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Digital Platform for Modeling the Development of Regional Innovation Systems of Russian Federation

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Abstract. The paper aims at the design of a digital tool for analyzing the impact of scientific and technological progress on socioeconomic problems and sustainable development of the region. The research focuses on the consistent development of a digital platform for analyzing and visualizing digital data on regional innovation development, as well as predicting the sustainable development of regions based on the available regional infrastructure of innovation systems and the Russian regions' cluster structure. When designing the digital platform, we gave special attention to ensuring efficient data collection, processing, and analysis processes required for studying the socio-economic system. In the course of the work, an automated process of working with data was developed. The digital platform is being developed as a flexible tool for a wide range of users, from research centers, investors, and private enterprises to individual users interested in regional innovation development models. As part of the work, the process of selecting technical tools for the software implementation of the platform in terms of tasks and technical features of designing digital platforms is presented. The result of the work is a prototype of the Russian regional innovation system digital platform with the implemented functionality of a personal account, a module of simulation experiments, and various approaches to data analysis and visualization. The research is carried out as part of a project to develop a digital model of the regional innovation system of the Russian Federation as a driver of sustainable development.

Keywords: Digital platform; Information systems; Regional innovation system; Sustainable development

1. Introduction

In 2022, the Russian economy faced changes in the foreign policy and epidemiological situation in the country and around the world that adversely affected the development, including socioeconomic systems. As a result, the Russian Federation ranked 47th in the Global Innovation Index in 2022, reflecting the ability of countries to innovate and the degree of success in their implementation. (Global Innovation Index, 2022). According to a study by the Higher School of Economics (HSE, 2022), negative contributions to the index composition were made, among other things, by the insufficient maturity of the conditions provided for the innovation creation and distribution cycle, the weakness of the institutional infrastructure, and the legislative framework under development. At the same time, the creation of incentives and the necessary infrastructure, the consolidation of the

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interests of stakeholders, the coordination of interaction, and the creation of a regulatory framework (HSE, 2017) relates to government management measures, as well as financial support for individual innovative initiatives. However, before selecting management tools and methods, it is necessary to monitor the current state of the socioeconomic system to develop the most effective plan (Harwahyu *et al.*, 2022). In addition, the control actions on the management object (the process of creating and distributing innovations) are performed by the participants of the process, which requires an open data source. It should provide a way to assess the current status and predict the system state (Stryn and Rodionova, 2020). Currently, socioeconomic research conducted, including for the purpose of making informed management decisions, is subject to digitalization trends (Zagloel *et al.*, 2021; Zvereva *et al.*, 2019). The introduction of digital platforms is common not only for solving the tasks of state statistical offices and research centers but also for business tasks (Shastitko and Markova, 2020), positively influencing profit increase (Cenamor, Parida, and Wincent, 2019), creating flexibility, expanding the coverage (Sutherland and Jarrahi, 2018) of enterprises' activities (Gutman *et al.*, 2022; Koroleva, Baggieri, and Nalwanga, 2020). The use of digital platforms allows automating of resource management processes (Abd-Rahman *et al.*, 2021), storing and analyzing big data, as well as modeling (Tarasov *et al.*, 2022), and predicting socioeconomic processes (Baran *et al.*, 2021; Belov *et al.*, 2021).

In order to monitor the state of the socioeconomic system of regional innovation development, this study aims to develop a digital platform as a tool to support informed management decision-making for a wide range of users, including research centers, investors, private enterprises, and individual users interested in regional innovation development models. A special feature of the digital platform is the improved functionality, which includes not only storage and visualization of data on the index of innovative development of regions but also a flexible tool for forecasting indicators of the innovation system by manually adjusting parameters. Within the project, the following techniques have been developed: data analysis to assess the resource efficiency of the regional innovation system, analysis and identification of cluster characteristics, and analysis of the relationships between the innovation systems and regional development parameters (Rudskaya *et al.*, 2022; Kudryavtseva *et al.*, 2021). Each of the techniques is a unique development and contains many steps implemented in the platform's program code.

The study examines international experience in the development and use of digital platforms for solving miscellaneous tasks. The issues of choosing platform design tools, data processing, and visualization are also raised. The research is carried out as part of a project to develop a digital model of the regional innovation system of the Russian Federation as a driver of sustainable development.

2. Methods

2.1. Analysis of the world experience in the development of digital platforms

The first stage of the research involved an analysis of international experience in the development and use of digital platforms in terms of diverse research tasks and implementation tools (Liu *et al.*, 2022; Sutherland and Jarrahi, 2018; Evtyanova, 2017). In this context, a digital platform is defined as a digital tool for handling digital data, encompassing tasks from collection and storage to analysis and modeling based on that data. The analysis of the international experience in developing digital platforms is carried out in order to study development trends and trends in the design of technical specifications for the platform. Therefore, the comparison criteria were the development methodologies and technologies, the scope of the application, and the app concept. Table 1

presents the results of the analysis of the international scientific community's experience in developing digital platforms.

Table 1 Analysis of digital platforms

Title	Technologies used	Methodologies used	Scope of application
DIGICOR (Liu *et al.*, 2022)	Java Messaging Services, Docker, Amazon Web Services, Java, ActiveMQ, AngularJS	EDSOA (Event-driven service-oriented architecture), Microservice infrastructure, FaaS (Function as a Service) or IaaS (Infrastructure as a Service), OPC Unified Architecture	The establishment of cooperative arrangements between small and medium-sized enterprises
Digital web platform for supercomputer modeling of particle deposition on substrates (Tarasov *et al.*, 2022)	JavaScript, Vue.js, Node.js, Express, Sequelize ORM, Quasar Framework, ParaViewWeb, Yaml.	SSR (Server-side rendering), SPA (Single page application)	Process modeling
LMDSS framework (Lean Manufactory Decision Support System) (Abd-Rahman *et al.*, 2021)	MySQL, PHP, Kepware	KBM (Knowledge-Based Modeling)	Decision support system for improving the manufacturing process
Analytical platform for socioeconomic studies (Belov *et al.*, 2021)	Kafka, Flume, Spark, HDFS, lizardfs, PostgreSQL, Contour BI, Neo4j	-	Support for socioeconomic oriented applications

By analyzing the obtained research results, we identified the general characteristics of the selected solutions, which were graded as the digital platform development trends. Web app concepts imply a client-server architecture. In this case, the platform program code is divided into (1) the client side responsible for processing the user interface, sending requests to the server, and receiving and processing responses from it; (2) the server side responsible for interacting with the platform database, performing resource-intensive data processing operations and then sending them to the client side. The use of technologies such as relational (PostgreSQL, MySQL) and non-relational (Neo4j) databases indicates the importance of assessing the database requirements, the amount of data, and the audience of the platform users. The use of the JavaScript programming language and its frameworks (Angular.js, Vue.js) is considered a certain standard in web interface design.

2.2. Digital platforms for the regional innovation system analysis

Further, we considered similar systems developed by specialists in order to analyze regional innovation development. This stage will allow adjusting the functional requirements and addressing options for visualizing integrated data. The Russian Cluster Observatory is a scientific, methodological, analytical, and consulting center in the field of regional, innovation, industrial, and cluster policy (HSE, 2023). The primary platform's visualization tool is a cartogram. This type of graph is visually intuitive for the user and allows quick comparison of regions. The platform has a wide register of information about each specific cluster. Despite the advantages presented, the digital platform does not provide sufficient tools for analyzing detailed data.

Canadian cluster map (Cluster Map, 2016) is a more advanced digital platform in terms of data analytics. This portal provides records of open industry clusters and regional business environments in Canada. The platform includes a broad range of data about the

region and clusters. However, the set of subjects for which information is available is limited.

The European Cluster Collaboration Platform (European Cluster Collaboration Platform, 2023) contains information about numerous cluster enterprises around the world. The portal includes a large number of different filters based on which the businesses of interest can be found. Note that, as in the case of the Russian Cluster Observatory, this platform does not provide a methodology for analyzing complex indicators. Hence, digital platforms are employed globally as fully functional tools for acquiring, processing, and analyzing digital data, enabling the prediction of socioeconomic indicator dynamics. Nevertheless, it is important to recognize and highlight both the distinctive features and drawbacks of existing solutions.

The cluster analysis algorithm for industries and aspects of human life in a country is applied in all platforms considered, which characterizes this method as the commonly used one in such platforms. It is also worth noting that none of the commercial platforms described above allows for predicting the development of the system with respect to changing the parameters of one of the systems. In addition, a significant drawback of all the presented systems is that they are built on the basis of predefined models and weights, which, in most cases, were chosen not empirically but according to the expert method. In practice, this will mean that when the external environmental conditions (economic, political, and others) change, it will be impossible to predict the dynamics of the indicators of the innovation system (Jonny and Toshio, 2021). It is this problem that is planned to be solved by developing a simulator for modeling scenarios of system development by manually configuring parameters.

3. Results and Discussion

3.1. Selection of tools and technical implementation

The choice of development tools is based on the requirements for the platform functionality and the specifics of its use. It is necessary to develop two sides of the application: the server one, which is responsible for interacting with the database and performing data analytics algorithms demanding computing power, and the client one, which is responsible for displaying the results and a user-friendly interface (Liu *et al.*, 2022; Shastitko and Markova, 2020; Constantinides, Henfridsson, and Parker, 2018).

TypeScript was chosen as the programming language for the server and client sides. This solution provided the platform's code base consistency. A huge number of libraries have been developed for JavaScript, the programming language into which TypeScript is compiled, which simplifies the development process and provides the necessary functionality of the digital platform. The platform's code base consistency allows developers to work successfully on both the client and server sides at the same time. In the case of the discussed above DIGIOR platform (Liu *et al.*, 2022), which used Java for the application's server-side and JavaScript for the client side, separate commands for each side of the platform would be required. TypeScript also facilitates code reading and managing by providing a description of types for the JavaScript language.

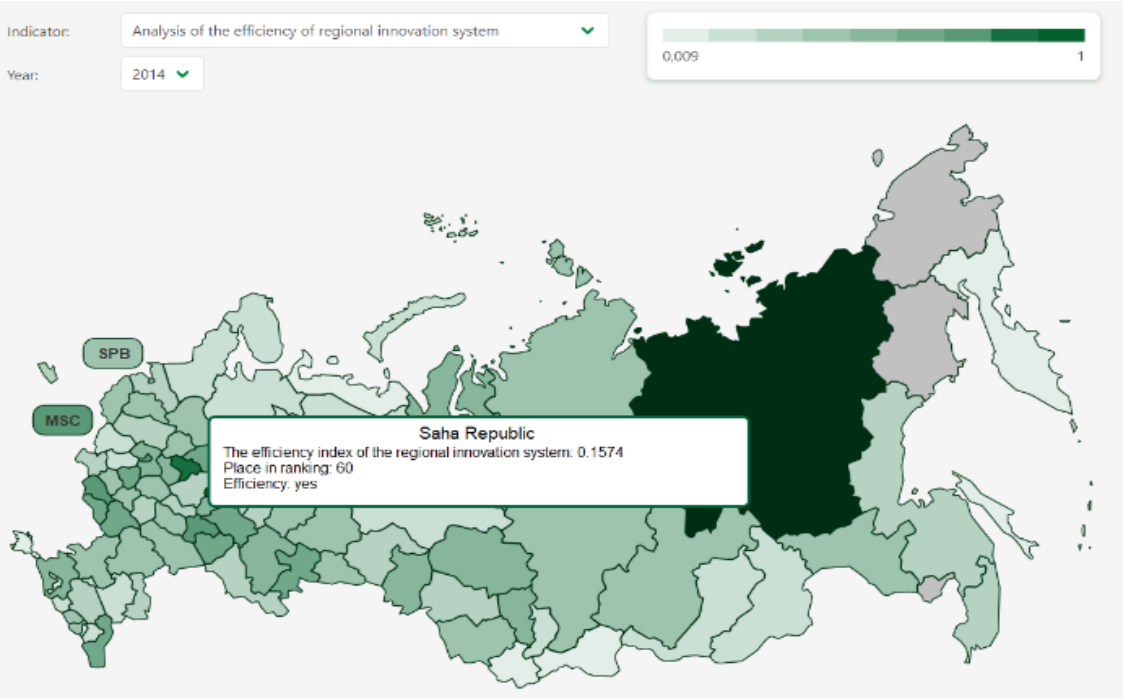
Since the digital platform implies the availability of a large amount of analytical information, data visualization is arranged in the form of various graphs. For this purpose, the Chart.js library is used, which simplifies the process of creating graphs in the web interface. The web interface is created by using the React library. This solution is superior to analogs in that the interface written with AngularJS (another library for client interface development used in the DIGIOR platform (Liu *et al.*, 2022)) is difficult to design and maintain. At the same time, Vue.js, used in a Digital web platform for supercomputer

deposition modeling (Tarasov *et al.*, 2022), is a fairly new technology, which is why frequent updates can lead to strong obsolescence of the code or stop its correct operation altogether. Initially, the SSR (server-side-rendering) concept was applied in the client-side design, which is why the decision was taken to use the Next.js library, providing tools for the technology mentioned above. However, later we decided to abandon this concept since it complicated the CI/CD process and required additional manipulations to synchronize states and switch to pure React.

An additional tool for implementing the server part of the platform is the Nest.js framework, which provides a wide range of solutions for organizing authorization, authentication, creating a REST API interface, and other aspects. The architectural solutions provided by it are easily scalable and well-supported. The technology allows for seamless transitions between designing client and server sides without necessitating a change in the programming language. JWT tokens are used to limit access to a registered user's personal account. Unregistered users can view the available statistics by region on the platform's home page and on the page of a separate region. Only registered users have access to the simulator and data download. Some functions of the personal account are limited by the role system. In addition to the user, the admin role has been added, which allows access to the database.

3.2. Data processing and visualization

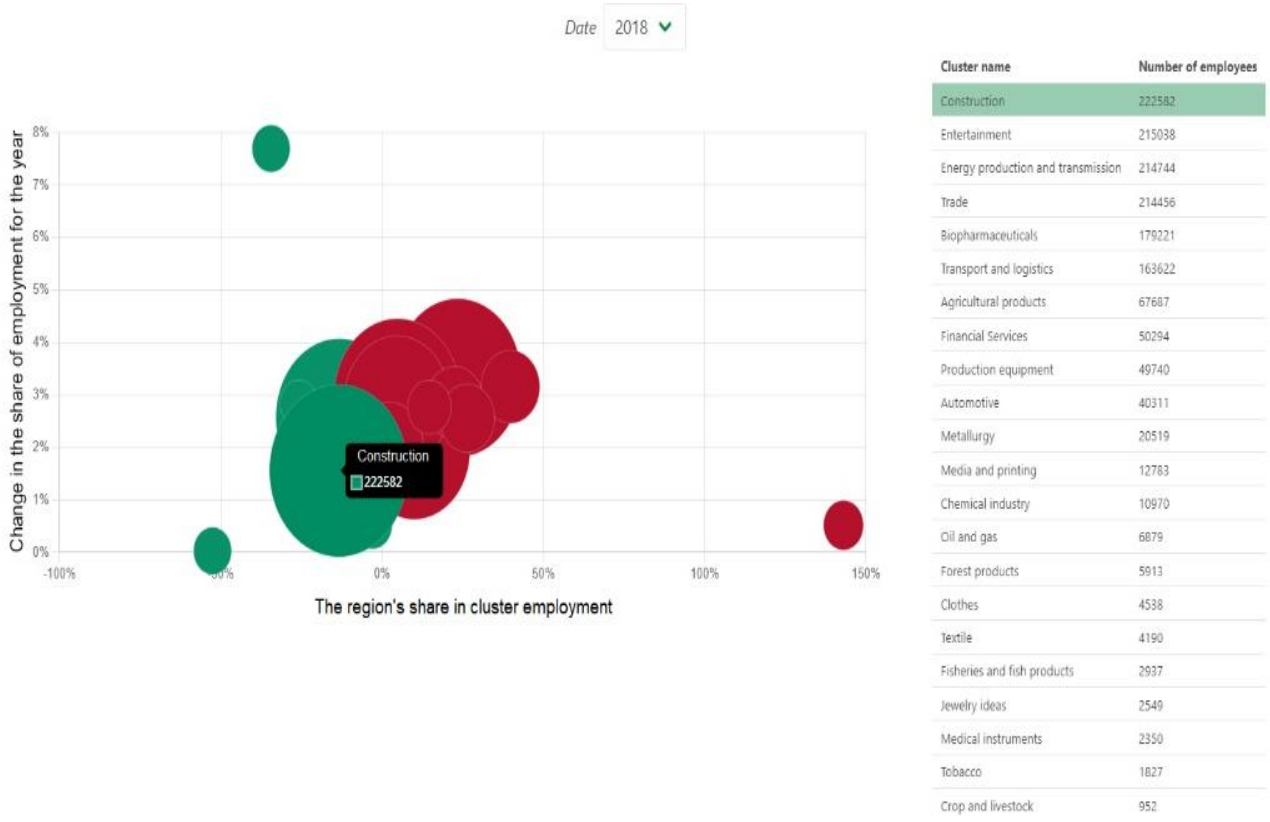
Since the platform under development has a huge number of Russian regional innovation system indicators, an important task was to conveniently present these data in the client interface. For these purposes, it was decided to organize the indicators in the form of various graphs, as shown in Figure 1(a) and (b) and Figure 2, which made it convenient to conduct a comparative analysis in terms of time and different regions.



(a)

(b)

Figure 1 (a) The cartogram of regions of the Russian Federation; (b) charts of indicators of development of the region



Cluster name	Number of employees
Construction	222582
Entertainment	215038
Energy production and transmission	214744
Trade	214456
Biopharmaceuticals	179221
Transport and logistics	163622
Agricultural products	67687
Financial Services	50294
Production equipment	49740
Automotive	40311
Metallurgy	20519
Media and printing	12783
Chemical industry	10970
Oil and gas	6879
Forest products	5913
Clothes	4538
Textile	4190
Fisheries and fish products	2937
Jewelry ideas	2549
Medical instruments	2350
Tobacco	1827
Crop and livestock	952

Figure 2 The chart of cluster employment

A comprehensive visualization of the main indicators available on the platform home page is implemented as a cartogram. This way, the user gets the opportunity to compare the dynamics of regional innovation development with an emphasis on territorial affiliation.

In order to ensure the consistency of data provided, it was decided to use a minimum set of color solutions since the cartogram is presented exclusively in green. The shade saturation is determined by the key indicator value. The general process of data handling when using a digital platform includes 4 stages (Figure 3):

1. Data input. The platform administrators select the information from open government sources of statistics necessary for calculating indicators. Then, the initial data processing is carried out, and they are uploaded to the platform through the personal account. The client-side initial data is processed on the server, taking into account the methods used, and then stored in the database. After the initial data processing, some indicators can already be used for graphical visualization on the platform pages;
2. Analytical data processing. The uniqueness of this platform lies in the use of methods for calculating regional innovation development indicators (Rudskaya *et al.*, 2022; Kudryavtseva *et al.*, 2021; Kryzhko *et al.*, 2020);
3. Operation. At this stage of the platform's operation, the user gets the opportunity to perform the necessary data samples and conduct simulation experiments through the developed simulator;
4. Data visualization. The processed data is presented through various graphs and tables, enabling users to independently assess information pertaining to regional innovation development. Often, the same data visualization is duplicated in both graph and table formats, enhancing the ease of perception for new users.

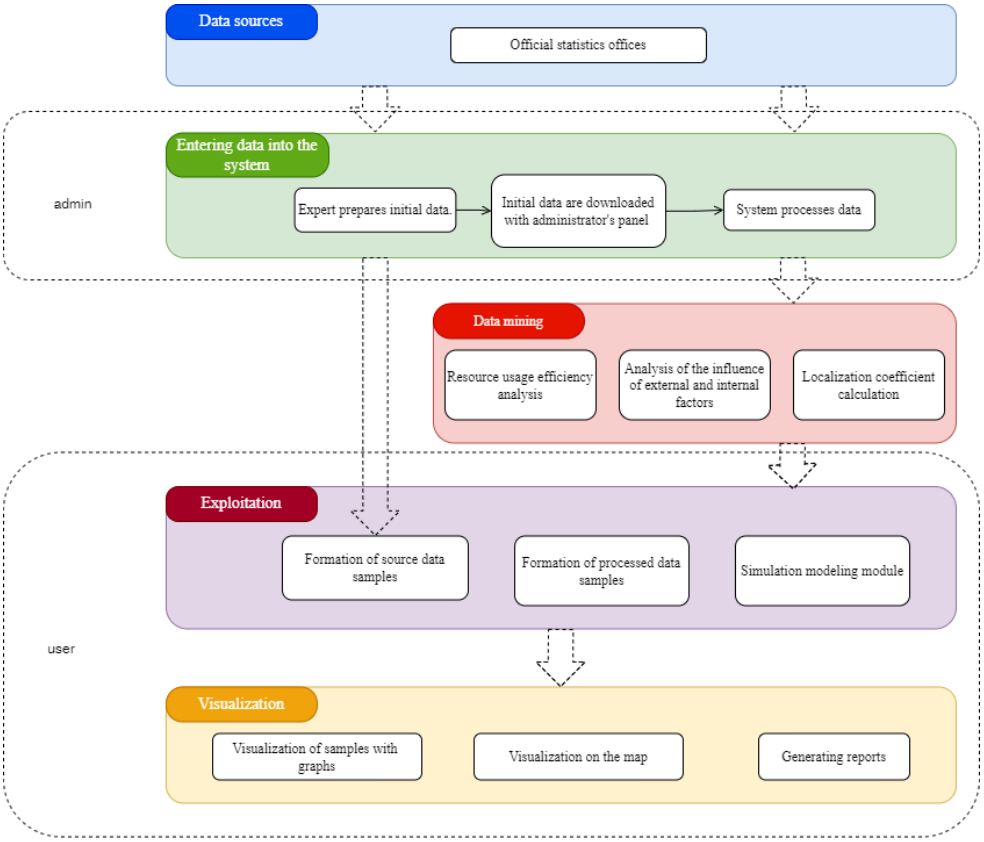


Figure 3 The general process of data handling

3.3. User's personal account

The user's personal account is designed to provide additional access to the interactive and computing capabilities of the platform. Within the first prototype of the user's personal account development, the following concept is assumed:

- The user's personal account contains one additional page with the user's personal data;
- Access to an additional mode of working with the platform is provided through the user's personal account;
- An additional mode of working with the platform allows recalculating the regional innovation index and the region's rating by changing the values of the calculation subjects.

It is worth noting that according to the research, the results of which are presented in the previous papers of the authors, the innovation index depends on the following indicators of regional development: economic development dynamics, social development dynamics, digitalization dynamics, activities of business entities, research centers, universities, and public policy. Each of these factors is divided into many more specific innovation development indicators.

Changing the calculation subject value leads to a recalculation of both the innovation index and each subject contribution. Therefore, in an additional mode, visualization of data on the share contribution of each subject in graphical and tabular form is added.

To analyze the contribution of changes in each of the innovation development index components, the chain substitution method of factor analysis is applied. Initially, the algorithm refers to the data on the innovative development index, indicators of actors, and conditions for a certain region for the year. The last parameters are set by the user through the interface. Then, differences between the data entered by the user and the values obtained from the database are found. Factor analysis is used to assess the impact of changes in these parameters on the increase or decrease in the index (Starovoytov *et al.*, 2019; Kucherova *et al.*, 2014). The chain substitution method is implemented by the gradual replacement of factors. Since the innovation development index of the region depends on 7 indicators, it is required to make 7 substitutions.

At this stage of development, the possibility of registration and authorization is implemented. The minimum required data for registration includes the user name and email address. This list will be expanded at the next stages of the project. The additional mode functionality has already been implemented on the server side of the application and will be further finalized in the user interface.

The developed digital platform includes a wide range of analytical data on the innovation development of the Russian regions. The home page of the platform provides access to regional data, including the regional innovation index, evaluation of the regional innovation system effectiveness, and information about regional clusters. Each of the regions can be considered separately from the others, providing detailed information about the region, such as employment in various areas of the region, increase or decrease in employment, region's technical efficiency, indicators of actors, and conditions affecting the innovation index. The simulator allows for predicting regional innovation development based on changes in actors and conditions of the region.

The automated functional and integration tests were developed to enable the addition of new functions without any changes to the already existing application logic and monitor the correctness of the interaction between the platform's code base and external modules, such as a database. The load testing of the platform revealed the maximum possible throughput of the digital platform, which coincided with the expected values.

At the next stage of the digital platform development, it is planned to finalize the simulator and automate analytical data processing techniques and data loading modules. Thus, the digital platform does not consider statistics on the most active regional enterprises that have a special impact on the socioeconomic development of the region, as is done on the platforms of the Russian Cluster Observatory (HSE, 2023), Canadian Cluster Map (Cluster Map, 2016), and Cluster Collaboration Platform (European Cluster

Collaboration Platform, 2023). Such enterprises' register arrangement, as in the Russian Cluster Observatory (HSE, 2023), will increase the analytical capacity of the platform.

4. Conclusions

The research focuses on the consistent development of a digital platform for analyzing and visualizing digital data on regional innovation development, as well as predicting the sustainable development of regions based on the available regional infrastructure of innovation systems and the Russian regions' cluster structure. Within the current context, the digital platform is being designed as a tool for studying the impact of scientific and technological progress on socioeconomic problems and sustainable regional development. The study provides an analysis of international experience in the development and use of digital platforms for the analysis of various socioeconomic systems. Based on the analyzed data and the project features, functional requirements for the platform are being developed. The process of selecting technical tools for the software implementation of the platform in terms of tasks and technical features of designing digital platforms is also provided. TypeScript was chosen as the main development language as the most versatile and functional tool for the server and client sides of the application. In the course of the research, an algorithm for working with data within a digital platform has been given, taking into account different user roles. The result of the work is a prototype of a digital platform for the Russian regional innovation system, featuring implemented functionalities such as a personal account, a module for simulation experiments, and diverse approaches to data analysis and visualization. The results encompass a detailed description of the technical aspects of platform design and can be adapted for use in other digital solutions. The research is carried out as part of a project to develop a digital model of the regional innovation system of the Russian Federation as a driver of sustainable development.

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