The Role of Geographic Information Systems in Ensuring Food Security in Countries During Epidemiological Crises

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Abstract. Sudden geospatial phenomena, whether natural or technocratic, regional, or global, including pandemics, confront industrial enterprises, including those in the chemical and technological complexes, with a new kind of uncertainty, creating new risks when making operational and strategic management decisions. These risks often have devastating consequences for economic and social agents caught in these geodynamic phenomena. Amongst the many kinds of dangers, the most economically and socially destructive are changes in consumer demand as related to quantitative, qualitative, and temporal parameters. These shockwaves can have dire effects, including the non-functionality of existing logistical systems, unrestrained costs, a terrifying level of unemployment, etc. In these dramatic scenarios, sector management must develop new strategies to deal with changes in the national economy, ensuring their ability to overcome factors that may otherwise destroy the existing socioeconomic parameters. To minimize these negative phenomena, it is necessary to develop a geographic information system (GIS), the elements of which entail dynamic information about all emerging risks, including the ability to ensure complete safety for all personnel, partners and suppliers, relations with government bodies and the public, and optimal use of financial resources. To build such an anti-crisis system, it is advisable to offer a scientific response to these challenges and many other problems associated with the operation of enterprises in such emergencies.

1. Introduction

The main task of the presented study is the scientific substantiation and development of a theory of geographic information systems (GIS) from a geographical nature to interdisciplinary one, including convergent sciences of adjacent areas, such as environmental (natural hazards and risks), sociological (sociological methods of research and regulation of socio-economic interactions, multidimensional analysis of sociological information, sociology of management, social dynamics and adaptation, professional and sectoral dynamics of the employed population, social mobility, adaptive behaviour of people, etc.), public (economics and management of the national economy, anti-crisis management, logistics, economic security), physical and mathematical (mathematical modelling and programming,
mathematical methods in economics, econometrics), technical (safety in emergency situations, systems analysis, information management and processing), and areas related to science. The "geographic information system" in our hypothesis is an integral, territorially localized system formed through convergence, close interconnection, and interactions of geographical science with the life support of the populations of local geographic regions. At the same time, the integrity of such a system is hypothetically determined by the multifaceted connections that develop between the elements of this system—its subsystems.

According to our hypothesis, a geographic information system is a complexly organized holistic association, multifaceted in its scientific nature (interdisciplinary, convergent in the scientific sense) and localized in its geographical space. Organizational formations of this kind hypothetically develop following the socio-economic spatial processes formed and controlled within it (this formation). At the same time, the local geosystem continuously interacts with similar external geosystems from other geographic locations.

The hypothesis being developed here is based on the theory of multifactorial interaction of systems within one geographic location with relative openness to external interactions with other systems located elsewhere. The identification, experimental study and formalization of these factors and their multifactorial interactions for the formation of socio-econometric controlled convergent models is intended to become an effective tool for strategic and tactical management of the effective functioning of a given geosystem. Specifically, the subject of this research is the chemical-technological branch of the Russian national economy. This study examines the multifaceted factors affecting its indicated efficiency.

2. Methodology
The idea of a geographic information system (GIS), a theory based on the provisions of general systems theory, received its form from the late 1950s to the early 1970s. In the initial stage, it generalized preliminary studies on the frontier areas of possibilities, interactions with the results of frontier areas of knowledge, and the search and formalization of technologies that met its requirements and requests. The science gained its original form as "Geographic Informatics" (GIScience) in the 1990s thanks to Anglo-American geographer Michael Frank Goodchild, a member of the British National Academy of Humanities and Social Sciences of the United Kingdom and the American Academy of Arts and Sciences. He defined this area and summarized its main interests, including spatial analysis, visualization, and the representation of uncertainty [1,2,3].

At the same time, other scientists working on the design of this complex information system moulded it into an independent scientific discipline, most notably through the works of a professor-geographer at the University of Buffalo (USA), Mark, David, et al. [4].

As a result, geoinformatics as a scientific discipline began to include the following areas of knowledge: methods of collection, presentation, processing and analysis of geographic information. Thanks to these inclusions, this discipline quickly became a practical tool for geographic practice and related fields, including information navigation (GIS) [5]. Thanks to the use of software, these easy-to-use, capacious tools have deservedly acquired the importance of irreplaceable satellites for all subjects and objects moving in space—from lone travellers to tracking logistics operations.

The development of geoinformatics as a science that provides irreplaceable practical navigational and logistic tools conceptually connects geography with informatics and, thanks to this, successfully acquires the status of an independent scientific discipline. The development of this area of knowledge in modern conditions combines elements of many related scientific disciplines: geo-computers, geomatics, geo-visualization, etc. Recently, the study of geographic data has acquired additional meaning as a scientific and academic discipline, and as a scientific technology about geographic information. It receives an internationally recognized term—GISci & T [6].

This science is fully supported by government projects in many countries. It was state support of geoinformation projects that stimulated the development of experimental research in the use of
geographic databases for the formation of automated navigation systems, the removal of urban waste and garbage, and for ensuring the optimal movement of vehicles in emergency situations.

The wide market for various software tools has led to the expansion of the field of application of geographic information systems through integration with nonspatial databases and the development of mobile applications. User-level geoinformation systems appeared, collecting, storing, analysing, and graphically visualizing spatial (geographic) data and related information about the necessary objects [7,8].

The purpose of this study is to expand the field of application for geoinformatics, as well as to explore the possibility of using geoinformation technologies to respond to dramatic new challenges, particularly the coronavirus pandemic, in an effort to both predict and prevent the worst of its socio-economic consequences.

The novelty of the results obtained in this study is the development of methods for studying the dynamics of socio-economic interactions in the event of a crisis and methods of regulating the regional-sectoral structure of the economy and the labour market in a difficult epidemiological situation.

The novelty of these results lies also in the convergence of the geographic information system with a social component that allows for the use of interpersonal communications of an anti-stress nature in order to form psychological attitudes for participants in spatial socio-economic processes, effectively delivering anti-crisis information to societies in order to avoid the formation of a negative mood in changing conditions.

Tasks solved during the study include:

• Description of the environmental phenomena of the current coronavirus pandemic. Formalization of natural hazards and risks that threaten the effective functioning and existence of the socio-economic spatial structure of the state and society.

• Selection, verification and formalization of sociological methods for research and regulation of socio-economic interactions, professional-sectoral dynamics and social dynamics of the employed population, its adaptation to crisis conditions, social mobility, etc.

• A multidimensional system analysis of socio-economic information resulting from the study of the current pandemic situation, its comparison by means of econometric and statistical methods with previous similar crisis phenomena of a global and regional scale, etc.

• Development and verification of mathematical models (programming, mathematical methods in economics, econometrics).

• Formalization of anti-crisis management methods for enterprises and sectors of the national economy, including logistics processes, in order to ensure economic security and their subsequent transformation on an innovative basis.

• Selection and verification of anti-crisis management methods for the professional-sectoral and social dynamics of the employed population, its social mobility and adaptation to crisis conditions, ensuring its safety in emergency situations, etc.

A GIS, according to the main fundamental task of this research, is understood as an integral, territorially localized system formed through the convergence, close interconnection, and interactions of geographical sciences with the life support of the population of local geographic regions. To ensure this integrity, a generally accepted systems approach was applied, proposed and methodically formalized by the biologist Ludwig von Bertalanffy [9] as the theory of systems (The Theory of Open Systems). In our country, this theory as a fundamental science, covering the entire set of problems associated with the study and design of systems, was criticized by philosophers and methodologists of science Yudin E.G., V.N. Sadovsky and I.V. Blauberg [10]. They rightly believed that with such an interpretation, the certainty of tasks and their content are lost to a certain extent. Soviet scientists developed a narrower approach: one apparatus, one research facility, etc. This approach, called "systems", is an extension and generalization of "general systems theory" and similar disciplines. Thus, a systematic approach was formed from adding the structural systematization in biology to the methodology of scientific knowledge. The formed scientific approach has become recognized by
scientists in the larger world community. It continues its development everywhere [11], including for the formation and management of information systems [12]. The systems approach is the theoretical and methodological basis of modern systems analysis [13,14]. This type of analysis is in turn the basis for the analytical part of this study.

Important elements of the experimental stage of our research are generally accepted sociological methods for studying socio-economic interactions, professional-sectoral and social dynamics of the employed population, its adaptation to crisis conditions, social mobility, polls, observations, content analysis, in-depth interviews, ZMET analysis, focus groups, etc. [15, 16]. Collection and verification of relevant data (Big Data generation) about the current pandemic crisis and similar epidemiological situations preceding it was carried out by an artificial intelligence system created via a combination of mathematical programming, content analysis, regression and statistical analyses.

The main tool of the analytical stage of our research is a multidimensional systematic analysis of socio-economic information that appears as a result of an experimental study of the current pandemic situation, including its comparison by econometric and statistical methods with previous similar crisis phenomena on a global and regional scale. The design stage of the proposed fundamental research involved the formalization of the revealed phenomena and patterns, which was carried out by methods of mathematical modelling, econometrics, multivariate combinatorics, etc. A widely tested foresight method was used to predict the socio-economic effect of the developed practical recommendations and conclusions based on the research results. The calculation of generalizing indicators of socio-economic efficiency as a result of the implementation of the research results in the period of difficult epidemiological situations was carried out by the method of system analysis, taking into account the time factor of the onset of cash inflows and outflows associated with the implementation of project recommendations.

The methodological stage of our research involves the formalization of scientific and practical recommendations through system analysis. According to our hypothesis, the results of our study will give grounds for the assertion that the geographic information system is a complexly organized holistic association, multifaceted in its scientific nature (interdisciplinary, convergent in the scientific sense), localized in geographic space. Organizational formation of this kind hypothetically develops following the socio-economic spatial processes formed and controlled within it (this formation). At the same time, the local geosystem continuously interacts with external similar geosystems from other geographic locations.

The basis for testing the hypothesis is a multifaceted experimental base containing the results of studying the multifactorial interactions of the system within one geographic location with relative openness to external interactions with other systems from other locations. The identification, experimental study and formalization of these factors and their multifactorial interactions for the formation of socio-economic controlled convergent models intended to become an effective tool for strategic and tactical management of the effective functioning of the specified geosystem are the objects of this project study. The subject of this research is the chemical-technological branch of the Russian national economy, particularly the multifaceted factors affecting the indicated efficiency.

3. Results

Theoretical provisions for the development of geoinformatics through a systematic scientific approach for its transformation are formulated. The prevailing view of the structures and function of geoinformatics and its description as a system by substantiating the list of its structural elements and researching and formalizing their interconnections and interdependencies is assessed. The theory of geoinformatics has been supplemented with a new generation of scientific data (information array) describing the variety of systemic relationships and their destructive impact on the economic potentials of sectors of the national economy using the example of the chemical-technological complex of the Russian Federation, as well as artificial intelligence software that collects relevant data in real time.
Highly effective socio-economic dynamic models have been developed for the management of sectors of the national economy and the region of the country as a whole (on the factual data of the current pandemic crisis) in conditions of complex epidemiological situations (for example, coronavirus) with their subsequent verification. Selected and methodically formalized effective methods of managing enterprises and sectors of the national economy in the face of emerging uncertainty to overcome negative socio-economic processes and advanced readiness to function in the post-crisis period on an innovative technical and organizational platform exceeding the pre-crisis parameters of functional efficiency.

4. Conclusions

The developed geographic information system includes fundamental science in our country and abroad, even where there is no information about such developments in available sources. The development of the geographic information system in the claimed study provides for the transformation of the theory and the practice of anti-crisis management of enterprises, shifting the focus of their management to relevant profit centres and increasing the weight of factors of social significance and national interest.

The scientific developments obtained in the course of this research come in the form of recommendations and methodological tools. Databases of generated data, algorithms and software for their generation and verification will ensure the effect of maintaining a pre-crisis volume of the socio-economic potential of the basic and infrastructural sectors of the national economy.

The provided scientific results make it possible to discover solutions for the basic national economic problems in the branches of the national economy in conditions of extreme epidemiological and similar crisis situations. This is demonstrated by the example of the chemical-technological complex of the Russian Federation.

The forecasts and methodological recommendations developed in this study allow for turning the destructive actions of pandemic/epidemiological crises into an innovative growth of military-economic potential with the simultaneous formation of a spiritual unity of society, focusing on the maturation of its civilian strength.

This developed geographic information system, based on scientifically grounded approaches, using the tools of scientific methods of infogramming as interdisciplinary communication, was created on the basis of the theory of the convergence of sciences.

Methodology and effective algorithms (recommendations) have been developed for making managerial decisions for the effective functioning of the chemical-technological complex as a subsystem of the national economic system of our country in any epidemiological situation.

5. References

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