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Architecture of a mobile transport route selection system by a team of volunteers in the conditions of the military state

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ABSTRACT

The work is devoted to the issue of designing the architecture of a mobile system for choosing the route of cargo transportation and passenger transportation by a team of volunteers under martial law. The system provides support to the decision-maker - the coordinator of the volunteer team in conditions of information uncertainty and dynamic changes in the external environment. The system allows you to receive and take into account operational information about the state of the route segments, which is provided by experts in the role of volunteers. The architecture of the mobile system for the volunteer team in the conditions of dynamic changes is client-server. The client sends data entered by volunteer experts to the server using a mobile phone or Internet connection. The volunteer team coordinator's mobile device is the server of the volunteer team's mobile decision support system. The server has a three-tier architecture: the presentation tier, the application logic tier, and the data tier. At the program logic level, a decision-making subsystem based on the multi-criteria modified Smart method is implemented. As a backup, data from the database on the volunteer team coordinator's device is uploaded to the database located on a remote web server. Based on the developed architecture, a mobile system for building a recommended route for a team of volunteers was developed in Java in Android Studio. As an application of the developed mobile system, a practical example of determining the best of five existing cargo transportation routes is considered.

Keywords: Mobile system architecture; decision- making; transport logistics; a team of volunteers; experts - volunteers

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INTRODUCTION

As a result of the military aggression of the Russian Federation against Ukraine, transport links between the country's cities have been destroyed and are being destroyed every day, which makes it difficult and sometimes impossible to deliver goods to consumers and transport people from dangerous zones [1]. Voluntary organizations are involved in solving this problem, the range of tasks of which has expanded significantly since the beginning of military operations in Ukraine [2]. However, the determination of the best route in the context of military operations and/or emergency situations is affected by the uncertainty of the state of the external environment. In [3], a conceptual model of decision-making by a team of volunteers is proposed, according to which information about the state of the route is provided by volunteer experts who are on different sections of the routes and have operational information about the state of the route. The coordinator of the volunteer team receives the provided information and makes the final decision on choosing the route. In the conditions of military operations and/or emergency situations, the use of information technologies will allow timely information on the state of the routes, which will allow the volunteer coordinator to take into account all factors and increase the speed and reliability of the received decision regarding the choice of the best route.

The most accessible means of information transfer today are mobile devices that allow you to transfer information using a mobile phone or Internet connection. But in the conditions of military operations and/or emergency situations, mobile communication or connection to the Internet may be temporarily unavailable. Therefore, the development of the above-mentioned mobile route selection system for a team of volunteers, which allows for the transfer of operational information from volunteer experts to the server using mobile and/or Internet communication, is relevant in practical terms.

ANALYSIS OF LITERATURE DATA AND STATEMENT OF THE PROBLEM

Finding the best route is one of the important tasks of transport logistics, the solution of which is greatly complicated by conditions of uncertainty state of the external environment. Transport logistics problems under stable transportation conditions include: transport problem [4], destination problem [5], traveling salesman problem [6]. The solution to the transport problem is the transportation plan from the point of departure to the point of need that is optimal according to some criterion. The destination problem is a partial case of the transportation problem, in which the number of departure points and needs coincide. The solution to the traveling salesman's problem is the distance-optimal route through all cities on the route from the point of departure and back to the point of departure, while each city can be visited only once.

The general characteristics of the above tasks include the following:

– the presence of one criterion: in the transport problem, it is the cost of delivery from the point of departure to the point of need, which must be minimized; in the assignment problem, the criterion can be the distance, or the delivery time, which is also subject to minimization; in the traveling salesman's problem, distance is the criterion;

– linearity;

– stable cargo transportation conditions.

However, in practice, problems of this type arise when there is uncertainty about the state of the external environment, in addition, the problems are multi-criteria and non-linear. For example, the transport problem according to the time criterion, which is minimized, is nonlinear, since in such a setting the objective function is represented by a nonlinear function of the variables [7].

In [8], the methods of solving multi-criteria transport problems were analyzed, which were divided into three classes: fuzzy programming with linear or nonlinear membership functions, genetic algorithms, methods of multi-criteria linear optimization. One of the methods of multi-criteria linear optimization, which is used when solving a multi-criteria transport problem, is the concession method [9]. In this case, a compromise solution is found, which provides the best solution according to the main criterion, provided that the solution according to the last criteria is not worse than the given one.

In [10], the authors propose a method for solving the canonical problem of transport logistics under conditions of uncertainty and propose a probabilistic formulation of the transport problem, where the cost of transportation is a random variable with a normal distribution law. In this regard, a set of density functions of random values of the cost of transportation is introduced, the density of the distribution of the random value of the total cost of transportation is determined, and the task is to find a plan of transportation that corresponds to the extreme value of the total cost of transportation under the appropriate restrictions.

In addition, multi-index transport problems are considered. Thus, in [11], a three-index problem is considered, in which to optimize transportation according to two criteria - transportation costs and cargo delivery time, additional transhipment warehouses are introduced, which is taken into account when solving the problem.

In the paper [12], the authors analyze the methods of solving the quadratic assignment problem, namely: the branching and boundary method; ant colony algorithm; genetic algorithms; taboo search. All these methods are time-consuming and do not find the best solutions when the dimension of the problem increases. The authors applied the Frank–Wolfe method to the solution of this problem, which made it possible to solve problems of large dimensions.

The analysis of the works showed that each individual practical task needs to be constructed the corresponding mathematical model and, depending on it, the development of the solution method. The solution is complicated by the growing number of criteria.

For the problems of transport logistics in the operational conditions associated with military operations, the state of the environment changes, which leads to a change in the number of criteria and makes it impossible to use classical optimization methods and their modifications to solve logistical problems. In this case, we have multi-criteria problems for the solution of which methods of multi-criteria selection are used [13-14]. In multi-criteria selection methods, the alternatives and criteria are known, but their number may vary depending on the state of the environment, while there is no need to build a new mathematical model and develop a new decision method. However, the increase in criteria affects the speed of decision-making regarding the selection of the best route. To solve this problem, decision support systems are used, which are based on multi-criteria selection methods [15], such as AHP (Analytic hierarchy process), MAHP (Multiplicative analytic hierarchy process), ELECTRE (ELimination et choix traduisant la realite), TOPSIS (Technique for order of preference by similarity to ideal solution), SMART (Simple multi-attribute rating technique), VIKOR (VlseKriterijumska optimizacija I Kompromisno resenje) [16]. Most of them are desktop or web systems.

However, when solving the task of choosing the best transport route by a team of volunteers under martial law, there is a need to develop mobile systems built on the basis of multi-criteria selection methods. Such systems should provide the members of the volunteer team with the opportunity to work autonomously regardless of the presence of an Internet connection, namely to send and receive operational information about the status of routes. The use of such systems should increase the speed of decision-making regarding the choice of the best logistics route by the coordinator of the volunteer team.

The author in [3] proposed a conceptual model for supporting decision-making by a team of volunteers in the conditions of dynamic changes in the external environment that occur as a result of military operations. The main idea of this model is that in order to take into account the state of the corresponding route, it is divided into sections, the state of which is monitored by members of the volunteer team located in places. This information is sent to the coordinator of the volunteer team, who, based on the information available to him, makes a decision on choosing the best route for the delivery of humanitarian cargo or passengers.

Within the framework of this article, it was decided to implement the previously proposed conceptual model in the form of a software-hardware representation. Namely, to develop the architecture of a mobile system for choosing the best transport route and implemented its based on multi-criteria selection methods.

Such systems should provide the members of the volunteer team with the opportunity to work autonomously regardless of the presence of an Internet connection, namely to send and receive operational information about the status of routes. The use of such systems should increase the speed of decision-making regarding the choice of the best logistics route by the coordinator of the volunteer team.

THE PURPOSE AND OBJECTIVES OF THE RESEARCH

The purpose of this work is to develop the architecture of a mobile system for choosing a transport route by a team of volunteers under martial law. The presence of such a system will allow the decision maker (DM) – the coordinator of the volunteer team – to work autonomously, receive and take into account operational information about the state of logistics routes, increase the speed of decision-making regarding the selection of the best logistics route.

To achieve the goal, the following tasks were formulated:

– designing the architecture of the route selection system for a team of volunteers in conditions of dynamic changes in the external environment;

– development of a mobile application for volunteer experts;

– conducting an experimental study of the developed system for choosing the best logistics route in real conditions.

ARCHITECTURE OF THE MOBILE TRANSPORT ROUTE SELECTION SYSTEM

When designing the architecture of a decision support system, it is necessary to take into account the communication between its components [1]. In work [3], a conceptual model of decision support for the task of transport logistics is proposed, which reflects the process of choosing the best logistics route by the commander of a volunteer team in conditions of dynamic changes in the external environment: determining the goal; formation of a set of alternatives; forming or updating a set of criteria; collection of information according to criteria. The peculiarity of this model is that operational information about the state of logistics routes comes directly from volunteer experts who are on the relevant sections of the routes. To take into account the peculiarities of information transfer from volunteer experts to the coordinator of the volunteer team, a scheme of information transfer in the system was built on the basis of this conceptual model (Fig. 1).

Volunteer experts, each of whom is responsible for their own section of the road, enter data about the state of the road section through a mobile application that is installed on their mobile phones. Before the volunteer expert starts filling in the data, his personal data is entered into the list of members of the volunteer team, and he is assigned a certain section of the road. To determine the state of the road section, volunteer experts choose answers to questions about the state of the road section from the proposed ones, in particular: evaluate the quality of the road surface; whether there are hostilities on the section of the route; whether there is a possibility of an enemy attack; is there a possibility of refueling; whether it is possible to repair the equipment;

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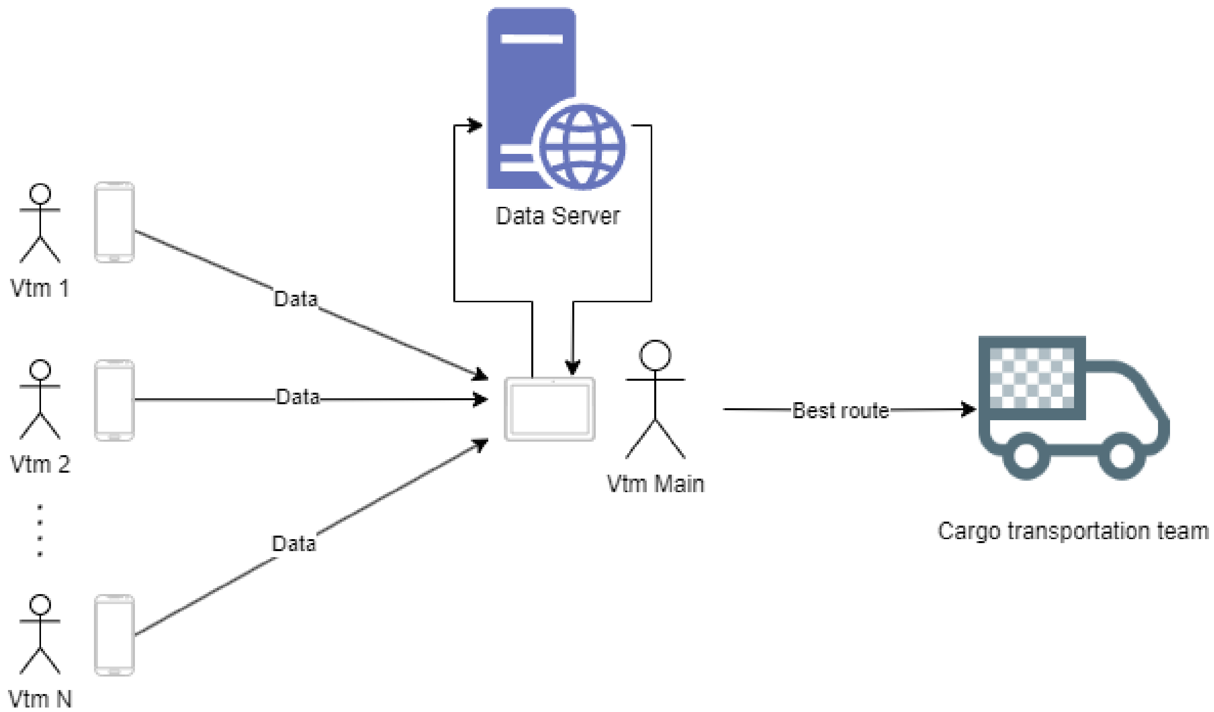

Fig. 1. **General scheme of information transmission in the transport route selection system**
Source: **compiled by the author**

Is it possible to receive medical assistance? In case of changes in the state of the site, volunteer experts update the data in the system. Thus, for calculations regarding the determination of the best route for the transportation of humanitarian cargo or passengers, up-to-date data on the state of the route sections from volunteer experts are transferred to the mobile system. The entered data is sent to the DM device on which the server part of the application is installed. DM enters into the system information about the distance between the point of departure and the point of destination and the average time of cargo delivery. After entering the data, the system calculates generalized estimates of the available routes under consideration. The DM analyzes the results of the calculations and makes a decision on choosing the best route from the available ones.

To ensure continuous operation of the system, data on route sections and the results of calculation of generalized route estimates are stored on a remote server in a database for backup. In the event that the DM device is damaged or the DM uses another device, it can receive information about data and decisions from a remote server.

Fig. 2 presents the architecture of a decision support system for a team of volunteers. The system consists of two systems: a data sending system and a decision support system. The data submission system is a mobile application for volunteer experts. The decision support system is a mobile application for the volunteer team coordinator.

The data sending system has a two-level architecture [17]: the presentation level and the application logic level. At the presentation level, the user interface and the user identification subsystem are implemented.

The application code of the view level is represented by the following classes:

– class IdentUser.java – implements the interface of the user identification subsystem, through which the volunteer expert is authorized in the system. After passing the identification, the expert-volunteer is allowed to fill in the data about his section of the route;

– class Data.java – implements the user interface through which data from volunteer experts enters the system (see Fig. 3).

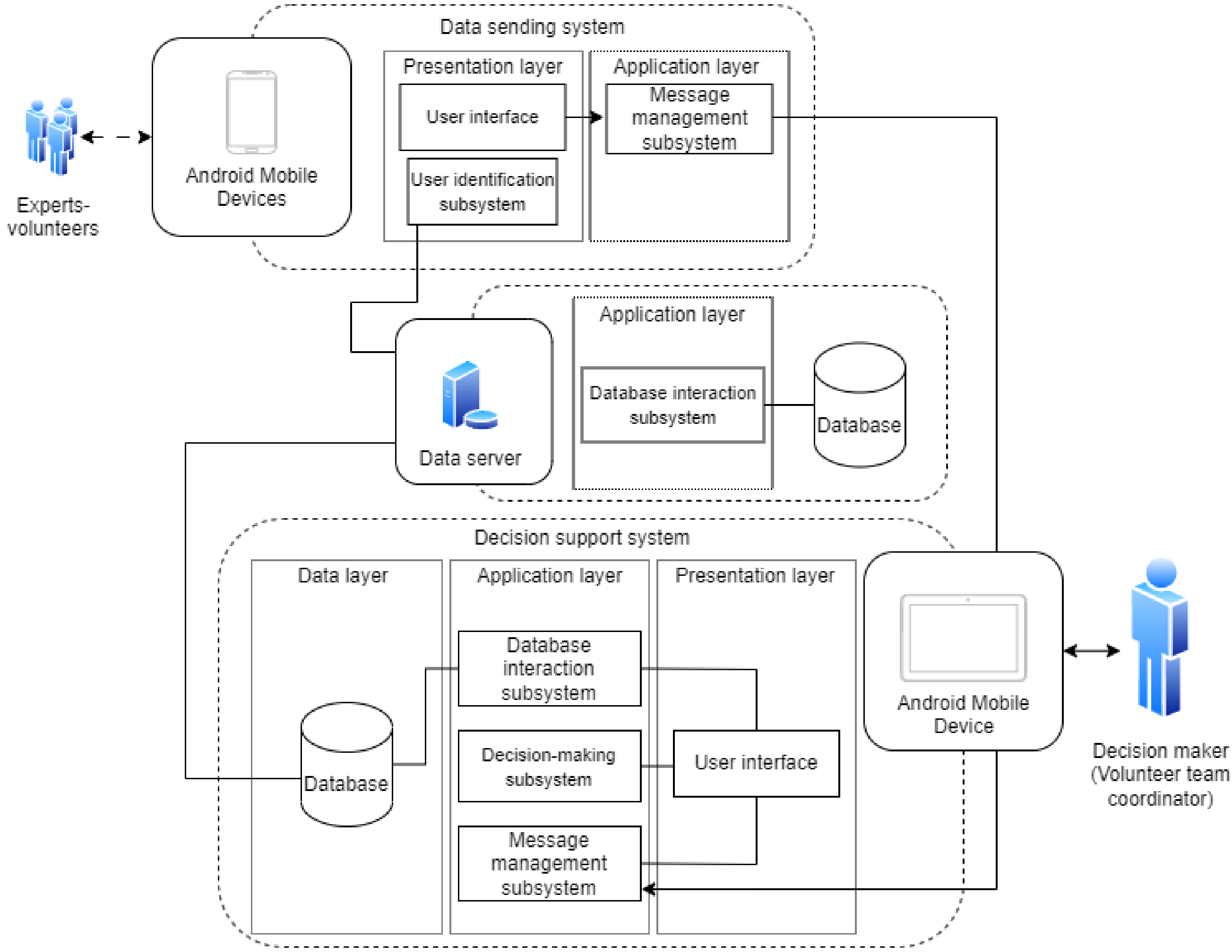

Fig. 2. **Architecture of the transport route selection system for the volunteer team**
Source: **compiled by the author**

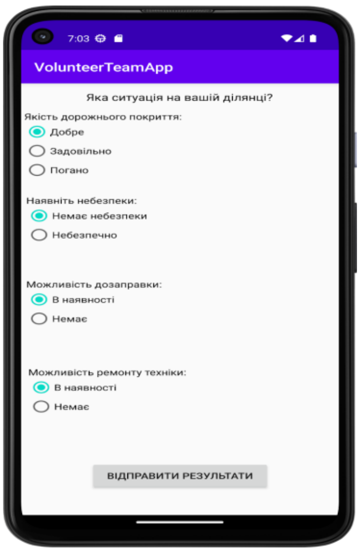

Fig. 3. **The interface of the mobile application of the expert-volunteer**
Source: **compiled by the author**

The send( ) method of which implements the processing of clicking the “Send results” button, namely, all data is collected and sent via the Internet to the DM device. If there is no connection via the Internet, a context menu opens with the option to select SMS messages as a method of data transmission.

The decision support system was developed in [18] and has three-level architecture: presentation level; application logic level; data layer. At the application logic level, a decision-making subsystem was implemented based on the modified Smart method [18, 19].

The SQLite relational database management system was used to create the database of the mobile SPPR. SQLite stores the entire database (including definitions, tables, indexes, and data) in a single standard file on the device running the application. Before the start of the transaction, the file in which the database is stored is locked, this simplifies the implementation.

The message management subsystem allows you to receive information from volunteer experts via the Internet or via SMS.

EXPERIMENTAL RESEARCH

The task of delivering humanitarian aid from Odesa to Mykolaiv was considered. 5 routes were investigated (see Fig. 4), which are shown in different colors on the Google map: the green color corresponds to the first route, 133 km long; the second route, 132 km long, is yellow; the third route with a length of 214 km corresponds to the turquoise color; the fourth route with a length of 145.54 km is purple; the fifth route with a length of 216 km corresponds to the gray color.

Each route is divided into sections for which an expert volunteer is assigned. So, the first route is divided into 7 sections, the second - into 8 sections, the third into 11 sections, the fourth into 7 sections, the fifth into 11 sections. Volunteer experts enter relevant information about the state of road sections into the system. Fig. 5 shows the windows that display the first window of the user interface of the mobile application of three volunteer experts with entered data on the state of the corresponding section of the first route: the quality of the road surface, the presence of hazards, the possibility of refueling and repairing equipment.

After entering the answers, the expert-volunteer clicks the “Send results” button and the data is sent as an SMS to the decision-making system located on the phone of the coordinator of the volunteer team.

An example of the window of the mobile application of the system, which is installed on the device of the coordinator of the volunteer team with the data received from the volunteer experts, is shown in Fig. 6.

By pressing the “Update” button, the data from the SMS is entered into the database of the coordinator's mobile application. In order to calculate the overall evaluations of the routes from which the best one is chosen, the DM enters the number of alternatives and criteria into the system; evaluations according to the criteria: distance and average speed; downloads data received from volunteer experts from the database (Fig. 7). Further, according to the modified Smart method implemented in the system [19], qualitative evaluations of alternatives according to criteria are automatically converted into quantitative ones and averaged. After entering all the data regarding the state of the routes, the DM clicks the “Get decision” button (Fig. 8a) and receives a window with ordered alternatives (routes). The best route has the highest overall rating and is ranked higher than other alternatives (Fig. 8b).

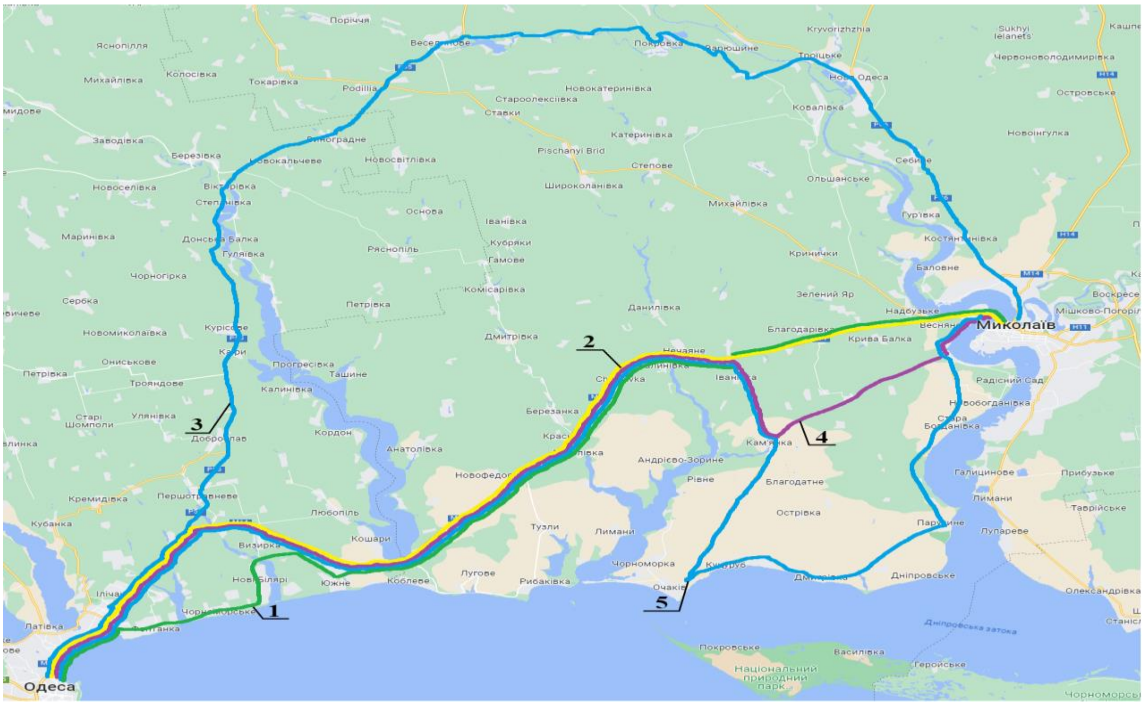

Fig. 4. **Google map [20] showing available routes**
***Source:* compiled by the author**

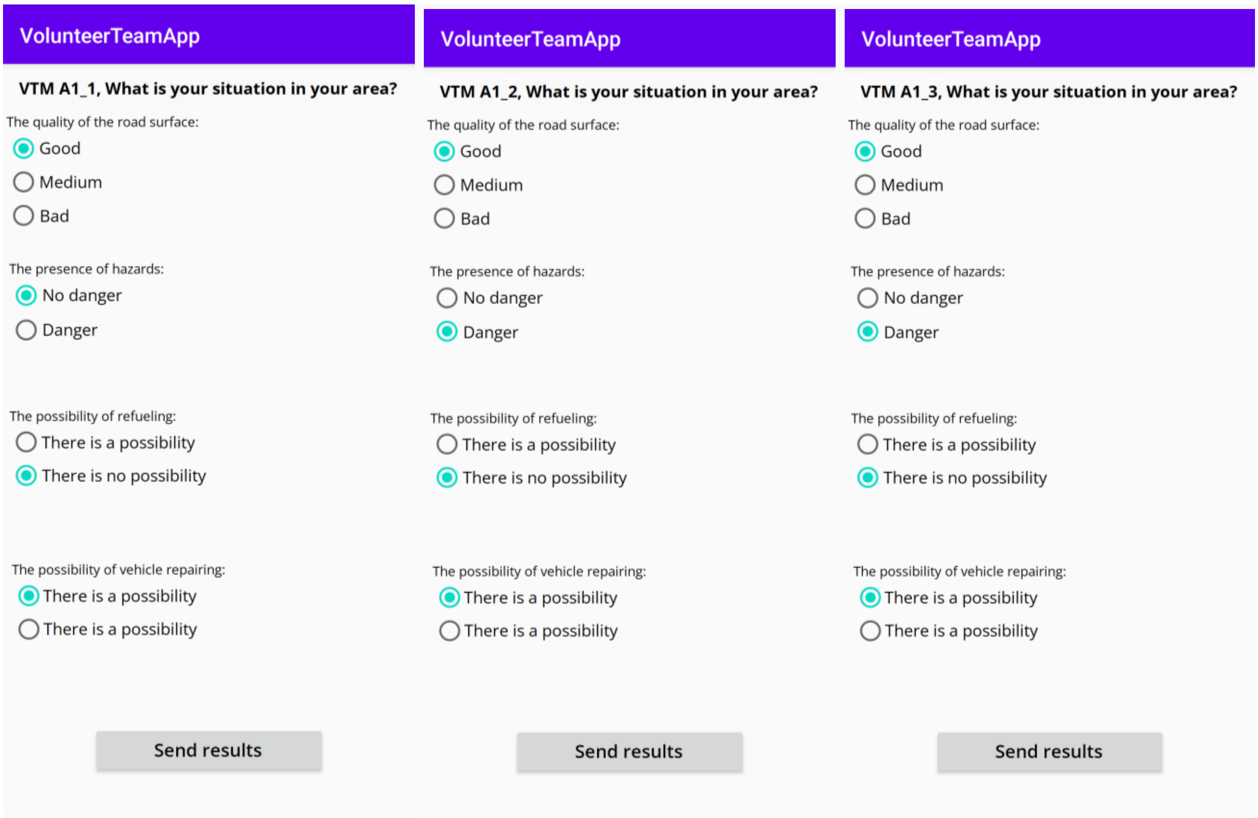

Fig. 5. **Interface windows of the mobile application of volunteer experts**
Source: **compiled by the author**

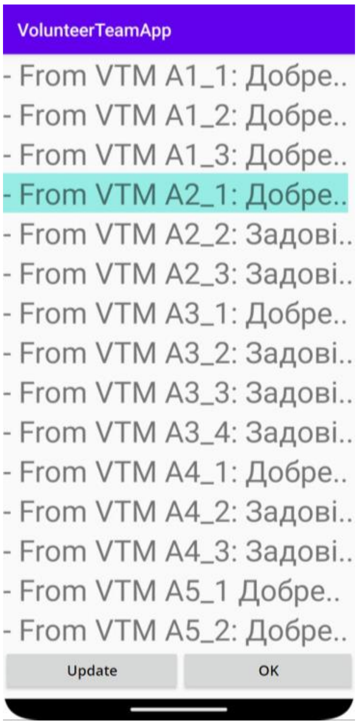

Fig. 6. **Interface window of the volunteer team coordinator mobile application**
Source: **compiled by the author**

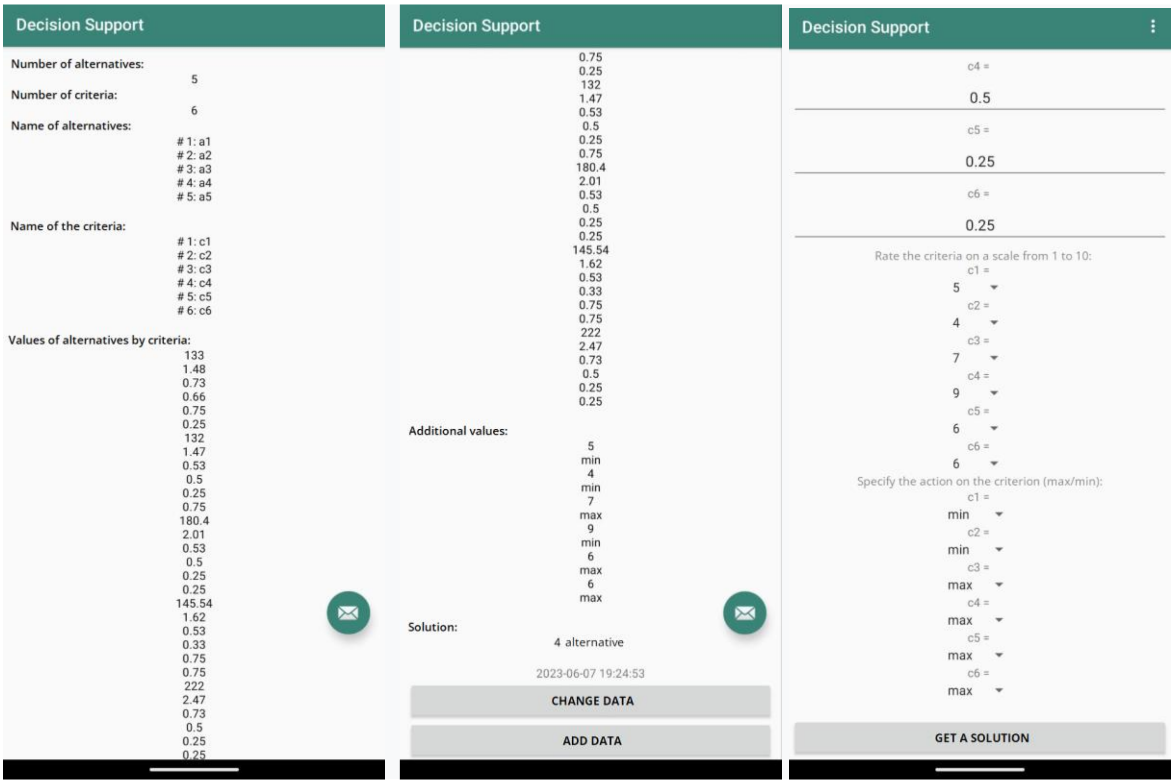

Fig. 7. **Interface window of the coordinator's mobile application with route data**
***Source:* compiled by the author**

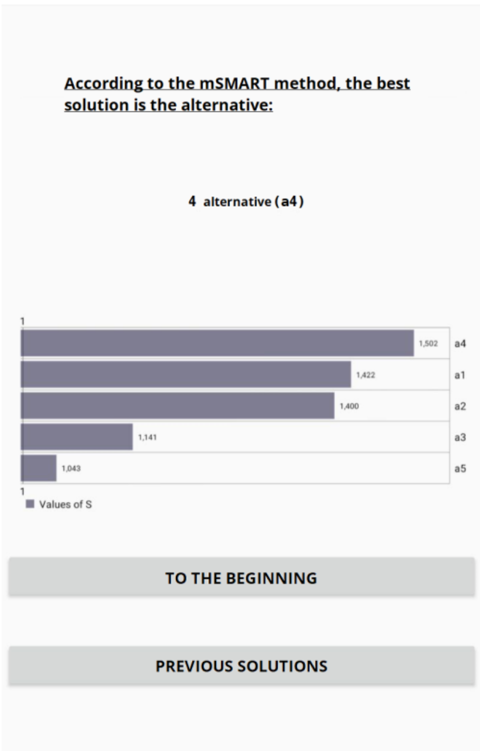

Fig. 8. **Interface window with ordered alternatives**
***Source:* compiled by the author**

As a result of using a mobile system for choosing the best solution, a team of volunteers found that the best route is route 4.

ANALYSIS OF THE RESULTS OBTAINED

Using existing systems, a team of volunteers would choose between taking the shortest route and trying to gather information from news, gossip and other sources. In the first case, after the humanitarian cargo has already moved along the chosen route, it may turn out that the road is unsuitable for travel to the final city. In the second case, the coordinator of the volunteer team spends a large amount of time, which distracts him on the one hand, and on the other hand, the information may become unreliable due to the time that the coordinator of the volunteer team will spend on collecting information on his own. And with the proposed system, all the up-to-date information necessary for decision-making is already in the device of the coordinator of the volunteer team. The developed system allows you to quickly receive information from volunteer experts about changes in the state of any area and instantly get a new best route based on the changed data. On average, the DM spends no more than two minutes on entering data into the system and obtaining a decision. The use of information technologies, algorithms and methods of solving optimization problems in the conditions of determining the state of the external environment provides savings in transport costs by 5-20 % [6].

CONCLUSIONS

The work developed the architecture of a mobile system for choosing a transport route by a team of volunteers under martial law. The design of the architecture of the route selection system for a team of volunteers in the conditions of dynamic changes in the external environment has been completed. A mobile application for volunteer experts has been developed.

Done experimental study of the developed system for choosing the best logistics route in real conditions. It was established that the DM spends an average of 2 minutes to enter and receive a decision. As a result of calculations, it was found that the best route is the fourth route. Separately, the delivery of cargo on the fourth route takes 2.5 hours. In the case when the second route of 132 km length was chosen according to Google maps of DM, it was found that the delivery of the cargo takes 3 hours due to the fact that the road surface is damaged on the sixth section . Thus, the use of a mobile transport route selection system by a team of volunteers reduced the time of cargo delivery by 1.2 times.

Therefore, the test of the mobile application developed according to the proposed architecture demonstrated the possibility of obtaining an operational decision on the choice of route in the conditions of a dynamically changing situation in the conditions of a state of war. The goal of development has been fully achieved.

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Архітектура мобільної системи вибору транспортного маршруту командою волонтерів в умовах військового стану

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АНОТАЦІЯ

Робота присвячена питанню проектування архітектури мобільної системи вибору маршруту транспортування вантажів та пасажирських перевезень командою волонтерів в умовах військового стану. Система надає підтримку особі, що приймає рішення – координатору команди волонтерів в умовах в умовах інформаційної невизначеності та динамічних змін зовнішнього середовища. Система дозволяє отримувати і враховувати оперативну інформацію щодо стану відрізків маршруту, яка надається експертами, в ролі яких виступають волонтери. Архітектура мобільної системи для команди волонтерів в умовах динамічних змін є клієнт-серверною. Клієнт відправляє введені експертами-волонтерами дані на сервер за допомогою мобільного зв'язку або підключення до мережі Internet. Мобільний пристрій координатора команди волонтерів є сервером мобільної системи підтримки прийняття рішень команди волонтерів. Сервер має трирівневу архітектуру: рівень подання, рівень логіки програми та рівень даних. На рівні логіки програми реалізовано підсистему прийняття рішень на основі багатокритеріального модифікованого методу Smart. В якості резервної копії, дані з бази даних на пристрої координатора команди волонтерів, завантажуються у базу даних, яка знаходиться на віддаленому веб сервері. На основі розробленої архітектури була розроблена мобільна система побудови рекомендованого маршруту для команди волонтерів мовою Java в Android Studio. В якості застосування розробленої мобільної системи розглянуто практичний приклад визначення найкращого з п'яти існуючих маршрутів транспортування вантажів.

Ключові слова: Архітектура мобільної системи; прийняття рішень; транспортна логістика; команда волонтерів; експерти-волонтери

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