DOI: https://doi.org/10.1134/S1075700718020119

2. S.N. Bobylev, S.V. Solovyeva, Studies on Russian Economic Development **28**, 259-265, (2017) DOI: 10.1134/S1075700717030054

3. I.L. Remco, Nonlinear Dynamics **59**, 173 (2010) DOI: 10.1007/s11071-009-9530-z

4. O.A. Kozlova, M.N. Makarova, The economy of the region **16(1)**, 84-96 (2020) DOI: https://doi.org/10.17059/2020-1-7

5. P. Checkland, Systems Research and Behavioral Science **17** (2000) DOI:10.1002/1099-1743(200011)17

6. A. Kwamie, H. Dijk, E. Ansah, I. Health Policy and Planning **31(3)**, 356-366 (2016) DOI:10.1093/heapol/czv069

7. S.N. Rastvortseva, Russian journal of economic theory **15**, 633-642 (2018) DOI: http://dx.doi.org/10.31063/2073-6517/2018.15-4.8

8. V.I. Barkhatov, D.A. Pletnev, Yu.Sh. Kapkaev, Society and power **5(79)**, 65-83 (2019) doi:10.22394/1996-0522-2019-5-65-83

9. S.S. Gordeev, S.G. Zyryanov, A.M. Sitkovskiy, *ERSME-2020* **217**, 1-7 (2020) DOI: https://doi.org/10.1051/e3sconf/202021707021