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MODELING OF DEVELOPMENT TRAJECTORIES IN THE MULTIDIMENSIONAL SPACE: SOCIO-GEOGRAPHIC INTERPRETATION

The purpose of this paper is justification of methodological peculiarities of the development trajectories modeling in the multidimensional space from the positions of social geography; their practical application (geodemographic process in Kharkiv region is taken as an example). The object of social geography is social and geographical system and social and geographical process. Combination of natural, social and economic systems in it creates a unique variety of features and properties requiring consideration of a large number of these systems parameters. According to the geographical, system and synergetic approach all these processes are described in hundreds of parameters. Adequate and correct mathematical processing of such actual material is possible only with use of virtual multidimensional geographic space where the mathematical model of the real development trajectory of the object or process is offered. The main estimation parameters are given, in particular the main diagonal in the hypercube of the multidimensional space is considered as the standard of optimal development. Comparison of the real trajectory with the optimal, determining the projection of the vector of development on the optimal trajectory, deviations from the optimal trajectory contain information on the peculiarities of the process.

The proposed method was used for modeling of the geodemographic development trajectory in districts of Kharkiv region for 2002-2015 on the basis of 72 initial statistical parameters which are characterizing this process to demonstrate its peculiarities on the results of certain studies. The grouping of the districts of Kharkiv region, temporal peculiarities are shown, the phases of progressive and regressive demographic development for the studied period are established taking into account a considerable amount of the initial data. Modeling the development path allows us to define a clear perspective, to model and predict further development, to plan the pace of development. It is also a convenient monitoring tool; it also helps to develop scientifically-based management measures, etc.

Keywords: social geographical process, sociogeosystem, multidimensional features space, modeling of development trajectory, optimal development trajectory, real trajectory model, deviation from an optimal trajectory.

Костянтин Немець, Катерина Сегіда, Людмила Немець, Євгенія Телебенієва, Катерина Кравченко. **МОДЕЛЮВАННЯ ТРАЄКТОРІЙ РОЗВИТКУ У БАГАТОВИМІРНОМУ ПРОСТОРІ: СУСПІЛЬНО-ГЕОГРАФІЧНА ІНТЕРПРЕТАЦІЯ**

У статті описано моделювання траєкторії розвитку у багатовимірному ознаковому просторі для аналізу складових суспільно-географічного процесу. Висвітлено методологічні основи моделювання траєкторії розвитку соціогеосистеми у багатовимірному просторі. У відповідності до географічного, системного і синергетичного підходів суспільно-географічні процеси описуються сотнями параметрів. Адекватна і коректна математична обробка такого фактичного матеріалу можлива з використанням нормованого багатовимірному ознакового простору, де пропонується математична модель реальної траєкторії розвитку об'єкту або процесу. Наведено основні параметри оцінки, зокрема головна діагональ у гіперкубі багатовимірному просторі розглядається як еталон оптимального розвитку. Порівняння реальної траєкторії з оптимальною, визначення проєкції вектору розвитку на оптимальну траєкторію, відхилення від оптимальної траєкторії містять інформацію про особливості перебігу процесу. Запропонований метод було застосовано для моделювання траєкторій геодемографічного розвитку в розрізі районів Харківської області за період 2002-2015 рр. на основі 72 вихідних статистичних параметрів для демонстрації його особливостей на результатах конкретних досліджень. Виконано групування районів області, показано часові особливості, встановлено фази прогресивного та регресивного демографічного розвитку за досліджуваний період з урахуванням значної кількості вихідних даних. Моделювання траєкторії розвитку дозволяє визначити чітку перспективу, моделювати та прогнозувати подальший розвиток, планувати темпи розвитку, є зручним інструментом моніторингу та дозволяє розробляти науково-обґрунтовані заходи з управління тощо.

Ключові слова: соціально-географічний процес, соціогеосистема, багатовимірний ознаковий простір, моделювання траєкторії розвитку, оптимальна траєкторія розвитку, модель реальної траєкторії, відхилення від оптимальної траєкторії.

Константин Немец, Екатерина Сегіда, Людмила Немец, Евгения Телебенева, Екатерина Кравченко.
МОДЕЛИРОВАНИЕ ТРАЕКТОРИЙ РАЗВИТИЯ В МНОГОМЕРНОМ ПРОСТРАНСТВЕ: ОБЩЕСТВЕННО-ГЕОГРАФИЧЕСКАЯ ИНТЕРПРЕТАЦИЯ

В статье описано моделирование траектории развития в многомерном признаковом пространстве для анализа составляющих общественно-географического процесса. Освещены методологические основы моделирования траектории развития социogeосистемы в многомерном пространстве. В соответствии с географическим, системным и синергетическим подходами общественно-географические процессы описываются сотнями параметров. Адекватная и корректная математическая обработка такого фактического материала возможна с использованием нормированного многомерного признакового пространства, где предлагается математическая модель реальной траектории развития объекта или процесса. Приведены основные параметры оценки, а главная диагональ в гиперкубе многомерного пространства рассматривается как эталон оптимального развития. Сравнение реальной траектории с оптимальной, определение проекции вектора развития на оптимальную траекторию, отклонения от оптимальной траектории содержат информацию об особенностях исследуемого процесса. Предложенный метод был применен для моделирования траекторий геодемографического развития в разрезе районов Харьковской области за период 2002-2015 гг. на основе 72 статистических параметров для демонстрации его особенностей на результатах конкретных исследований. Выполнено группирование районов области, показаны временные особенности, установлены фазы прогрессивного и регрессивного демографического развития за исследуемый период с учетом значительного количества исходных данных. Моделирование траектории развития позволяет определить четкую перспективу, моделировать и прогнозировать дальнейшее развитие, планировать темпы развития, разрабатывать научно обоснованные мероприятия регионального управления. Также моделирование траектории развития является удобным инструментом мониторинга.

Ключевые слова: социально-географический процесс, социogeосистема, многомерное признаковое пространство, моделирование траектории развития, оптимальная траектория развития, модель реальной траектории, отклонение от оптимальной траектории.

Introduction. Social geography today is one of the few branches of geographic science where methods of multidimensional analysis are widely used. It is due to peculiarities of the object of social geography – territorial organization of society, or, i.e. the social geographical process in social geographical system (sociogeosystem). Combination of natural, social and economic systems in it creates a unique variety of features and properties that require consideration of a large number of these systems' parameters. The complex social geographical research shows that formalization and parametrization of the studied sociogeoprocesses and sociogeosystems cause creation of working databases from hundreds of various parameters – one requires methods of multidimensional analysis to process everything correctly.

Along with active use of traditional and classic methods – cluster and factor analysis, image recognition, multivariate regression-correlation analysis, linear scaling methods, etc., there is a constant search for new methods for representing and analyzing data in a multidimensional geographic parametric space. The basis of it is the mathematical apparatus of multidimensional analytic geometry and linear algebra, which, on the one hand, provides mathematical correctness and accuracy of the analysis, and, on the other hand – it gives an opportunity to represent systems and the processes under study in the form of geometric images. In general, it is typical for geography, the core of which is chorological paradigm. Due to it, many traditional geographic problems related to spatial-temporal analysis can easily be solved by vector analysis, transformations of multidimensional space, etc.

Analysis of previous research. Currently, multidimensional phase space is widely used in various fields of science and technology for describing and analyzing multidimensional objects and processes. In particular, the economic theory uses models of territorial competition based and developed on the works of both American (M. Porter, M. Enright, etc.) and European (B. Jonson, B. Lundval, E. Reinert, G. Lindquist, etc.) economic schools. The interest of economists in the study of com-

plex economic processes of multidimensional phase space is not accidental. It requires taking into account a large number of factors, often of a stochastic nature and varying in time and space. One more important thing is social economic management information support based on monitoring the trajectory of a controlled object or process in a multidimensional phase space in order to bring it closer to the optimal trajectory. It should be noted that comparing to economic processes social geographical processes in sociogeosystems are even more complex because they integrate almost all aspects of social life, including economic aspects.

In general, methodology for modeling trajectories in multidimensional space is reduced to definition of some generalized parameter of the investigated process as the sum of measured partial parameters. This generalized parameter is further discussed in phase space of a smaller dimension. Different methods are used to determine it. The simplest variant is methods of multidimensional regression linear and nonlinear analysis. In particular, method of group analysis GBTM is used for retrospective analysis of the object's development trajectories in psychology, sociology, forensics, medicine, epidemiology, etc. It is based on the application of multidimensional nonlinear regression which describes trajectory of a group of objects and further studies their individual deviations.

Interpretation of results of deviations determines its causes and ways of elimination (Daniel S. Nagin, Bobby L. Jones, Vale'ria Lima Passos and Richard E. Tremblay [9]). This method was used in the study of children's individual development (Daniel J. Bauerand, Heathe Luz, McNaughton Reyes [10]). Similarly, multi-level objects are studied. For example, in forensics (Frauke Kreuter and Bengt Muthén [14], Wesley G. Jennings and Caitlyn Meade [13], etc.).

Another approach is to use Bayes' model, a graph that displays changes of random process' parameters and their conditional dependencies. It makes possible to evaluate information transfer at the gene level, etc. (J.A. Stamps and W.E. Frankenhuis [15]).

For analysis of the trajectory in multidimensional space, the method of main components is used most often. As described in the works by A. Zinoviev and Yu. Polunin [1] about trajectories of countries' development, this method makes it possible to determine main factors of individual objects' development.

That's why modeling of development trajectories in multidimensional space is widely used in various fields of science and practice. In our opinion, in social geographical research it can be a convenient tool for analysis. Proceeding from the previously proposed sociogeographical concept of multidimensional space, the approach is different in that we use as a measure of normalized multidimensional space a hypercube's diagonal which is considered as an optimal trajectory of development [3, 5]. Deviations of real trajectories from it are main efficiency indicators of management of development process that is an integral part of social systems' development to which sociogeosystems relate. Similar research can be carried out for individual components of sociogeosystems, for example, demographic. As far as it is stated demographic processes are complicated by a number of factors, covering practically all regions and countries of the world. Therefore, it is important to investigate structural-dynamic and spatial characteristics of demographic processes. Without this, it is impossible to optimize processes of social economic development, build promising development strategies, make scientifically sound management decisions, and so on.

The **purpose** of this paper is justification of methodological peculiarities of modeling of development trajectories in multidimensional space from the positions of social geography; their practical application (geodemographic process in the Kharkiv region is taken as an example).

Methodology. Objects of social geography – sociogeosystems – are open, complex, dynamic, and heterogeneous systems as they include completely different subsystems (biological, mineral, social, and economic). Naturally, many parameters are used to describe, evaluate, and analyze the state of sociogeosystems. The observed vector of sociogeosystems contains a great variety of coordinates. When studying the dynamics of a set of sociogeosystems, the array of initial data may contain a large number of parameters which inevitably leads to the need to use multi-dimensional analysis methods for its processing. The theoretical basis for such an analysis is multidimensional analytical geometry, the mathematical apparatus of which was developed in the 19th century and now has been adapted for computer analysis. It should be noted that in geography the concept of multi-dimensional attribute space was formed in the first half of the 20th century, but its use in practical research became possible due to development of computer technology and related methods.

In human geography multidimensional space is increasingly being used as a special way of reflecting geographic space. It allows, on the one hand, to describe and analyze social geographical objects according to a complex of features, and on the other, to study more deeply relationships between them. At the Department of Human Geography and Regional Studies of V.N. Karazin

Kharkiv National University a set of methods for studying social geographical objects in a normalized multidimensional parametric space has been developed [3, 5]. In particular, a method for modeling of the trajectory of social geographical objects development. Today it is implemented as a complex of computer programs.

A normalized multidimensional space is formed by linear scaling of the set of social geographical objects signs (obtaining indices) to change the metric so that values of the parameters vary in interval [0 ... 1]. Isomerism of space is of fundamental importance for the study and comparative analysis of state and dynamics of the studied social geographical objects. Then normalized multidimensional space is represented as a hypercube, the main diagonal of which is {000 ... - 111 ...} and it is optimal (effective, the shortest) trajectory of social geographical objects development. Position of any social geographical objects in normalized multidimensional space is fixed by a point, coordinates of which are given by its indices. Analyzing correlation of social geographical objects position in normalized multidimensional space, in particular, with respect to main diagonal of the hypercube, one can compare their state, development level, etc. When time series of social geographical objects signs appear, it is possible to analyze not only the time layers of social geographical process, but also dynamics of social geographical objects development.

In the simplest case, motion of social geographical objects in normalized multidimensional space can be represented as a trajectory – segments that sequentially connect social geographical objects points in a time series. If it is necessary a more detailed study of the trajectory nonlinear, i.e. parabolic interpolation between points is used. The trajectory of social geographical objects in normalized multidimensional space is characterized by two sets of indicators – direction of movement and linear parameters, i.e. social geographical objects motion distance for a certain period of time.

The first set of indicators includes the cosines of angles formed by a segment of the trajectory with trajectories of other objects or other characteristic directions (some average, optimal, project, predictive trajectories). If we consider the analyzed social geographical objects as subsystems of some more general sociogeosystem, i.e. regional sociogeosystems as part of a region or regions within a subregion or country. Then according to movement direction parameters effectiveness of social geographical objects functioning in the system can be evaluated. As a result, a quantitative assessment of each subsystem's contribution to the system's state or development is obtained. In the same way, consistency of subsystems' movement (functioning) can be assessed. Increase in the cosine value (decrease in the angle) between their trajectories indicates their convergence and cooperative interaction, which, in particular, can be regarded as evidence of similarity in their development. The cosines of angles between social geographical objects trajectories can be interpreted as social geographical objects correlation coefficients by a set of signs.

The second set of indicators is represented by various linear trajectory characteristics:

a) the path (ΔL), passed by social geographical objects for a certain period of time; it is defined as the Eu-

clidean distance between the points of the trajectory at adjacent time points. It is a dynamic trajectory characteristic since its length characterizes intensity of social geographical objects motion;

b) speed of social geographical objects motion; it is defined as ratio of the length of the traversed path to the time interval between adjacent calculated moments ($\Delta L / \Delta t$);

c) remoteness of the current trajectory point from the origin of coordinates (L_0); it characterizes the efficiency of social geographical objects motion: since in an equal time period a more effective social geographical objects will move more away from the starting position and from the origin of coordinates;

d) P_{L_0} – the projection of L_0 onto the main diagonal of the hypercube;

e) ratio P_{L_0} / D (D is the length of the main diagonal) – the projection progress coefficient which characterizes rates of social geographical objects motion from the initial to the end point; more advanced social geographical objects in development are characterized by large values of this parameter. In case of normal social geographical objects development this indicator continuously increases in time;

f) distance from the current point of the trajectory to the main diagonal along the normal that is deviation from the optimal trajectory.

Development of social geographical objects in normalized multidimensional space can be viewed as a mechanical process of motion of a material point in space. Perhaps, this analogy has not yet revealed prospects of the method. In general, using angular and linear parameters of the trajectories of social geographical objects sets of the same type, one can obtain substantially more information in comparison with traditional methods of classification, grouping and comparative analysis. Thus, determining angular and linear characteristics of individual fragments or the entire trajectory as a whole, one can get an idea of development of a given sociogeosystem over a certain time period. A detailed description of this method is given in the works [3, 5]. Here in the article one notes only two trajectory parameters that are important for social management obtained by processing its angular and linear characteristics.

The first of them is coefficient of progress which is calculated as ratio of length of the projection of radius vector on optimal trajectory of development to its length. It reflects advancement of sociogeosystem in development. The second, a very important parameter of the trajectory is distance from the point of the sociogeosystem's state (the end of radius vector) along normal to optimal trajectory of development. It characterizes deviation of the real trajectory of the sociogeosystem from optimal trajectory of development. Interpretation of this indicator is ambiguous. On the one hand, magnitude of deviation from optimal trajectory of development may indicate, for example, inefficient use of social management resources or other manifestations of its imperfections, i.e. to be evaluation of management quality. On the other hand, asymmetry of development arises due to heterogeneity of the sociogeosystem's development,

caused. In the ideal case of even development along all multidimensional space coordinates, the real trajectory of the sociogeosystem's development exactly coincides with optimal trajectory of development, but this case is an unattainable abstraction.

The method of modeling of the development trajectory of the sociogeosystems' development has been made for research in the field of human geography, but it can also be successfully applied in other areas of science and technology where it is necessary to study history or predict development of objects, monitor management processes, production, etc. Particularly interesting results are obtained in a simultaneous comparative analysis of a set of homogeneous objects when it is possible to evaluate consistency of their trajectories among themselves and with the trajectory of a higher hierarchical object, to rank them according to various criteria, to find out bottlenecks in their development, etc. We demonstrate possibilities of this method in description and study of demographic processes.

Research and discussion. The method of modeling of the trajectory of socio-geographical objects' development is effective for analysis of various components of the social geographical process in regional sociogeosystems, social management of sociogeosystems of different levels, organization of social geographical monitoring of processes in various sociogeosystems, etc. In this case, the trajectory of development – the trajectory of demographic process – serves as a convenient tool for social geographical analysis, makes it possible to evaluate the course of the process by a set of features, identify periods with different directions of motion, etc. [3]. The proposed method was used for modeling of the geodemographic development trajectory in districts of the Kharkiv region for 2002-2015 on the basis of 72 initial statistical parameters [7, 8] which are characterizing this process to demonstrate its peculiarities on the results of certain studies.

Consequently, distribution of geographic objects (in this case, districts) on the phase plane makes it possible to determine peculiarities of these objects' location along a set of traits relative to each other and relatively optimal trajectory [3, 5, 6]. Distribution of the districts of the Kharkiv region on the phase plane along the geodemographic development trajectory for 2002 and 2015 (Fig. 1, 2) shows that the best tendencies are observed in the Kharkivskiy district. Then follows the Derhachivskiy district where the indicators of the geodemographic process are worse in comparison with the Kharkivskiy district, but are somewhat better in comparison with the others. Next there is a relatively dense group of most region's districts. However, there one should pay attention to the Zmiyivskiy and Balakliya districts which are characterized by the highest efficiency of the geodemographic process (have a minimum deviation from the optimal trajectory of development). The worst tendencies of geodemographic process for deviations from optimal trajectory are observed in the Kolomatskiy and Pechenizhskiy districts, according to the progress coefficient it is the Barvinkivskiy district.

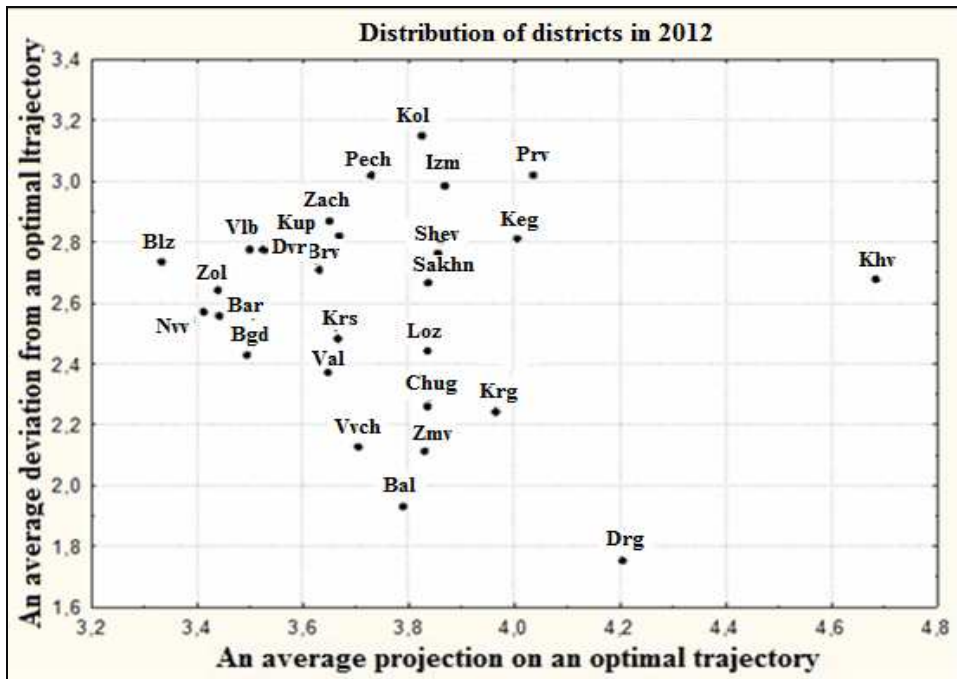


Fig. 1. Distribution of the districts of the Kharkiv region on the phase plane according to average indicators of the geodemographic development trajectory, 2002 (constructed according to the modeling results)

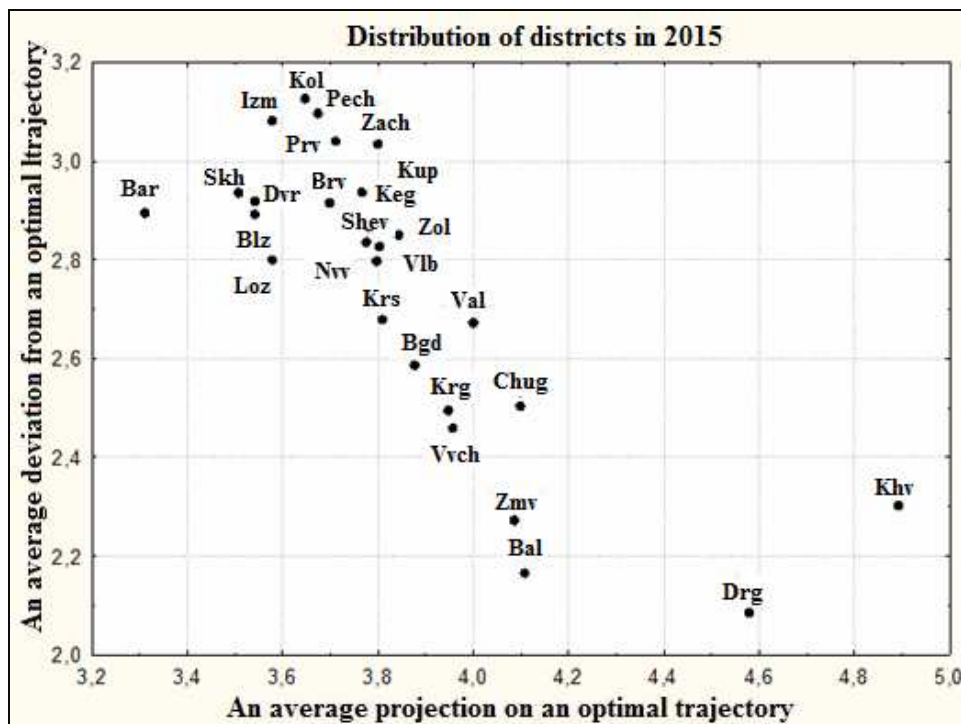


Fig. 2. Distribution of the districts of the Kharkiv region on the phase plane according to average indicators of the geodemographic development trajectory, 2015 (constructed according to the modeling results)

Comparison of initial and final distribution (Fig. 1, 2) shows some positive changes in the location of districts in the phase plane, but configuration has almost not changed, although there is a greater concentration of districts and a greater deviation from the optimal trajectory of development. It is worth noting the Kharkivskiy, Balakliyskiy and Zmiyivskiy districts where deviations from the optimal development trajectory have decreased. The same districts along with

the Chuguevskiy and Derhachivskiy also demonstrate progress along the trajectory.

The trajectories of geodemographic development of all districts of the Kharkiv region for 2002-2015 have been constructed. For typization of the districts of the Kharkiv region up to the peculiarities of the trajectory of the geodemographic development, one can apply a general trend of changing key indicators: projection of the optimal trajectory and deviation from the optimal

trajectory as well as general character of the trajectory's development for the investigated period: progressive, regressive, and nonequilibrium (Table 1). Below are graphs of the trajectory of geodemographic development of districts with extreme indices belonging to different observed groups.

For the Balakliyskiy district (Fig. 3) the trajectory

of the geodemographic development is approximated to the optimal one. It indicates progressive development nature, correspondence with trends of the system with the modelled development. The Balakliyskiy district has a characterial motion along the optimal trajectory with a decrease in deviation from it (by 2010) and an increase in deviation from it (starting from 2010).

Table 1

Grouping of districts of the Kharkiv region on the peculiarities of the trajectory of geodemographic development, 2002-2015 (systematized and constructed according to the modeling results)

CHARACTER OF DEVELOPMENT			
PROJECTION OF THE OPTIMAL TRAJECTORY	progressive	regressive	nonequilibrium
Approximation	Balakliyskiy Borovskiy Valkivskiy Velikobrurluts'kiy Vovchanskiy Zahopilivskiy Krasnokutskiy Kupyanskiy Novovodolazhskiy Chuguevskiy		Dvorichanskiy, Krasnogradskiy
Constancy	Bogodukhivskiy, Zolochivskiy, Zmiyivskiy Dergachivskiy	Barvinkivskiy, Bliznyukivskiy, Lozovskiy, Sakhnovshchynskiy	Kharkivskiy
Distance		Kegichevskiy Pechenezhskiy	Iziumskiy, Kolomackiy, Pervomaiskiy, Shevchenkivskiy

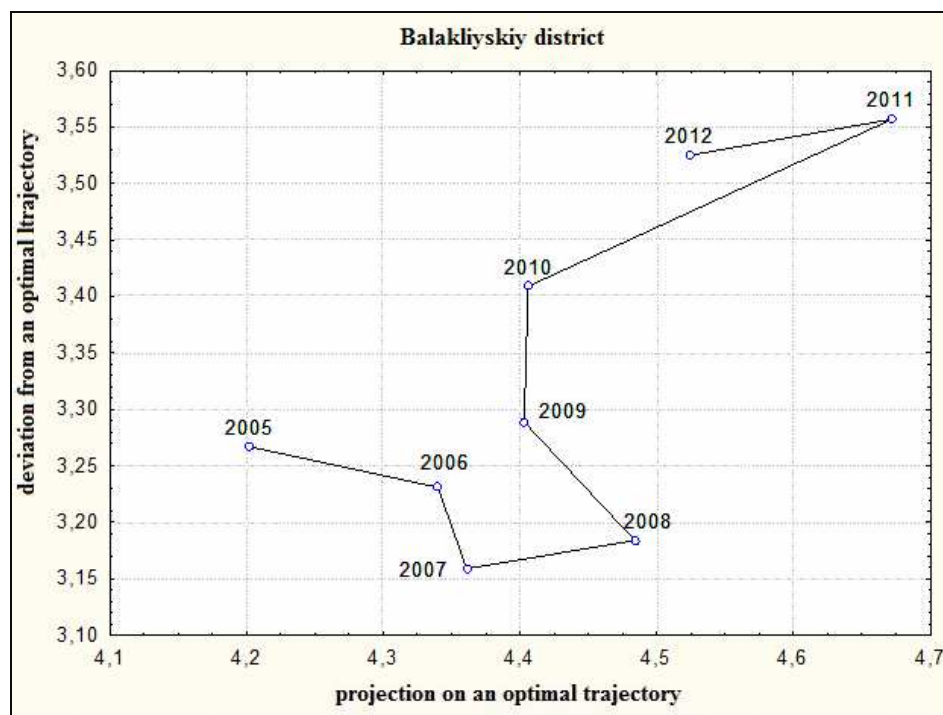


Fig. 3. The trajectory of geodemographic development of the Balakliyskiy district of the Kharkiv region, 2002-2015 (constructed according to the modeling results)

In addition to the Balakliyskiy district, the Borovskiy, Valkivskiy, Velikobrurlutskiy, Vovchanskiy, Zachepylivskiy, Krasnokutskiy, Kupyanskiy, Novovodolazhskiy, Chuguevskiy districts belong to a group of areas with a progressive character of geodemographic development which approaching the optimal trajectory.

During the period under study, on the trajectory of geodemographic development of the Dergachiy district (Fig. 4), there is "progress" along the optimal trajectory

of development, except for the periods of 2003-2004, 2005-2006, 2012-2013 where regressive development is observed. Periods of 2004-2005, 2006-2010, 2011-2012, and 2014-2015 reflect positive dynamics both in terms of approximation and decrease in deviation from the optimal trajectory of development. It should be noted that overall deviation reduction from the optimal development trajectory appears in the mentioned periods, the maximum deviation was observed in 2003.

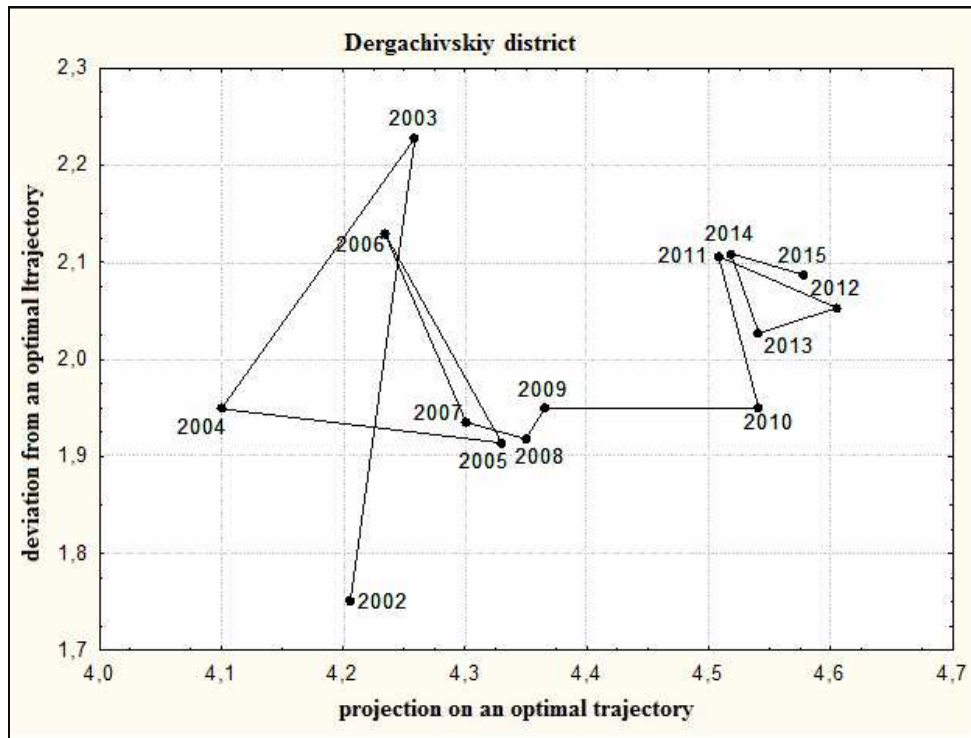


Fig. 4. Trajectory of geodemographic development of the Derhachivskiy district of the Kharkiv region, 2002-2015 (constructed according to the modeling results)

In addition to the Dergachivskiy district, the Bogodukhivskiy, Zolochivskiy and Zmieviskiy districts are among the areas with a progressive character of geodemographic development and constancy in relation to the optimal trajectory.

The Dvorichanskiy and Krasnogradskiy districts form a group with nonequilibrium nature of the trajectory of geodemographic development; they are approaching the optimal trajectory. The trajectory of geodemographic development of the Dvorichanskiy district (Figure 5) is characterized by alternating periods of progressive (2002-2003, 2005-2006, 2008-2010) and regressive (2003-2005, 2007-2008, 2010-2015) dynamics. There is also an increase in deviation from the optimal trajectory during 2007-2015.

The Kharkivskiy district is the only one which trajectory of development has nonequilibrium character with constancy of position relatively to the optimal trajectory of development (Fig. 6): during the studied period there are years with positive and negative dynamics, which constantly change each other. Thus, the periods of 2004-2006 and 2013-2015 are characterized

by positive changes both in terms of approximation along the trajectory and decrease of deviation from the optimal trajectory of development. Instead, the periods of 2003-2004, 2010-2011, 2012-2013 are characterized by negative changes in both indicators. One should notice that decrease in the value of deviation from the optimal trajectory of development, the maximum deviation was observed in 2003 and 2004, the minimum – in 2009 and 2015.

The trajectory of the geodemographic development of the Izyumskiy district has a nonequilibrium character, and the tendency of distance from the trajectory of optimal development can be traced (Fig. 7). Thus, the period 2002-2004, 2006-2009, 2011-2015 is characterized by an increase in deviation from the optimal trajectory. Positive changes are characterized by the period of 2004-2006. In addition to the Izyumskiy district, the Kolomatskiy, Pervomayskiy, Shevchenkiyskiy districts are among the regions with a progressive character of geodemographic development and constancy in relation to the optimal trajectory.

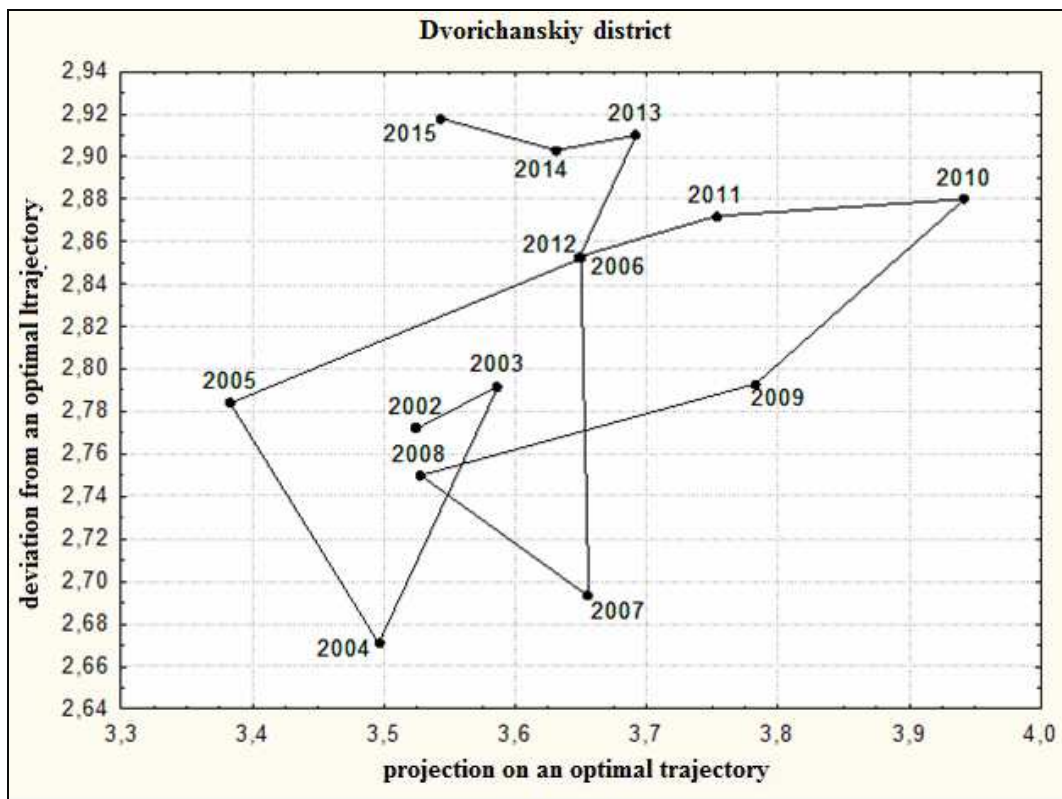


Fig. 5. Trajectory of geodemographic development of the Dvorichanskiy district of the Kharkiv region, 2002-2015 (constructed according to the modeling results)

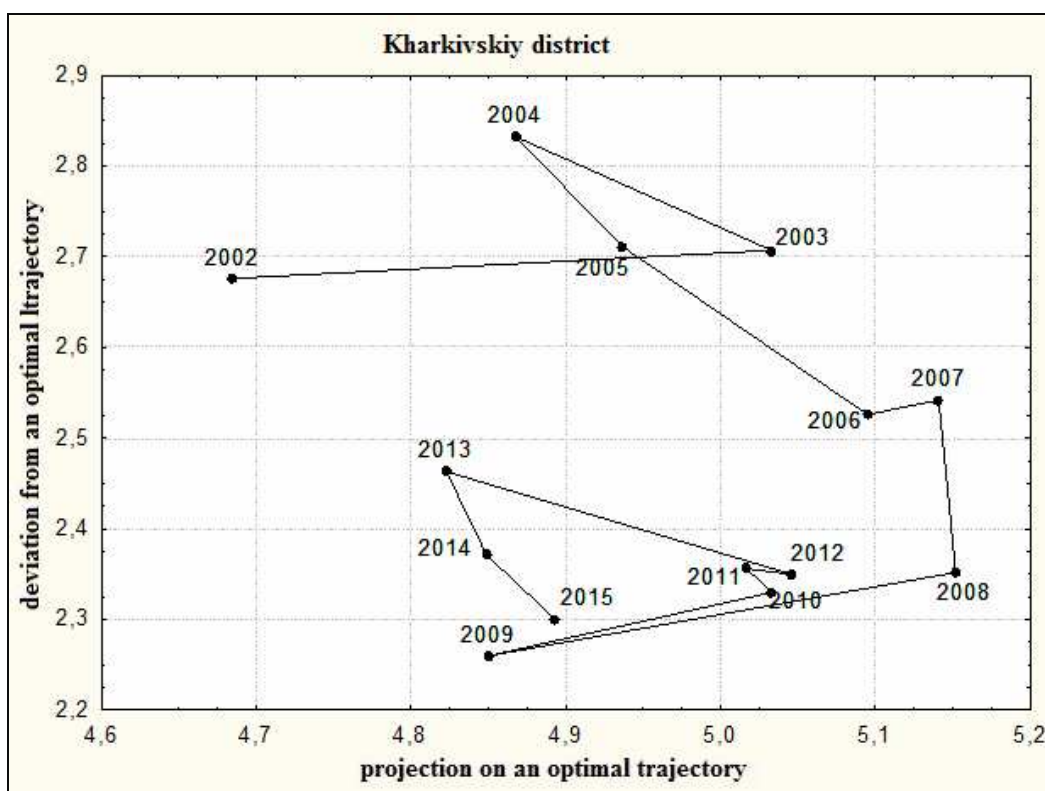


Fig. 6. Trajectory of geodemographic development of the Kharkivskiy district of the Kharkiv region, 2002-2015 (constructed according to the modeling results)

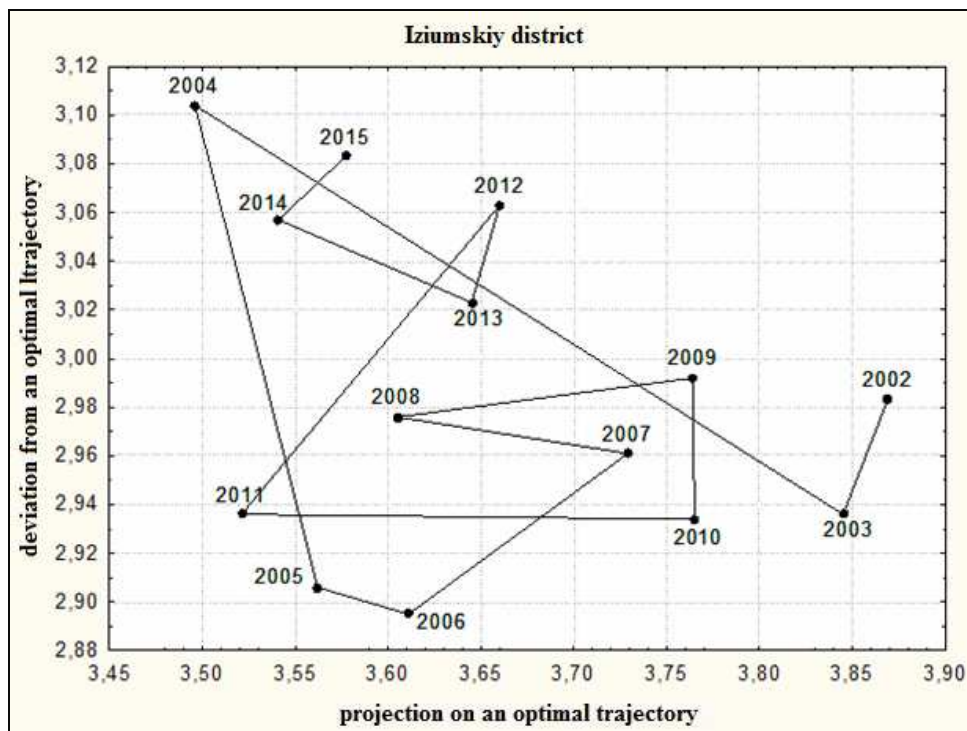


Fig. 7. Trajectory of geodemographic development of the Iziumskiy district of the Kharkiv region, 2002-2015
(constructed according to the modeling results)

The trajectory of the geodemographic development of the Barvinkivskiy district (Fig. 8) shows regressive nature of development. Periods of 2005-2006, 2008-2009 and 2011-2014 are periods of progressive development, 2002-2005, 2009-2011, 2014-2015 - regressive development. Mostly, development is accompanied by an increase in deviation from the

optimal trajectory, except for the period of 2008-2009. In addition to Barvinkivskiy district the group of districts with a regressive nature of geodemographic development and constancy of the situation relatively to the optimal trajectory includes the Bliznyukivskiy, Lozovskiy and Sakhnovshchynskiy districts.

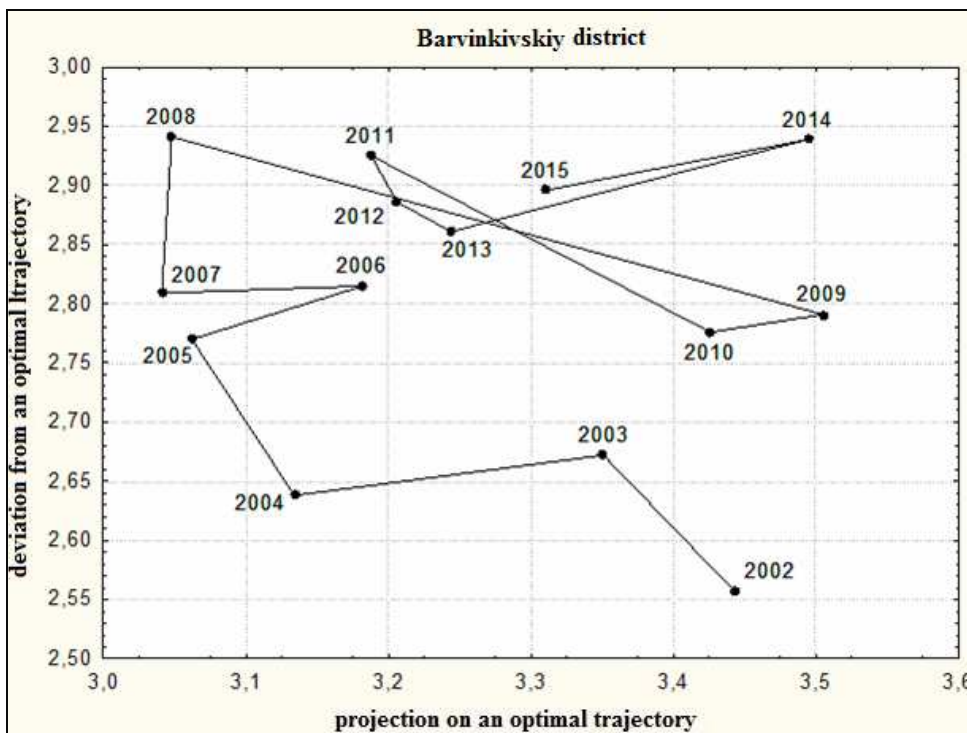


Fig. 8. Trajectory of geodemographic development of the Barvinkivskiy district of the Kharkiv region, 2002-2015
(constructed according to the modeling results)

For the Kegichevskiy district (Fig. 9), the trajectory of the geodemographic development has a regressive character: during the studied period there is a "backward movement" along the optimal trajectory of development, except for the periods of 2007-2009 and 2013-2014 when there is progressive development. Periods since

2010 characterize by negative dynamics both in terms of approximation and deviation from the optimal trajectory of development. The Kegichevskiy and Pechenizkiy districts are characterized by a regressive nature of trajectories of geodemographic development with a distance from the optimal trajectory.

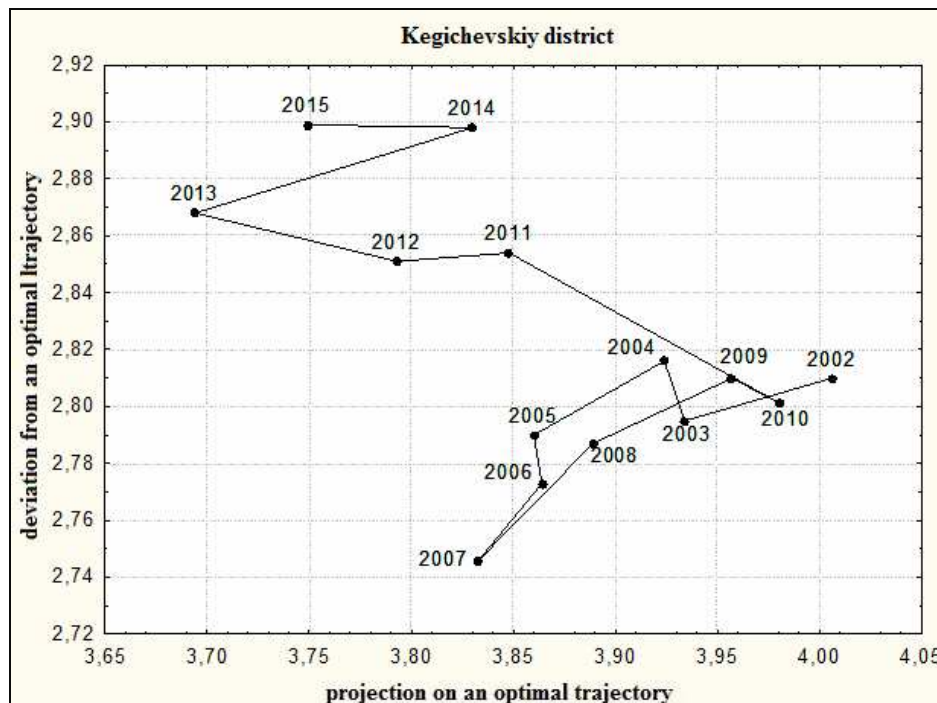


Fig. 9. Trajectory of geodemographic development of the Kegichevskiy district of the Kharkiv region, 2002-2015 (constructed according to the modeling results)

Thus, seven types of districts of the Kharkiv region with distinctive features of trajectories of geodemographic development can be distinguished (Fig. 10):

- progressive character of geodemographic development and approaching the optimal trajectory (the Balakliyskiy, Borivskiy, Valkivskiy, Velikobrurlutskiy, Vovchanskiy, Zachepilivskiy, Krasnokutskiy, Kupyanskiy, Novovodolazhskiy, Chuguevskiy districts);
- progressive character of geodemographic development and stability of the situation in relation to the optimal trajectory (the Bogodukhivskiy, Dergachivskiy, Zolochivskiy, Zmiivskiy districts);
- nonequilibrium character of geodemographic development and approaching the optimal trajectory (the Dvorichanskiy and Krasnogradskiy districts);
- nonequilibrium character of geodemographic development and stability of the position relatively to the optimal trajectory (the Kharkivskiy district);
- nonequilibrium character of geodemographic development and distance from the optimal trajectory (the Iziyumskiy, Kolomatskiy, Pervomaiskiy, Shevchenkiy districts);
- regressive character of geodemographic development and stability of the situation in relation to the optimal trajectory (the Barvinckiy, Bliznyukivskiy, Lozovskiy, Sakhnovshchynskiy districts);
- regressive character of geodemographic

development and distance from the optimal trajectory (the Kegichevskiy and Pechenizkiy districts).

The previous studies indicate that there is a significant territorial differentiation of demographic potential [12] within the region, in particular concerning cities and districts. Especially, the highest significance of demographic potential has the Dergachivskiy and Chuguevskiy districts, above the average – the Kharkivskiy, Zmiivskiy and Valkivskiy ones. Four of these districts are characterized by progressive nature of the trajectory of geodemographic development while the Kharkivskiy district is nonequilibrium. It happens due to large population (this is the largest administrative district in Ukraine), significant migration indicators and their dynamic change. The lowest indicators of demographic potential are in the Kolomazkiy, Bliznyukovskiy and Barvinckiy districts which are in depression by all the indicators. The stated is confirmed by certain tendencies – the created trajectory has regressive character which indicates aggravation of demographic problems. The constructed trajectories are a convenient analysis tool for determining phases of development, monitoring and expanding the possibilities of social management. The application of the method of modeling of development trajectory has made it possible to establish spatial-temporal features, it generally includes a wide range of information about the demographic process in the context of the districts of the region.



Fig. 10. Grouping of districts of the Kharkiv region according to the features of the geodemographic development trajectory, 2002-2015 (constructed according to the modeling results)

Conclusions. The normalized multidimensional parametrezad space is a convenient medium for analyzing various characteristics of the social geographical process. In particular, modeling of a real trajectory of the socio-geographical objects' development and comparing it with an optimal trajectory makes it possible to evaluate the main parameters quantitatively and qualitatively – projection to the optimal trajectory and deviation from it. Interpretation of these parameters creates preconditions for optimization of development, adjustment of managerial decisions and the fastest achievement of the expected result. The use of multidimensional space for classification of social geographical objects and processes allows to analyze state and dynamics of their development by such systemic indicators as the area of the object's projection on the plane, sum or average value

of indices of statistical parameters and the index of development homogeneity. They have unambiguous interpretation and reflect different aspects of social development. Modeling of development trajectories has already been applied to social infrastructure research [6], competition [2], demographic development [8] research, etc. Modeling of development trajectories complements traditional research methods. It is a convenient tool in the study of time features, establishment of phases of progressive and regressive development, taking into account a large amount of output data. It allows to define a clear perspective, to model and predict further development, to plan the pace of development. It is also a convenient monitoring tool; it also helps to develop scientifically-based management measures, etc.

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