

Complex Network Models Used to Make Decisions on Optimizing Regional Education Systems

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Abstract. This article discusses how the analysis of complex network models through geoinformation modeling can be used to make decisions on optimizing education systems. The article uses the foundations of management theory to study the impact of territorial availability of secondary vocational education services and institutions on decision making to optimize a regional network of vocational education institutions (a case study of Lipetsk Oblast, Russia).

Keywords: Complex Systems, Geoinformation Systems, Decision Theory, System of Education Management, Regional Education Network.

1 Introduction

The development of modern Russian education amid the digitalization of economy and society [1-4] implies significant changes in education syllabi, education economics, and educational management [5-9].

To address these issues and settle them effectively, one may either develop existing models or explore new syllabi and organizational structures of educational institutions as well as regard new economic environment and models of education management, with respect to network character of interaction between educational and other social institutions.

Management theory [5, 6, 10] shows that the following criteria should be used in order to find the most efficient models and conditions to optimize structures of various types, such as networks of regional educational institutions:

- economic efficiency;
- social efficiency;

- their compliance with the current state and trends of the labor market of a particular territory.

Social efficiency is based on the availability of education, in particular territorial availability, that is closely connected to the exercise of right to education and the freedom to choose any form of education, with social efficiency in this case including expectations, concerns, and needs expressed by citizens.

In the context of economic efficiency, we suggest making intergovernmental regulation and allocation of funds provided to a particular municipality of the region on the basis of transport availability that results from territorial availability and the cost of budgetary education services arising therein.

The case study of Lipetsk Oblast, Russia, [11] carried out to consider challenges that are faced by the system of secondary vocational education in a given region has revealed the necessity to study the effect of territorial availability of secondary vocational education services on decision-making process oriented to optimizing a regional network of vocational education institutions.

Above all, the attention to this issue plays a crucial role in ensuring favorable social conditions in the region that will result in human capital development that increases territorial competitiveness. Moreover, disregard for the problem and its urgency may trigger social tensions and economic recession in the region.

A regional network of secondary vocational education is represented by a complex of interconnected institutions – vocational colleges and schools – that creates the system of secondary vocational education in the region. The object of the research is a regional network of secondary vocational education institutions of Lipetsk Oblast that refers to a set of elements (education providers) that offer spatial and temporal access to education to local population with due regard to their needs and values and with respect to social, demographic, and other characteristics of the region.

A territorial availability (spatial accessibility) is understood to mean rational distribution of secondary vocational education institutions in order to provide free access to available resources.

With geoinformation modeling of a regional network in mind, the paper studies territorial availability of vocational education institutions in Lipetsk Oblast, its demographic characteristics, and the existing trends in spatial development providing for the peculiarities of its social and economic development (SWOT). It also analyzes the current indicators and forecast data and projection until 2024. All things considered, the article suggests a number of possible scenarios to develop a network of secondary vocational education in a given region [10].

2 Materials and Methods

It is a commonly known fact [12] that the analysis and problem-solving methods depend on the type of a problem to be solved. Besides, problems may be classified into:

- standard problems that have a clear structure, cause-and-effect relationships, and analogues;

- well-structured problems that may be separated into blocks of questions that usually have a set number of possible solutions;
- ill-structured problems that have no clear or immediately obvious solution, while cause-and-effect relationships and problems themselves are poorly defined;
- unstructured problems that usually lack analogues, while cause-and-effect relationships and solutions are unclear.

Standard and some well-structured problems have a set of standard solutions in specific situations indicated in regulatory documents: manuals, rules, standards, guidelines, etc. These documents clearly define the right sequence of actions to analyze a situation and solve a problem.

All decision-making methods can be divided into two groups: formalized (mathematical) and non-formalized (heuristic) ones. Formalized methods are based on the obtaining of calculated quantitative results and are used in solving well-structured and some ill-structured problems to evaluate possible solutions, select the optimal one, and verify its optimality. Non-formalized methods are used in solving complex ill-structured and unstructured problems to generate possible solutions, analyze and evaluate them as well as to select the optimal solution and verify its optimality.

Formalized methods used to choose the optimal solution and to verify its optimality include:

- economic and mathematical models and methods that formalize the relationships between processes and phenomena;
- system analysis that allows to identify interactions between system components and how they evolve;
- expert judgments that allow qualified specialists to evaluate the significance of events and factors, to forecast the development of a system and subsystems, and to assess the proportion of deterministic and probabilistic factors.

Above all, different methods of decision-making result in the different level of optimality of the decision.

Another approach to problem solving is based on the theory of complex systems (models of complex networks). The conceptual framework of a network theory highlights the necessity of process synchronization in order to achieve the desired result and outcome [13]. Besides, this synchronization is aimed at increasing the connectivity of a network that maximizes the adaptive potential of the whole, saves time, and reduces distance between network nodes. In this context, connectivity implies the maximum possible number of contacts between network nodes. Being a structure, a network is based on:

- a system of relationships (including management, responsibility distribution, property relations, decision-making regulations, financing structures);
- job allocation between network participants;
- network nodes;
- regulatory and administrative/technical support.

The main types of networks (including education) are established to ensure the effectiveness of a core process behind the network itself and focus on the product/result.

The theory of complex systems may be considered to be a useful tool to analyze a network like this. While defining “complex systems”, we refer to the views of Hiroki Sayama [14] who uses this term to refer to network structures “made of a large number of microscopic components interacting with each other in nontrivial ways.”

More than that, the theory of complex systems is interrelated with game theory, collective behavior, the theory of distributed systems, evolution and adaptation, non-linear dynamics, structural modeling, and general systems theory.

Upon studying the regional system of secondary vocational education in Lipetsk Oblast [10], we decided that it would make sense to analyze it and suggest possible ways of its optimization by applying both non-formalized (heuristic) methods [14] and formalized (mathematical) methods based on the network theory, the theory of complex systems, and geoinformation modelling. In earlier studies [5-9, 10, 13], we have already described the methodology behind the approach used in the article to construct and analyze a network model of the secondary vocational education system of the given region.

3 Results and Discussion

To identify the effectiveness of a network of secondary vocational education system that meets the training priorities of regional economy, the paper analyzes the regional education system by making use of the theory of complex systems and geoinformation analysis. Importantly, the paper also considers how secondary vocational education optimization plans for a separate Russian region may be prepared or adjusted.

The main analysis criteria used as optimization criteria include economic and social efficiency as well as the compliance of the system with the current state and trends of the labor market of a particular territory.

In the context of economic efficiency, we suggest making intergovernmental regulation and allocation of funds provided to a particular municipality of the region on the basis of transport availability that results from territorial availability and the cost of budgetary education services arising therein.

In comparison, social efficiency implies how expectations, concerns, and needs expressed by the citizens are matched and satisfied. Again, the degree to which all this is satisfied illustrates the availability of education, including territorial availability, that is closely connected to the exercise of right to education and the freedom to choose any form of education.

Furthermore, optimization plans should also consider the fact that secondary vocational education institutions may expand in line with their strategy designed to rest on flagship education providers that have considerable learning resources (technology, human resources, methodology, data, social networking).

The applied complex of methods allowed us to develop the evaluation framework for the territorial availability of secondary vocational education services and institutions that can be used to:

1. objectify and systemize information on the availability of secondary vocational education services and institutions with due regard to the needs of population (by utilizing automated systems as well);
2. draw “availability maps” of regional and federal services and provide experts and Russian citizens with relevant information and reference materials;
3. make and design reasonable management decisions (optimization decisions on regional level as well), plans, and programs to develop regional networks of secondary vocational education institutions, to control them, and to assess the effectiveness of the implementation of these plans.

The main contributions of this paper are as follows:

- it identifies the methodological background of territorial availability as one of the factors that determines decisions made on optimizing secondary vocational education network;
- it describes methodology to assess the territorial availability of secondary vocational education institutions and services;
- it assesses territorial availability and considers the impact of existing challenges, including disruptions on road network that decrease transport availability, on it as well as identifies how municipalities in Lipetsk Oblast are well connected to or isolated from secondary vocational education network and what territories have optimal or dissatisfactory territorial availability;
- it arrives at science-based conclusions and suggests alternative managerial decisions on reorganizing secondary vocational education network in Lipetsk Oblast, including reasoned proposals relating to specific educational institutions (their M&A or conversion).

4 Conclusion

All things considered, the findings will be of interest to the heads of regional departments of education, labor, and local employment when they make decisions on optimizing vocational education network as the empirical findings in this study provide a new methodology for assessing territorial availability of secondary vocational education institutions and services. Above all, this methodology may be adapted for any Russian region and applied without limitation. In addition, the case study of 30 secondary vocational education institutions of Lipetsk Oblast enables us to verify the applicability of the described methodology and the geoinformation system based therein and to prove their effectiveness.

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