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THE INTELLECTUAL SUPPORT EFFICIENCY METHODS EVALUATION IN THE SPHERE OF SOCIAL INFRASTRUCTURE ACCESSIBILITY MANAGING FOR LOW-MOBILE POPULATION GROUPS

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Abstract. Modern society significant part is made up of People with Limited Mobility (PLM). This category of citizens is limited in movement and experiences problems of interaction with social infrastructure: first of all, these are people with disabilities (disabled people), who, according to the World Health Organization (WHO), make up more than 15% of the world's population, as well as people moving, for example, from baggage or stroller. Researchers identify three main problems in the interaction of PLM with social infrastructure: the first is related to the physical barriers of social infrastructure facilities (SIF) the second is the inaccessibility of information about SIF, and the third includes a number of social problems caused by the attitude towards PLM within society. Efficiency improving in the field of urban management and ensuring the information availability of SIF for PLM is possible through the use of geographic information technologies, electronic maps and digital city information systems, as well as specialized decision support systems. **The purpose of research** is to solve an urgent scientific and technical problem of implementing a support system for making informed management decisions in the field of ensuring the availability of information systems for PLM, as well as developing a methodology for assessing the effectiveness of the DSS. **Materials and methods.** Control theory for the development of an intelligent decision support method, software and hardware implementation tools, as well as an analytical, computational and graphical method for evaluating the effectiveness of development. **Results.** A DSS has been developed in the field of managing the availability of SIF for PLM. An assessment of the DSS functioning quality and efficiency was made, the analytical and graphical results of the efficiency assessment were reflected. **Conclusion.** The paper describes a methodology for the development of a DSS for managing the accessibility of SIF for PLM, including the introduction into the existing urban management system and evaluating the effectiveness of intellectual support methods in managing the accessibility of social infrastructure for PLM.

Keywords: DSS, management, intellectual support, decision-making, map, accessibility, territory, PLM, SIF, efficiency, quality

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ОЦЕНКА ЭФФЕКТИВНОСТИ МЕТОДОВ ИНТЕЛЛЕКТУАЛЬНОЙ ПОДДЕРЖКИ В СФЕРЕ УПРАВЛЕНИЯ ДОСТУПНОСТЬЮ СОЦИАЛЬНОЙ ИНФРАСТРУКТУРЫ ДЛЯ МАЛОМОБИЛЬНЫХ ГРУПП НАСЕЛЕНИЯ

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Аннотация. Значительную часть современного общества составляют маломобильные группы населения (далее МГН). Данная категория граждан ограничена в перемещении и испытывает проблемы взаимодействия с социальной инфраструктурой: в первую очередь это лица с ограниченными возможностями (инвалиды), составляющие по данным Всемирной организации здравоохранения (ВОЗ) более 15 % населения мира, а также лица, перемещающиеся, например, с багажом или коляской. Исследователи выделяют три основные проблемы взаимодействия МГН с социальной инфраструктурой: первая связана с физическими барьерами объектов социальной инфраструктуры (далее ОСИ), вторая заключается в недоступности информации об ОСИ, а третья включает ряд социальных проблем, вызванных отношением к МГН внутри общества. Эффективность решений в области обеспечения информационной доступности ОСИ для МГН может быть повышена за счет использования электронных карт городских территорий и ОСИ (цифровой город). Применение электронных карт в задачах анализа геопространственных данных возможно реализовать за счет проведения исследований и разработок в области геоинформационных технологий. **Целью исследования** является решение актуальной научно-технической проблемы реализации системы поддержки принятия обоснованных управленческих решений в области обеспечения доступности ОСИ для МГН, а также разработка методики оценки эффективности функционирования системы поддержки принятия решений. **Материалы и методы:** теория управления для разработки метода интеллектуальной поддержки принятия решений, программно-технические средства реализации, а также аналитический, вычислительный и графический метод оценки эффективности разработки. **Результаты.** Разработана СППР в области управления доступностью ОСИ для МГН. Произведена оценка качества и эффективности функционирования СППР, отражены аналитические и графическое результаты оценки эффективности. **Заключение.** В работе описана методика разработки СППР управления доступностью ОСИ для МГН, включая внедрение в существующую систему управления городским хозяйством и оценку эффективности методов интеллектуальной поддержки при управлении доступностью социальной инфраструктуры для МГН.

Ключевые слова: СППР, управление, интеллектуальная поддержка, принятие решений, карта, доступность, территория, МГН, ОСИ, эффективность, качество

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Introduction

Modern society significant part is made up of People with Limited Mobility (PLM). This category of citizens is limited in movement and experiences problems of interaction with social infrastructure: first of all, these are people with disabilities (disabled people), who, according to the World Health Organization (WHO), make up more than 15% of the world's population, as well as people moving, for example, from baggage or stroller. Researchers identify three main problems in the interaction of PLM with social infrastructure: the first is related to the physical barriers of social infrastructure facilities (SIF) the second is the inaccessibility of information about SIF, and the third includes a number of social problems caused by the attitude towards PLM within society. Efficiency improving in the field of urban management and ensuring the information availability of SIF for PLM is possible through the use of geographic information technologies, electronic maps and digital city information systems, as well as specialized decision support systems [1, 2].

The city can be viewed as an artificially created complex organizational system to meet the expanding needs of the population. The urban economy or its part, including elements of the urban environment, social infrastructure facilities and the population, can be represented using the theory of organizational systems [3].

The decision-making process in urban management in order to ensure high-quality social effects related to territorial planning, budgeting, operational information and other tasks in the management of social infrastructure facilities (SIF) of the city and affects a wide range of processes associated with the accumulation, processing and analysis of data on the urban environment, the characteristics of the SIF, public opinion, as well as the control of the correctness of the management process by federal and municipal authorities [4]. The field of urban and real estate management covers the interests of individuals and organizations with a variety of purposes, including enterprises engaged in property management, management companies and housing and communal services, authorities and the public, which have individual requirements for an automation system.

The processes of information provision, processing and analysis of data aimed at supporting decision-making in the field of managing the availability of SIF for PLM are laborious and require a long processing time due to the large volume, and are also difficult to identify and compare due to receipt from several sources, which leads to lead to errors and incorrect management decisions. Today, information portals have been created in many municipalities of Russia, the purpose of which is to meet the information needs in the field of accessibility of the SIF for PLM. However, often such resources do not have data analysis tools and solve a limited number of problems. Equipping government bodies and housing and communal services with decision support systems (DSS) is an urgent task due to the large volume of semi-structured data and the need for analytical and computational procedures for making management decisions. Fig. 1 shows the conceptual model of the DSS [5, 6].

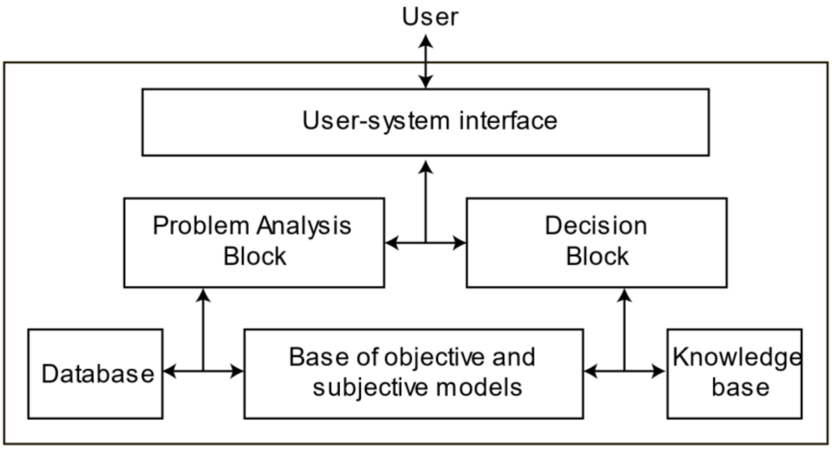

Fig. 1. DSS conceptual model

Methods

The problem of accessibility information inaccessibility of social infrastructure facilities for people with disabilities in many countries is an urgent social task supported by the state and public associations. (Fig. 2). Public authorities ensure the development and development of information resources aimed at solving the problem of information accessibility about the SIF. Such resources are often referred to as Disabled maps [7, 8].

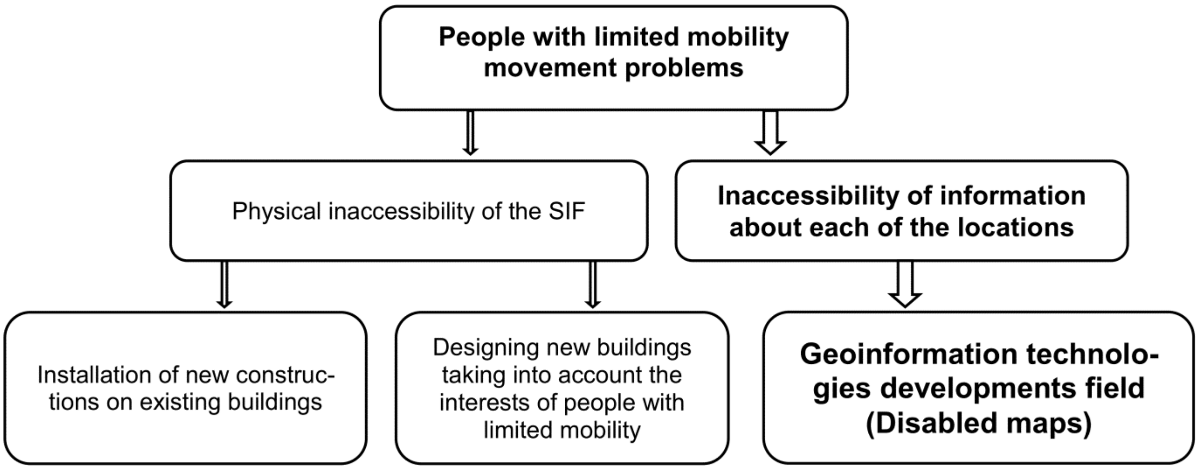

Fig. 2. Flowchart of SIF accessibility problems for PLM

The decision support process in the field of ensuring the social infrastructure availability is associated with the identification of structural features in unstructured territorial socio-economic data, complex indicators of SIF and territories, as well as spatial data coming dynamically from various sources. The main idea of the proposed decision support method is to solve two main tasks [9]:

1. Consideration and search of social infrastructure objects on the map and sorting by accessibility levels and other parameters. This problem is solved by means of GIS and spatial analysis.

2. The research of structured arrays of attributive, spatial and socio-economic data regarding the accessibility of the SIF. The problem is solved with the help of mathematical methods and algorithms for processing semantic and numerical data.

From the point of view of the scientific and methodological foundations for supporting the adoption of managerial decisions to ensure the accessibility of the SIF, the concept of software and information support for the process of managing the accessibility of the SIF for PLM is proposed (Fig. 3).

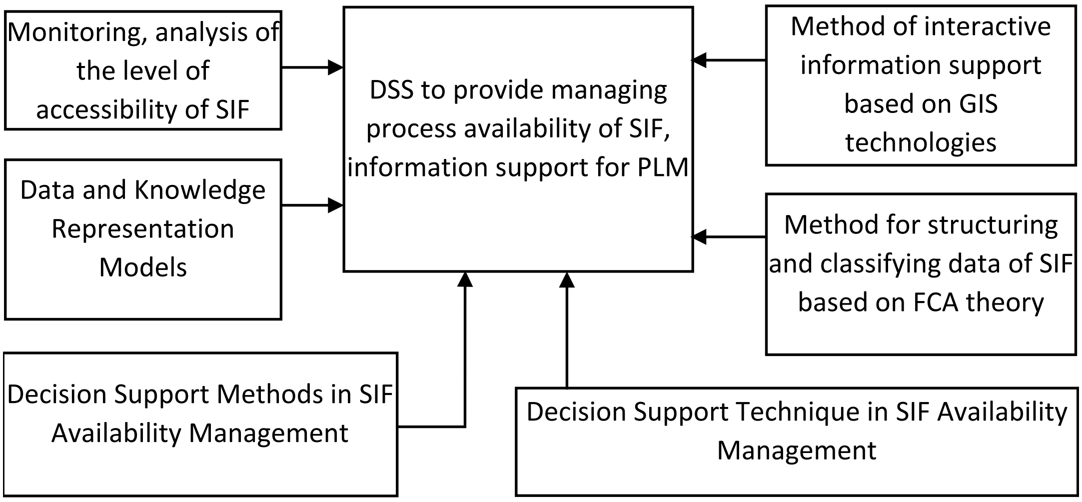

Fig. 3. Scheme of the concept of management decision support to ensure the availability of SIF

The decision support system consists of three main components: a database, a model database and a software system, which in turn consists of a database management system (DBMS), a model database management system, and a user interface management system [10]. The data from the database in the decision support information technology is used by the user for calculations using mathematical models. A software control system can be represented as a set of subsystems:

1. The communication subsystem, using queries, imports data that characterizes the state of the SIF to identify the degree of availability, exports the same data back to the DBMS with the result of identification.

2. The database update subsystem is designed to automate the transfer of data for calculations.

3. The analysis subsystem solves the problem of classification analysis, i.e. identification of the degree of severity of the accessibility of the SIF.

Decision support information technology is used at different levels of management and implies the coordination of decision makers at all levels. The structure of the decision support system, the functions of its constituent blocks that determine the main technological operations are shown in Fig. 4.

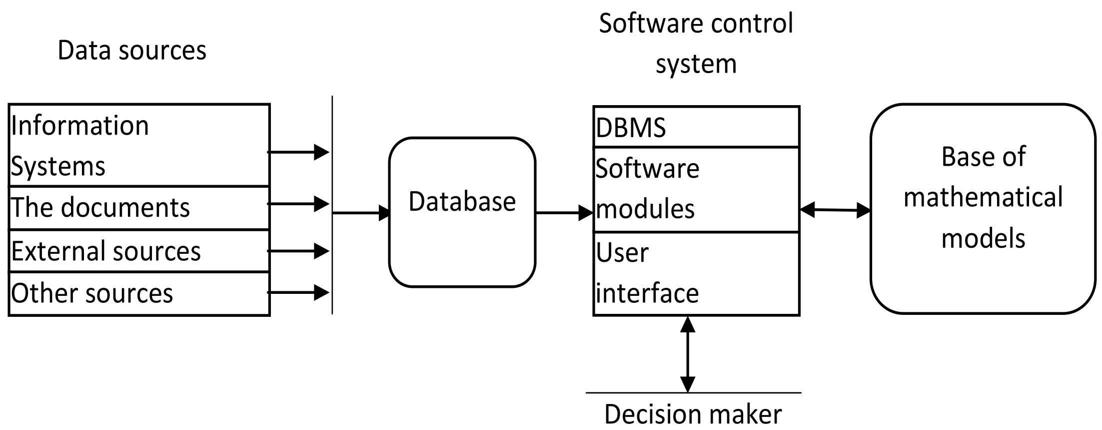

Fig. 4. Main components of decision support information technology

The user or decision maker, through the interface of the automated system, translates queries to the database, on the basis of which the database management system generates responses. The user receives answers in the form of generated documents displayed through the interface of the automated system. The results obtained make it possible to form a unified catalog of social infrastructure facilities, provide a classification according to the totality of the most common and most important features, and also provide decision support in the management of SIF for PLM [11]. This technology of data analysis and structuring allows building an ontology for searching and revealing new knowledge and intellectual support. The structure of the DSS in general can be represented as a process of interaction of the described blocks with each other (Fig. 5).

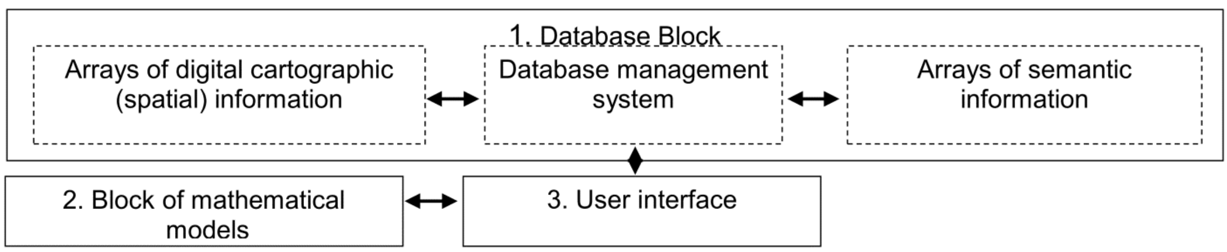

Fig. 5. DSS elements

A software-computer complex based on geoinformation technologies has been implemented, which makes it possible to accumulate, systematize, and effectively use folksonomic data to support the process of SIF for PLM availability managing and research tasks. A decision support system has been created that implements the developed models and methods to support the decision-making process in the field of managing the state of availability of the SIF for PLM. Fig. 6 shows the main window of the DSS created to control the availability of the SIF for PLM geowheel.ru [12].

The functionality of the system, the DSS for managing the availability of SIF for PLM, provides the introduction of information about point objects, linear and areal (polygonal) objects. Objects are connected by a single coordinate space and a single system of measures. The application of the developed methods in the real process of managing the state of availability of the SIF for PLM makes it possible to increase the efficiency of its implementation by improving the quality of information support through the use of the implemented DSS, as well as by significantly reducing the time spent on the analysis of folksonomic data.

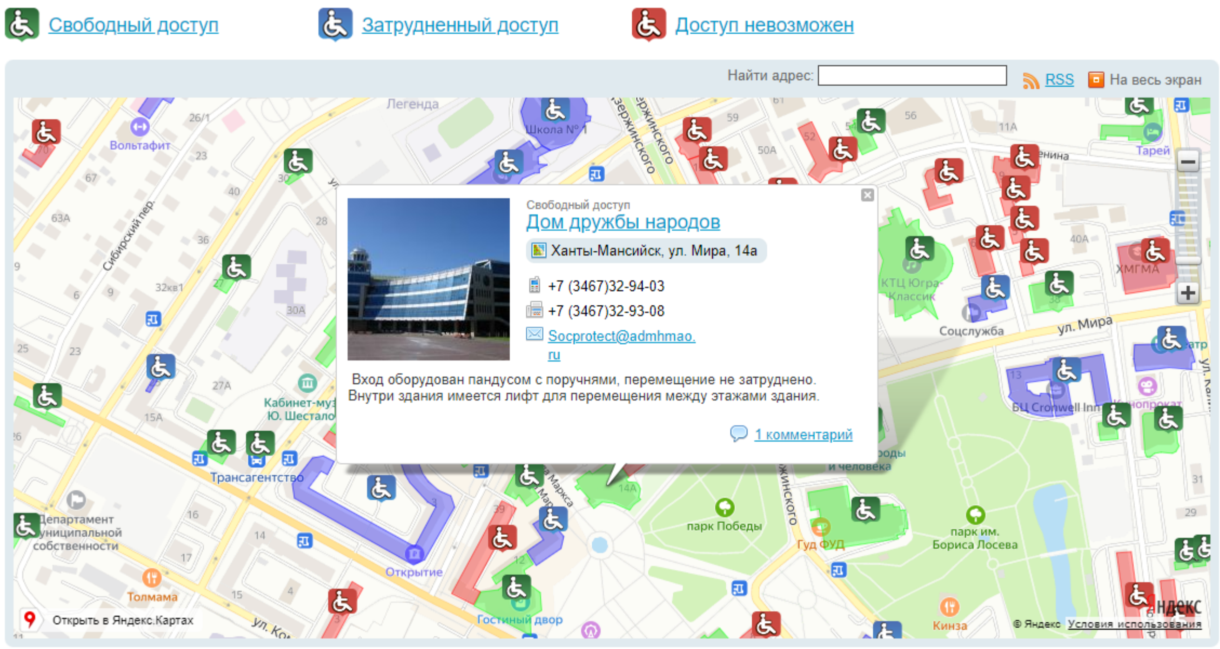

Fig. 6. Screenshot of the DSS created for managing the availability of the SIF for the PLM geowheel.ru

The developed DSS was put into operation and is actively used by authorities and departments, housing and communal services institutions and other organizations, as well as individuals. The implemented models and methods serve to meet the needs in obtaining formalized spatial data, as a geographic orientation tool, as an information and reference system for decision support, and provide opportunities for social information exchange. The system is used by PLM as a tool for spatial orientation, as well as by municipal authorities to make managerial decisions regarding the provision of informational and physical accessibility of social infrastructure facilities, in particular, it has been introduced into the work of the regional public movement of wheelchair users of the Khanty-Mansiysk Autonomous Okrug – Ugra “Transformation” (preo86.ru) and to the Federal Institution Khanty-Mansiysk branch of the FAU “Main State Expertise of Russia” (gge.ru), Information resources of the Administration of the city of Khanty-Mansiysk (admhmansy.ru) as a decision support system in the field of accessibility of SIF for PLM.

As the basic criteria for evaluating the effectiveness of urban management in the field of decision support to ensure the accessibility of SIF for PLM, it is proposed to use the actual indicators of the level of accessibility of SIF, reflected in the latest version of the state program of the Khanty-Mansiysk Autonomous Okrug – Ugra “Accessible environment in the Khanty-Mansiysk Autonomous Okrug – Ugra for 2016–2020”. The goal of the program is to ensure the availability of priority facilities and services in priority areas of life for people with disabilities and other people with limited mobility. The accessibility indicator was based on the criteria reflected in the annex to the table of achieved targets.

Immediate Outcome Indicators:

1. The share of priority objects of social, transport, engineering infrastructure accessible to disabled people and other groups of the population with limited mobility in the total number of priority objects, %.

2. The share of the rolling stock fleet of automobile and urban public transport, equipped for the transportation of people with limited mobility, in the fleet of this rolling stock, %.

3. The share of vocational education institutions in which a universal barrier-free environment has been formed that allows for joint training of people with disabilities and people without developmental disabilities in the total number of vocational education institutions, %.

4. The share of specialists who have undergone training and advanced training on the issues of rehabilitation and people with disabilities social integration, among all specialists employed in this area, %.

Outcome indicators:

5. The share of people with disabilities who positively assess the level of accessibility of priority facilities and services in priority areas of life, in the total number of people with disabilities, %.

6. The share of disabled people who received positive results of rehabilitation (adults (children)), %.

7. Share of people with disabilities who positively assess the attitude of the population towards the problems of people with disabilities in the total number of people with disabilities surveyed, %.

The annual values of the key indicators of the accessibility of the SIF can be represented as a series of successive stages ($Э_1, ... Э_N$), while at each stage the developed decision support system in the field of ensuring the accessibility of the SIF for the PLM is used to ensure the tasks ($ОЗ_1, ... ОЗ_N$) for urban management, obtaining information, solving the problems of accessibility of SIF for PLM (Fig. 7).

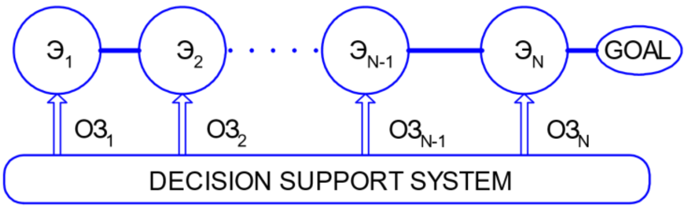

Fig 7. Stages (years) of operation of the DSS for managing the availability of SIF for PLM

The indicator Q_i has been introduced, reflecting the $i-th$ stage (year) implementation quality of using the DSS for managing the availability of SIF for PLM in the urban management system. It is proposed to use a linear approximation of the probability density function of the quality indicator to research the effectiveness of the use of DSS [13].

The analysis of indicators of the SIF availability criteria for PLM given above allows us to conclude that the quality assessment is measured as a percentage, that is, the quality indicator is a continuous value that takes values from 0 to Q_M. In relative units Q_i/Q_M, the value of the quality indicator $Q_i{}^*$ can vary from 0 to 1:

$Q_i{}^* \in 0{,}1;\ \ i = 1, \dots, n.$

The quality indicator of each stage (year) $Q_i{}^*$ of using DSS, taking into account a significant number of non-deterministic conditions, can be considered a random variable and characterized using the probability distribution density function. In this case, the probability density of the value $Q_i{}^*$ will depend on the efficiency and quality of the used DSS, which can be expressed as δ_i – the intensity of the influence of the DSS on the urban environment in the area of ensuring the accessibility of the DSS. In relative units, the value of the intensity indicator $\delta_i{}^*$can vary from 0 to 1, the larger the value, the more effectively the DSS affects the indicator of the availability of the SIF for PLM.

The process of urban management in the field of ensuring the availability of SIF for PLM is divided into stages (years), that is, each stage is determined by the presence of the previous one, and the probability density indicator of the quality of the current stage (year) implementation depends on the quality indicator of the previous stage (year). The quality of the implementation of the selected stage is related to the conditional probability density of the quality indicator $Q_i{}^*$:

$P\left(\frac{Q_i{}^*:}{Q_1{}^*:}, \dots, Q_{i-1}{}^*, \delta_i{}^*\right).$

For a simple serial circuit:

$P\left(\frac{Q_i{}^*:}{Q_{i-1}{}^*:}, \delta_i{}^*\right).$

The requirements for the level of availability of SIF for PLM at different stages (years) of using the DSS can be different and are determined as the value of the quality indicator for the implementation of the stage $Q_{yi}{}^*$ in the range $0 < Q_{yi}{}^* \le 1$, at which the established to the requirement stage. The most significant is the quality indicator of the final stage (Fig. 7 – GOAL), reflecting the result and effectiveness of the implementation of the DSS for managing the availability of SIF for PLM.

Implementation stages (years) are sequential, without feedback, which can be represented as a simple Markov chain of events, which allows us to express the n-dimensional probability density of the quality indicator along the entire chain as follows:

$$P(Q_0{}^*, Q_1{}^*, \dots, Q_n{}^*, \delta_1{}^*, \dots, \delta_n{}^*) = P(Q_0{}^*) P\left(\frac{Q_1{}^*}{Q_0{}^*}, \delta_1{}^*\right) \dots P\left(\frac{Q_n{}^*}{Q_{n-1}{}^*}, \delta_n{}^*\right),$$

where $P(Q_0{}^*)$ is the probability distribution density of the quality index at the chain input.

As a result of the introduction of the DSS in the field of managing the availability of SIF for PLM and use during stages (years), the probability of assessing the quality of the DSS is higher than satisfactory, can be represented as follows:

$$P({Q_1}^*, \delta_1, \dots, \delta_n) =$$
$$= \int_{Q_{y1}^*}^{1} \dots \int_{Q_{yn}^*}^{1} P({Q_1}^*) P\left(\frac{{Q_1}^*}{{Q_0}^*}, \delta_1\right) P({Q_2}^*) P\left(\frac{{Q_2}^*}{{Q_1}^*}, \delta_2\right) \times \dots \times P\left(\frac{{Q_n}^*}{{Q_{n-1}}^*}, \delta_n\right) \mathrm{d}{Q_0}^* \dots \mathrm{d}{Q_n}^*,$$

where ${Q_0}^*, {Q_i}^*, \dots, {Q_n}^*$ – the value of the DSS quality indicator at the corresponding stage in relative units;

$\delta_o, \delta_i \dots \delta_n$ – the value of the intensity of the influence of the DSS at the corresponding stage in relative units;

$P(Q_{i-1}, \delta_i)$ – conditional probability density of the quality indicator at the $i-th$ stage.

To assess the average value of the quality indicator of the use of DSS, the expression is formulated in the following form:

$$\overline{Q^*}(\delta_1, \dots, \delta_n) = \int_{Q_{y1}^*}^{1} \dots \int_{Q_{yn}^*}^{1} Q_0\, Q_1 \dots Q_n\, P(Q_0^o) P\left(\frac{Q_1^o}{Q_0^o, \delta_1^o}\right) \times \dots \times P\left(\frac{{Q_n}^*}{{Q_{n-1}}^*}, {\delta_n}^*\right) \mathrm{d}{Q_0}^* \dots \mathrm{d}{Q_n}^*.$$

A discrete assessment of the quality index Q_i characterizing the result of the $i-th$ stage (year) using the described expressions can be made for the known probability distribution law $P\left(\frac{{Q_i}^*}{{Q_{i-1}}^*}, {\delta_i}^*\right)$. Finding the probability density function is possible experimentally, while it is possible to distinguish the properties that characterize this function:

– The quality of ensuring the availability of SIF for PLM at each stage depends on the degree of use of the DSS (the more intensively the DSS is used, the higher the quality).

– The probability of the quality of the $i-th$ stage depends on the quality of the previous stage (the higher the indicator, the higher the probability).

– The probability density function satisfies the following normalization condition:

$$\int_0^{Q_M} P\left(\frac{{Q_i}^*}{{Q_{i-1}}^*}, {\delta_i}^*\right) \mathrm{d}Q_i = 1.$$

With regard to the described properties, it is possible to approximate the function to a simple one. For example, a linear function was used, expressed as follows:

$$P\left(\frac{{Q_i}^*}{{Q_{i-1}}^*}, {\delta_i}^*\right) = \frac{1}{Q_M} - \frac{{\delta_i}^*}{2-{\delta_i}^*}\left(\frac{2{Q_{i-1}}^* - Q_M}{Q_M}\right)\left(1 - \frac{2{Q_i}^*}{Q_M}\right),$$

where $Q_i *$ – the value of the quality indicator at the $i-th$ stage in relative units;

Q_M – the maximum value of the quality indicator in relative units;

${\delta_i}^*$ – the value of the intensity of the influence of the DSS at the $i-th$ stage in relative units.

The behavior of the reduced function of three variables is possible to show with the help of curve graphs, for which one of the function parameters was selected and fixed. With a fixed (maximum) value of the DSS influence intensity indicator ${\delta_i}^* = 1$ on the quality of decisions made in the field of ensuring the availability of the SIF, it is possible to determine the form of the probability density function of the quality index of the support for the ensuring the SIF availability process for one of the stages ${Q_i}^*$ depending on the quality of the previous stage ${Q_{i-1}}^*$. The example of 2019 (stage) shows the dependence of the probability density of the quality of the DSS on the quality indicator of the $i-th$ stage, taking into account the different values of the quality indicator at the previous stage – Fig. 8.

With a fixed value of the DSS quality index at the previous stage ${Q_{i-1}}^* = 1$, it is possible to determine the form of the probability density function of the DSS quality index at one of the operation stages ${Q_i}^*$ depending on the quality of decision support ${\delta_i}^*$. The example of 2019 (stage) shows the dependence of the probability density of the quality and efficiency of decisions made on the intensity of DSS operation ${\delta_i}^*$ – Fig. 9.

Function behavior research with a change in the intensity parameter of the use of the DSS ${\delta_i}^*$ in the range $1 \geq {\delta_i}^* > 0$ is characterized by a change in the amplitude of the DSS quality density probability dependence, while the nature of the dependence remains unchanged. At zero intensity of use of DSS ${\delta_i}^* = 0$, the DSS does not affect the quality of decisions made when controlling the availability of the SIF for the PLM.

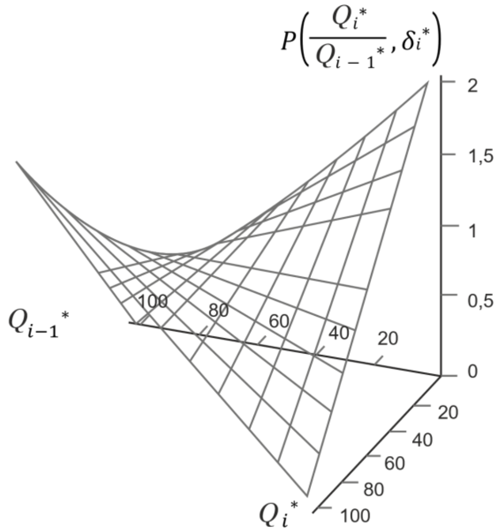

Fig. 8. The quality probability density of the DSS at a fixed (maximum) value of the DSS influence intensity

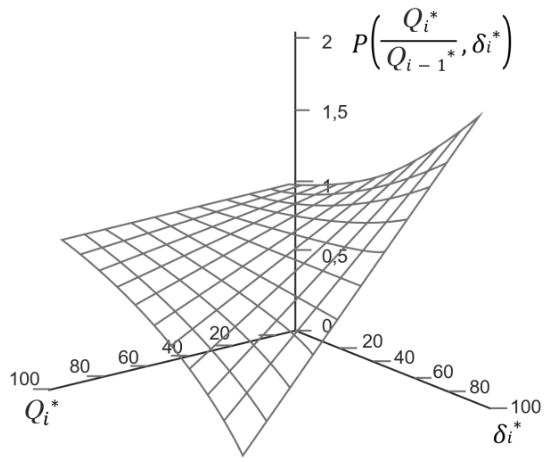

Fig. 9. Probability density of the DSS quality at fixed (maximum) of the DSS influence intensity value

To determine the required DSS use influence level in urban management, an indicator of the DSS number of usages was introduced – m. With known values of the probability density decisions made quality distribution, it is possible to establish analytical quality average value dependences and effectiveness $\overline{Q^*} = f(m, \delta)$ on the use intensity level δ and the number of usages m. The type of the described dependencies is presented using the graph in Fig. 10.

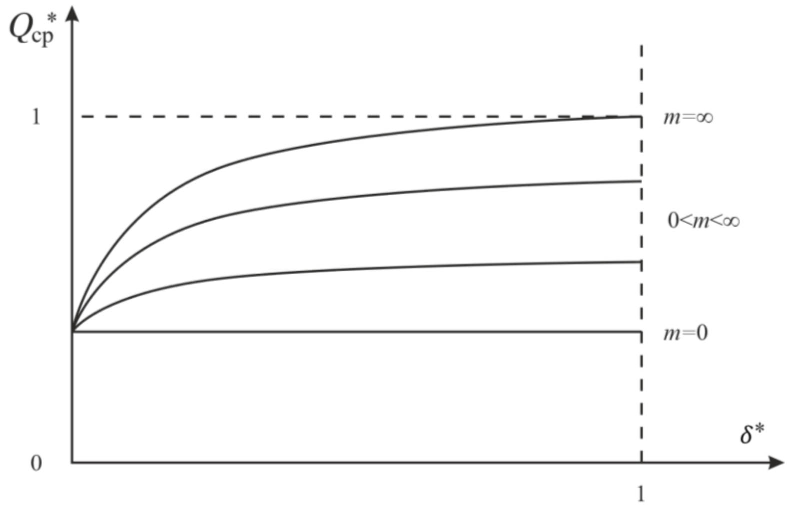

Fig. 10. DSS quality and effectiveness indicator dependence on the intensity of use and the number of usages

DSS quality indicator function behavior research allows us to conclude that with an increase in the number of accesses to the DSS, the average value of the quality indicator grows non-linearly, tending to the maximum indicator. The resulting expressions give an idea of the DSS influence on the support quality for the management process of ensuring the SIF for the PLM availability. Based on them, the number of calls m to the DSS can be determined, at which the required quality indicator average value Q_{cp}^* of support for the urban management process is achieved, that is, the requirements for the composition and level of information content of the DSS for managing SIF for PLM availability.

Systematic research of public opinion using a variety of means and methods for collecting and analyzing information made it possible to ensure the objectivity and correctness of the implementation of the system for supporting the adoption of decisions in the field of managing the accessibility of the SIF, to ensure the effectiveness of public authorities in relation to the research topic, to form a qualitative social effect in ensuring the accessibility of the SIF. Public opinion, the opinion of the citizens themselves, including PLMs and people with disabilities, played a special role in assessing the effectiveness of the SIF accessibility management system [14, 15].

The development and implementation of new techniques, means and methods, technologies of intellectual support and management support, their widespread development by government bodies and citizens contributes to the creation of important prerequisites for a serious improvement in the functioning of the state-civil regulation of the level of accessibility of SIF in the context of the country's dynamic development.

To date, the developed DSS is used in various subject areas as a tool for improving the productivity and quality of management decisions in the field of accessibility of SIF, significantly speeding up the process of substantiating and making decisions. In the foreseeable future, it is possible to improve the functioning of the developed DSS for managing the availability of SIF for PLM in the following areas:

- Development of a methodology for forecasting the prospects for various options for decisions made from an economic and social point of view.
- Development of a method for intellectual identification of a spatial object (SIF or other object of the urban environment) on raster and vector maps.
- Development of a methodology for classifying SIF by class with division into subclasses with the determination of the percentage of belonging to a particular class (subclass).
- Development of a methodology for developing recommendations for various services of municipal government and housing and communal services.
- Integration of data exchange processes between DSS and regional social services, health authorities, housing and communal services.
- Implementation of standards for ensuring the accessibility of PSI in the work of social services and authorities.
- Development of methods for improving the quality of social communication between society and the state, the level of education in the field of regulating the accessibility of SIF.
- Ensuring information interaction with other related SIF accessibility management systems.

Discussions and Conclusions

The paper solves an urgent scientific and technical problem of implementing information support for making informed management decisions in the field of managing the state of the availability of IOS for PLM. The application of the developed methods in the real process of managing the state of availability of the SIF for PLM makes it possible to increase the efficiency of its implementation by improving the quality of information support through the use of the implemented DSS, as well as by significantly reducing the time spent on the analysis of folksonomic data.

The use in practice of the developed technologies and algorithms, including the implementation in the form of a DSS of managing the availability of SIF for PLM, made it possible to evaluate the effectiveness and quality of the development and the correctness of the methods used in relation to the research topic. A methodology for assessing the overall effectiveness of the functioning of the DSS by the availability of SIF for PLM has been developed, an analytical, computational and graphical method for assessing the effectiveness of development has been presented. The quality of the work of the information system for decision support in the management of the availability of information systems for PLM was assessed, the results of the assessment of efficiency were shown, a retrospective analysis of the effectiveness of the introduction of DSS into the urban management system was performed.

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