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CONCEPTUAL MODEL OF FORMING A PROPOSAL FOR PROVIDING COMMUNICATION TO A UNIT USING ARTIFICIAL INTELLIGENCE

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Abstract. *The article discusses the problematic issue of the large time spent by a technical specialist when searching for options to provide communication to a unit in a new area. This paper analyzes commercial and non-commercial tools from both global companies such as Google, Ubiquiti, and special developments based on state military institutes. All of the considered tools allow technical personnel to find ways to solve the problems of building radio relay communication lines, but require professional knowledge and experience, which significantly increases the impact of the human factor on the result. A conceptual model has been developed that can be used to create software that will reduce the time spent analyzing the data required for decision-making, reduce human involvement, which in turn will increase the efficiency of a potential communication system. This data includes a topographic map of the area, the existing telecommunications network, a list of own mobile communications equipment, and the power grid. At the same time, the proposals provided by the program at the planning stage can be evaluated by the level of efficiency of the task according to the criterion of the best quality of the communication channel with the least involvement of communication means. User feedback will allow the built-in artificial intelligence to learn and provide better suggestions in the future. The purpose of this paper is to develop a conceptual model for the automatic construction of a communication system based on the existing telecommunication and topographic situation of the area, consider the possibilities of deploying (increasing) own (donated) means (equipment) of communication within the framework of the task. An additional extension of the model may be to take into account information about the power grid available in the area, which will reduce the financial costs of maintaining the communication system in constant operation (readiness).*

Keywords: artificial intelligence, communication means, conceptual model, radio relay communication

KONCEPCYJNY MODEL TWORZENIA PROPOZYCJI ZAPEWNIENIA KOMUNIKACJI JEDNOSTCE Z WYKORZYSTANIEM SZTUCZNEJ INTELIGENCJI

Streszczenie. *Artykuł omawia problematyczną kwestię dużego czasu spędzanego przez specjalistę technicznego podczas poszukiwania opcji zapewnienia komunikacji jednostce w nowym obszarze. W artykule przeanalizowano komercyjne i niekomercyjne narzędzia pochodzące zarówno od globalnych firm, takich jak Google, Ubiquiti, jak i specjalne opracowania oparte na państwowych instytutach wojskowych. Wszystkie rozważane narzędzia pozwalają personelowi technicznemu znaleźć sposoby na rozwiązanie problemów związanych z budową linii łączności radiowej, ale wymagają profesjonalnej wiedzy i doświadczenia, co znacznie zwiększa wpływ czynnika ludzkiego na wynik. Opracowano model koncepcyjny, który można wykorzystać do stworzenia oprogramowania, które skróci czas poświęcony na analizę danych wymaganych do podejmowania decyzji, zmniejszy zaangażowanie człowieka, co z kolei zwiększy wydajność potencjalnego systemu łączności. Dane te obejmują mapę topograficzną obszaru, istniejącą sieć telekomunikacyjną, listę własnych mobilnych urządzeń komunikacyjnych oraz sieć energetyczną. Jednocześnie propozycje dostarczane przez program na etapie planowania mogą być oceniane pod kątem poziomu efektywności zadania według kryterium najlepszej jakości kanału komunikacji przy najmniejszym zaangażowaniu środków komunikacji. Informacje zwrotne od użytkowników pozwolą wbudowanej sztucznej inteligencji uczyć się i dostarczać lepsze sugestie w przyszłości. Celem niniejszego artykułu jest opracowanie koncepcyjnego modelu automatycznej budowy systemu łączności w oparciu o istniejącą telekomunikację i sytuację topograficzną obszaru, rozważenie możliwości rozmieszczenia (zwiększenia) własnych (przekazanych) środków (sprzętu) łączności w ramach zadania. Dodatkowym rozszerzeniem modelu może być uwzględnienie informacji o dostępnej na danym obszarze sieci elektroenergetycznej, co zmniejszy koszty finansowe utrzymania systemu łączności w ciągłej pracy (gotowości).*

Słowa kluczowe: sztuczna inteligencja, środki komunikacji, model koncepcyjny, komunikacja radiowa

Introduction

In recent years, the number of natural and man-made disasters has increased significantly, and rapid elimination of their consequences is impossible without communication means. In this paper, we propose to consider the need to provide communications for power units and the population in different conditions and locations by examining the experience of active hostilities in the context of the full-scale invasion of Ukraine by the Russian Federation, the war between Hamas and Israel, and the civil war in Syria. After all, in the context of high-tech warfare, a delay in the passage of control and warning signals leads to the loss of lives, equipment and territories. At the same time, the deployment of military (power) units of all levels in combat orders requires communication specialists to quickly build up the communication system in certain positional areas. From a civilian perspective, it is important to restore the communication system that was disrupted by the hostilities in order to provide the population with access to alert and coordination services, Internet banking, etc. The easiest way to solve the problems is to use satellite communication terminals, but the equipment and cost of the communication channel are expensive. At the same time, the use of only one type of communication does not allow to fulfill the requirement for resilience. By resilience, we mean the ability of a communication system to perform tasks under the influence of various factors (physical damage, radio interference, cyber-attacks, etc.). Radio relay communication is the second most mobile means of deploying communication lines with the ability to exchange data in real time. However, the rapid and high-quality deployment of radio relay communication lines require high professional training of communications personnel.

The purpose of this paper is to develop a conceptual model for the automatic construction of a communication system based on the existing telecommunication and topographic situation of the area, think of the possibilities of deploying (increasing) own (donated) means (equipment) of communication within the framework of the task. An additional extension of the model may to allow for the possibility information about the power grid available in the area, which will reduce the financial costs of maintaining the communication system in constant operation (readiness).

1. Analysis of existing publications

Research of existing publications and developments in this area has indicated the relevance of the development of tools for organizing wireless communication (radio relay, WiFi). This is confirmed by the availability of commercial and non-commercial tools. The most well-known non-commercial tools that allow free use of their products in this paper are presented by Google (Google Earth Pro [27]) Fig. 1. and Ubiquiti (UISP Design Center [14]) Fig. 2.

For the organization of radio relay and tropospheric communication lines using military communications, there is a program called "Rakurs" (Fig. 3) [11, 25–26, 28]. As shown in Fig. 3, it uses a large number of maps, which increases both the possibilities of terrain analysis and its volume for the user. This program has data on the technical characteristics of the main radio relay and tropospheric lines used in the Armed Forces of Ukraine, which helps communication specialists in performing their assigned tasks [3–13, 15–18, 19–22].

Further research of the tools is proposed to be carried out in the direction of finding possible ways to build radio relay lines (RRL) with a length not exceeding 15 kilometers and antenna height up to 15 meters. The non-commercial tools presented in this paper from Google and Ubiquiti allow the user to analyze the radio visibility of the RFR, taking into account the topographic features of the area, consider natural and artificial obstacles [1–11].

The main disadvantages of the software under consideration:

- lack of complete and up-to-date data on available (operating) communication points and their technical capabilities in a given area;
- in case of detecting the absence of radio visibility of the RRL, the user must often spend a significant amount of time to find possible ways to solve this problematic issue of providing communication to a certain point. At the same time, the quality of the decision made largely depends on the user's experience and the time spent on finding the best way to solve this issue. For example, by introducing a relay point (Fig. 4).
- lack of data on the technical characteristics of all available communication means on the market, and/or the ability to manually create such means.

Thus, the development of software that will offer the user ways to solve the task of providing communication to a certain unit (organization), think about the characteristics of the area and evaluating the effectiveness of each option is an urgent scientific and applied task.

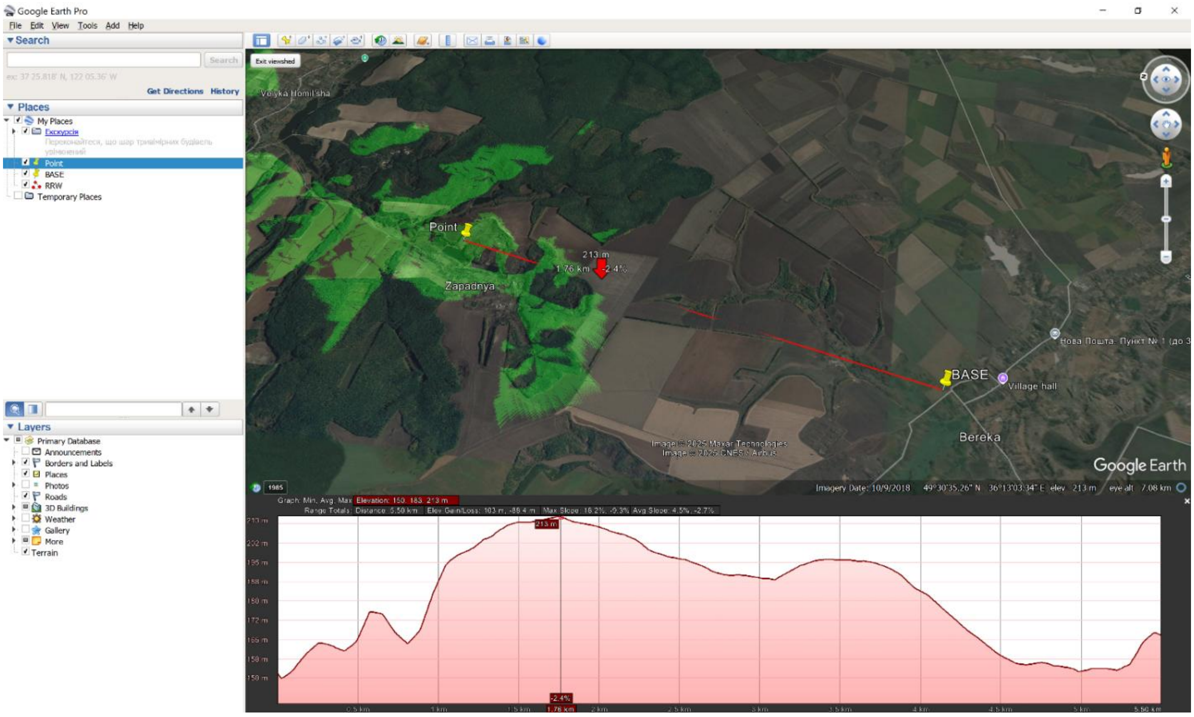

Fig. 1. Screenshot of the Google Earth Pro program for building a radio relay direction with radio visibility zones

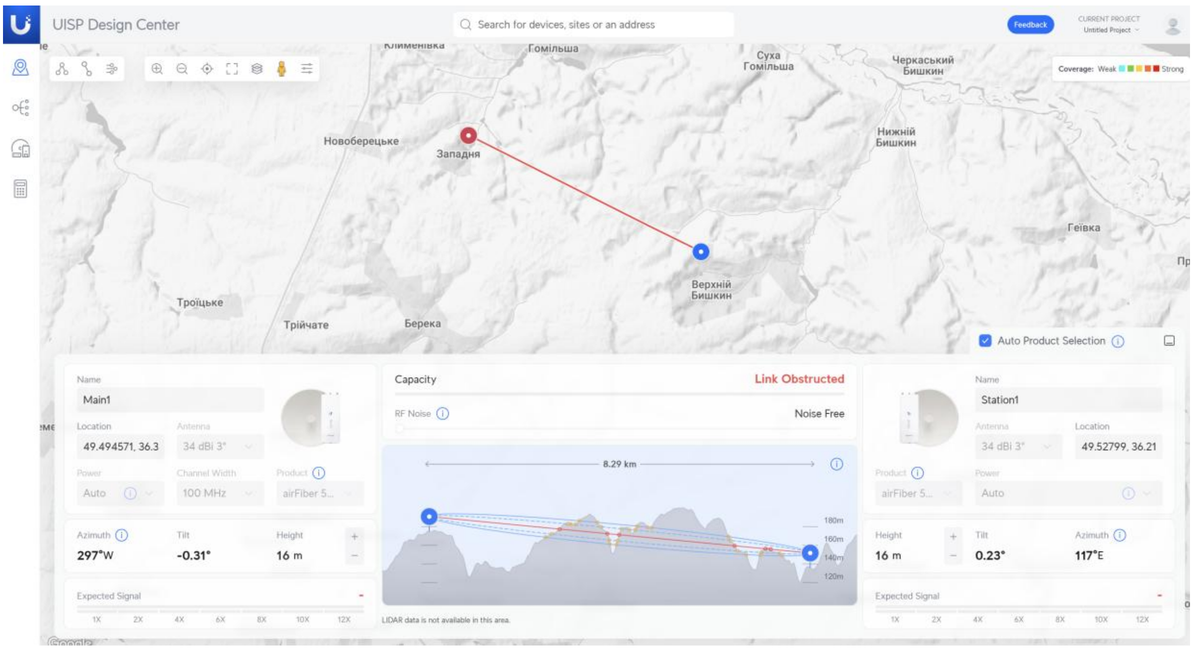

Fig. 2. Screenshot of Ubiquiti's UISP Design Center program for building a radio relay direction

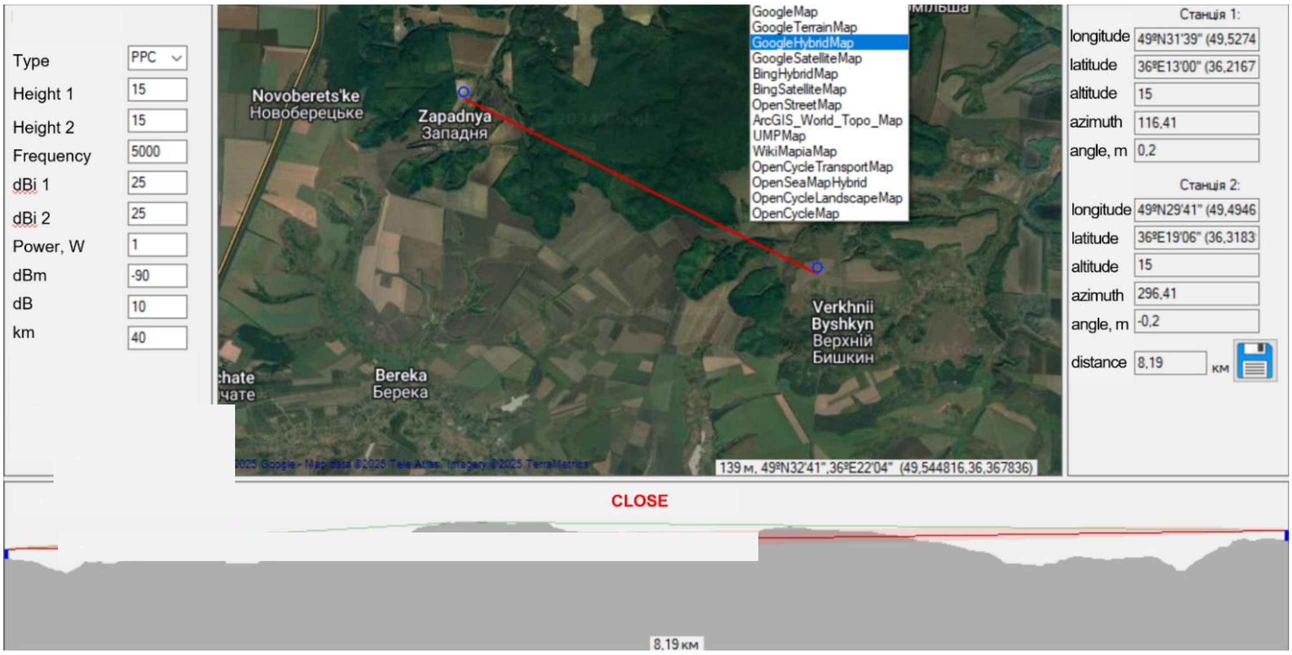

Fig. 3. Screenshot of the "Rakurs" program for building a radio relay direction

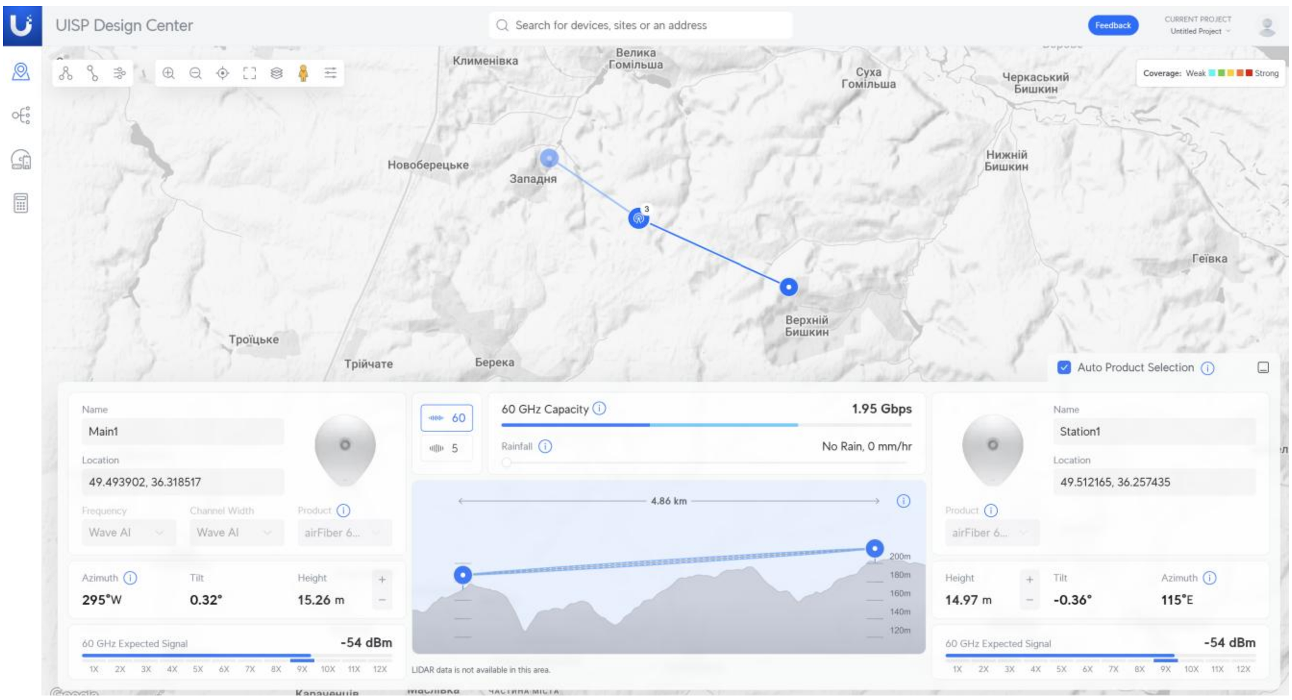

Fig. 4. Screenshot of Ubiquiti's UISP Design Center program for building a radio relay direction with retransmission

2. Development of a conceptual model

To develop a conceptual model (Fig. 5) for the automatic construction of a communication system based on the existing telecommunication and topographic situation of the area, taking into account the possibilities of deploying (increasing) own (donated) means (equipment) of communication within the framework of the task, it is necessary to determine the main input data that must thinking about for decision-making. In this paper, the task is understood as the decision of the organization's (company's) managers regarding the level of communication support for a unit in a certain area of work (task). The level of communication provision, in turn, means the number, type and type of communication channels, their capacity, quality, etc.

The main type of communication in this paper is radio relay communication due to the relatively short time to deploy a communication line, which allows data to be transmitted within line of sight. At the same time, the topographic features of the area, consider natural and artificial objects, are the main limiting factor that affects the ability to provide communication to a unit in a certain area.

Thus, the first element of input data for the formation of a communication proposal is a set of up-to-date information (database) (DB_{top}) about the topographic plan of the area, give consideration natural and artificial objects that may affect radio visibility.

The modern telecommunications system in Ukraine is well-developed, as evidenced by 3G/4G mobile coverage, which as of 2022 is estimated at 88% of the population's communication needs, and 93% by Lifecell. As you know, most 3G/4G stations in Ukraine communicate with each other via radio relay channels, which are an integral part of ensuring high-quality mobile communication. The high rate of meeting the needs of the population with mobile data exchange indicates the importance of having data on the exact location and technical characteristics of base stations, antenna masts, trunk communication lines, and deployed communication nodes of government and civilian organizations. After all, the analysis of these data will allow us to formulate the primary ways to solve the task. For the convenience of further use, it is proposed to formalize and organize the set of these data in a relational database.

Thus, the second element of input data for the formation of a proposal for providing communications is a database (DB) (DB_{net}) that contains information on the exact location and technical characteristics of base stations, antenna-mast structures, trunk communication lines, and deployed communication nodes of government and civilian organizations.

However, between 7% and 12% of the population does not have access to 3G/4G data exchange or has it in unsatisfactory (low) quality. To solve this problematic issue, it is proposed to involve additional means (equipment) of communication, antenna-mast devices, etc. The deployment of which will increase the level of communication coverage of a certain area. In order to formulate a proposal for increasing communication, the system (program) must have data on the available means (equipment), their models and technical characteristics. Analysis of these data will allow to form a list of proposals for their use with an assessment of their effectiveness.

Thus, the third element of input data for the formation of a proposal for providing communications is the database (DB_{ce}), which contains information on available mobile antenna-mast devices and communications equipment that can be used to increase the capacity of the telecommunications network in a particular area.

Radio signals do not respect legal laws (state borders, private property) or areas that are difficult to access (war zones, mountainous terrain, water obstacles), which is why it is important to have such data to increase the level of opportunities for implementing plans.

Thus, the fourth element of input data for the formation of a proposal for providing communications is the database (DB_{area}), which contains information about the area (territorial boundaries) of possible operation of communications groups (units).

An additional extension of the model may be to take into account information (DB_{power}) about the power grid available in the area, which will reduce the financial costs of maintaining the communication system in constant operation (readiness).

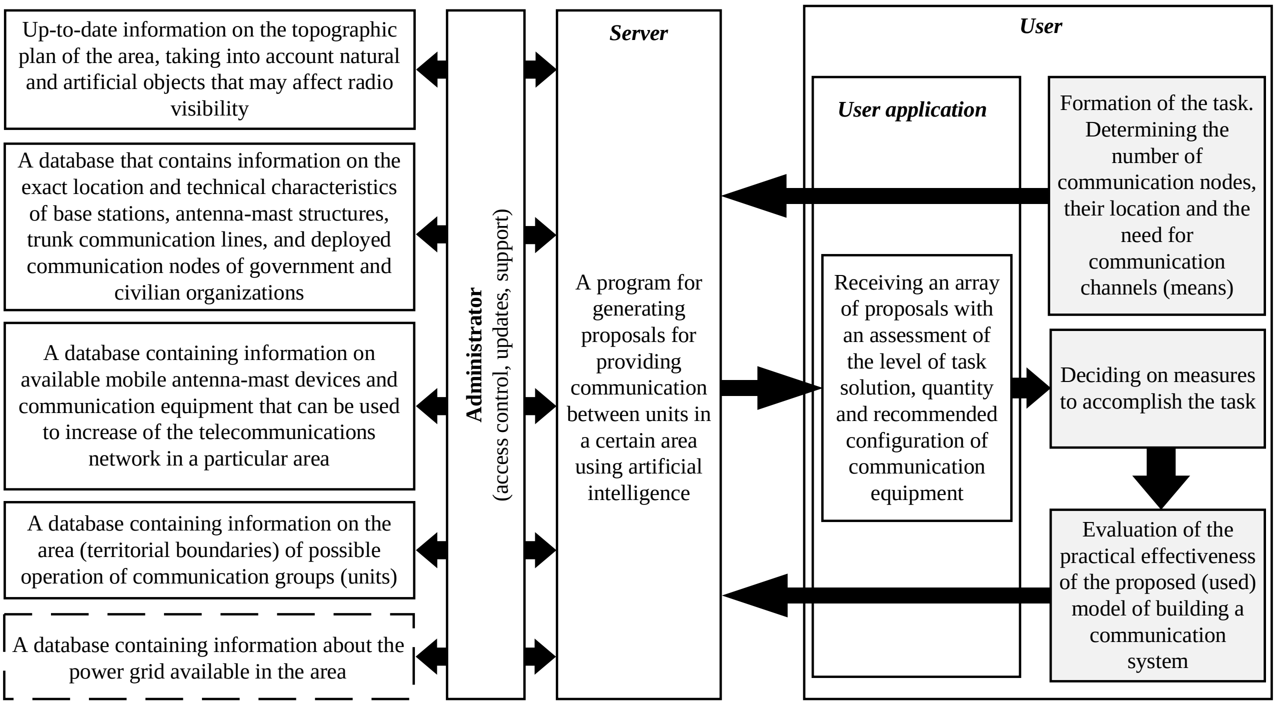

Fig. 5. Conceptual model of automatic construction of a communication system based on the existing telecommunication and topographic situation of the area

In a formalized form, the process of forming proposals for solving the problem will take the form:

$$DB_{area} \cap (DB_{net} \cup DB_{top}) \Rightarrow [p_i]_{el}, \quad (1)$$

where $[p_i]_{el}$ – an array of proposals for solving the problem of providing communication in an elementary way. That is, only through the existing telecommunications network, taking into consideration the terrain; i – the number of offers from 0 to max. In this context, the value max is the maximum number of possible offers that can be limited by the user.

In verbal form, formula 1 can be described in the following steps:

- selection of the territorial zone for solving the problem, consider access rights;
- identification of the existing telecommunication network in the area of the task;
- calculation of the capacity of the existing telecommunication network, reckon with the topographic features of the area.

In the absence of offers, or with a low efficiency assessment, the process of forming an offer may be complicated by think about possibility of deploying own mobile communications. Then, formula 1 will look like this:

$$DB_{area} \cap (DB_{net} \cup DB_{top} \cup DB_{ce}) \Rightarrow [p_i]_{int}, \quad (2)$$

where $[p_i]_{el}$ – an array of proposals for solving the problem of providing communication via an intermediate route. That is, bear in mind the existing telecommunications network, terrain and the possible deployment of own mobile communications equipment.

In order to reduce the cost of maintaining the deployed communication system, the user should be able to keep in mind the capacity of the power grid available in the area. Then, formula 2 will look like this:

$$DB_{area} \cap (DB_{net} \cup DB_{top} \cup DB_{ce}) \cap DB_{power} \Rightarrow [p_i]_{adv}, \quad (3)$$

where $[p_i]_{adv}$ – an array of proposals for solving the problem of providing communication in an advanced way. That is, reckon with the existing telecommunications network, terrain, deployed own mobile communications equipment and the state of the power grid.

The implementation of this program is proposed to be based on a client-server architecture due to the following requirements:

- confidentiality. The information in the proposed databases should have limited access, because its possession by an attacker can cause significant damage to the communication system. Also, the user should possess data only in the area of his/her responsibility to reduce the likelihood of data leakage from the database;
- relevance. Changes to the communication system at the local level can often be made that are unlikely to be tracked by individual users. Instead, making changes by the server administrator will reduce the human effort of this measure and provide all users with up-to-date data. The appropriate level of administrator access will further increase control over possible information leakage.
- operational efficiency. The volume of the database will reach tens of gigabytes, and storing it on the user's side will require increased requirements for technical means of using the software and communication channels for updating it. Instead, storing the database and performing calculations on the server will significantly reduce the requirements for both user communication tools and communication channels for the program to work.

As a result of implementing the developed conceptual model, it is expected to achieve:

- 40% reduction in time spent on reconnaissance of telecommunication equipment deployment positions by reducing human involvement and delegating the solution search to artificial intelligence (Fig. 6);
- improving the quality of radio relay direction building by 10% by using artificial intelligence to improve the accuracy of topographic mapping and applying expert opinion and user feedback (Fig. 7).

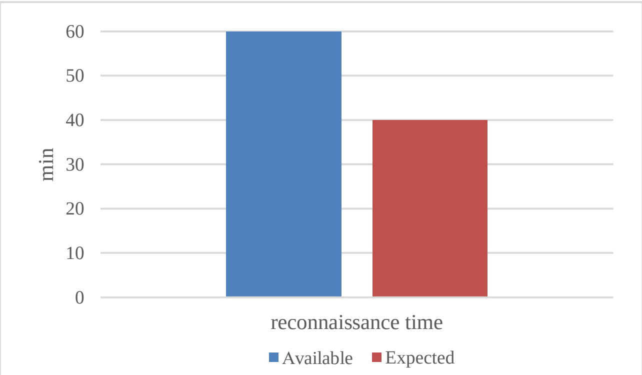

Fig. 6. Expected assessment of the effectiveness of the developed concept

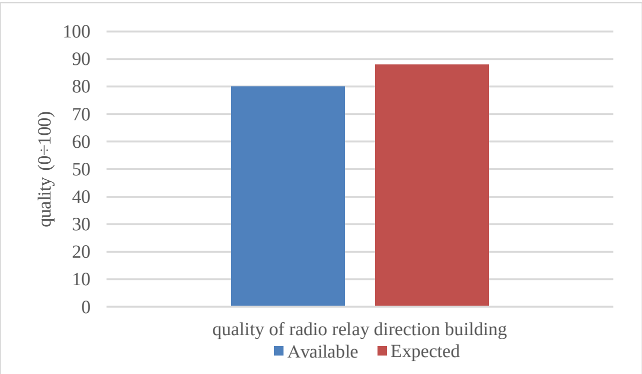

Fig. 7. Expected assessment of the effectiveness of the developed concept

The role of artificial intelligence is to find possible ways to solve the task with an assessment of the effectiveness (quality) of communication channels, the number of communication means involved, and give consideration data on the quality of existing (operating) communication channels in automatic mode and user feedback.

Implementing well-known machine learning methods with an expert will allow you to:

- reduce the time for decision-making (through the automatic analysis of Big Data);
- exponentially improve the quality of evaluation of the proposed options for building radio relay routes (due to user feedback);
- reduce the risk of personnel mistakes in decision-making.

3. Conclusions

A conceptual model for the automatic construction of a communication system based on the existing telecommunication and topographic situation of the area, take heed of the possibilities of deploying (increasing) own (donated) means (equipment) of communication within the framework of the task using artificial intelligence, has been developed. The possibility of additional expansion of the model is based on information about the power grid available in the area. The software implementation of the developed model will allow the user to reduce the time for making a decision on providing communication to a unit in a certain area of the task and can reduce the cost of power supply of communication means while maintaining the communication system in constant readiness.

Anticipated benefits from the deployment of the developed conceptual model include:

- 40% reduction in the time expenditure associated with site reconnaissance for telecommunication infrastructure, achieved by offloading analytical tasks to artificial intelligence, thereby minimizing direct human involvement;
- 10% uplift in the fidelity of radio relay link design, attributed to the utilization of artificial intelligence for more accurate topographic mapping, alongside the incorporation of professional expert evaluations and user-generated data.

Thus, the purpose of this work, which was to develop a conceptual model for the automatic construction of a communication system based on the existing telecommunications and topographic situation of the area, to consider the possibility of deploying (increasing) own (donated) means (equipment) of communication, has been achieved.

The next stage of the study is to develop a system of interaction between the databases of terrain topography, existing telecommunications network, own mobile communications, power grid, and permitted area. Define software architecture and database types.

The software implementation is planned to be implemented in the high-level programming language Java, Spring Boot framework.

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