Creating an Information System for Logistical Support of Volunteer Tasks: Basics and Functionality

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Abstract

The paper examines the theoretical and analytical principles of creating an information system for logistical support of volunteer tasks (IS LSVT) to ensure the achievement of humanitarian goals. The parameters of the external environment of IS LSVT functioning are identified on the basis of a system approach. The dominant role of time as a safety factor over profit in the logistic tasks of the IS LSVT functional model is determined. The conceptual principles of building the IS LSVT functional model were determined, taking into account the following parameters: the volunteer task, data on the territory of military operations, indicators of resource provision and criteria for the optimal load of road transport and routing. The elements of the IS LSVT structure in the conditions of military operations, which generates the necessary input information for building the task of resource optimization, have been established. Numerical experiments were carried out on IS LSVT approbation based on the method of resource minimization, during which the influence of the total time factor on the optimization of volunteer tasks based on the time spent on decision-making and cargo delivery under the conditions of curfew and the presence of an air alert was determined.

Keywords

Information system, logistical support, volunteer task, military operations, time, resource provision

1. Introduction

With the beginning of Russia's full-scale war against Ukraine, there has been an increase in the level of involvement of Ukrainians in volunteer activities. As of July 2023, about 61% of the population of territories controlled by Ukraine were involved in one or another type of volunteer assistance to the defense forces and/or IDPs [1].

However, the full-scale war not only mobilized people, it also created new challenges for the volunteer sector. A large number of Ukrainians who had no previous volunteer experience and had to acquire it in practice joined volunteering. Today, the conditions in which volunteering is carried out have changed: it has become more dangerous to provide volunteer assistance, and volunteering has begun to require more time and has replaced work for many volunteers [2].

It has become much more difficult for volunteers, whose activities involve covering long distances, with the introduction of curfews and air raids, to provide assistance to the injured and the military. The main obstacle was the increase in the time spent on providing volunteer assistance and

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the complication of logistics [3], in cases where volunteers tried to avoid being outside at night (curfew) or it was necessary to find a shelter area (airborne alarms) during cargo transportation or evacuation people and animals.

The functional circle of logistical support of volunteer tasks and goals includes the elements shown in Figure 1.

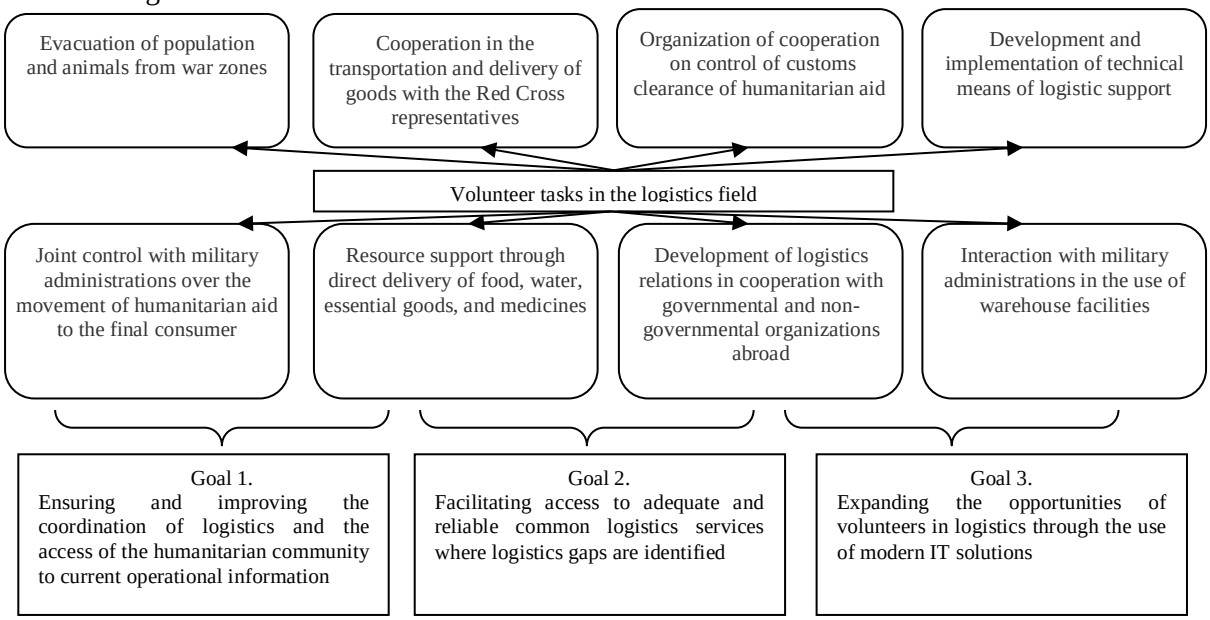

Figure 1: Functional range of volunteer tasks and goals in the field of logistics in wartime

The outlined functional range of volunteer tasks and goals in the field of logistics indicates the need for the development of information systems for automated management of logistics operations support services that will facilitate and optimize the movement of goods for the needs of the civilian population and the armed forces of Ukraine from volunteers. In order to build effective and economical wartime logistics for these needs, it is also necessary to be able to monitor the dynamics of the movement of goods stocks, fuel and time consumption, problems in the organization of resource provision in certain places with subsequent elimination.

The reasons given allow us to draw a conclusion about the need to create an information system for logistical support of volunteer tasks, due to the high level of dependence of the needs of the military and civilian population on the quick and complete provision of everything necessary by volunteers.

2. Related works

Analysis of the literature and related works showed the absence of comprehensive studies on the topic of publication. Currently, there are studies in the field of the role of information technologies for logistics infrastructure based on digital visualization and WEB-cartography in the conditions of military conflicts [4], as well as on the integration of logistics systems [5] and on the development of a supply chain strategy taking into account the capabilities of information systems [6]. Available and publications revealing the issue of the humanitarian role of logistics under conditions of natural disasters [7], as well as in the framework of the evacuation of victims, determining the need to introduce information technologies into supply chains in health care institutions [8] and the urgency of designing humanitarian-logistics information systems [9].

Source [10] presents approaches to forecasting volunteer decisions using neural networks, but the issue of logistical support for task performance is neglected. A significant amount of scientific research is devoted to the role of volunteer design of a geoinformation system [11], the use of voluntary geographical information and night light remote sensing data [12], the development of a methodology for assessing the impact of external factors on the operation of the geolocation system using the Android GPS API [13], the impact of the traceability of information systems on the

effectiveness of humanitarian logistics [14], as well as the study of opportunities provided by geoinformation systems and voluntary geographic information for timely response to emergency situations [15].

A review of research and practice in the management of humanitarian logistics describes the achievements of blockchain technologies in this field [16], as well as its role in the security parameters of information systems [17]. The authors define the implementation of information technologies in any field as a way to sustainable development [18] and a solution to countering crisis situations [19].

Articles [20; 21] define the needs for the development of IT solutions on the basis of crowdsourcing for the management of emergency situations in which volunteers can participate. Publications [22; 23] emphasize the role of information systems in achieving the set tasks and the overall goal.

The peer-reviewed works are mostly devoted to the review of the application of modern IT solutions for humanitarian logistics under the conditions of natural crises and the implementation of geo-information systems in solving the practical tasks of volunteers. However, none of the works proposes the creation of an information system for logistical support of volunteer tasks. Also, the above-mentioned works do not consider the influence of the military conflict on the fulfillment of logistical tasks by volunteers.

Therefore, the issue of developing the creation of an information system for logistical support of volunteer tasks is urgent and relevant today.

3. Parameters of the external environment of the functioning of the information system of logistical support of volunteer tasks

Transportation of goods and evacuation of the population and animals on the vehicles of civil organizations is one of the directions in the organization of logistics by individual volunteers and volunteer organizations. Transportation by road transport in the service of volunteer initiatives is carried out taking into account economic feasibility, in comparison with transportation by other types of transport, which are impossible in the conditions of war due to attacks by missiles and drones in the air, blockade of ports and congestion of railways. In order to effectively solve the outlined issues, it is necessary to implement information systems for logistical support of volunteer tasks in the organization of motor transport operations.

Today, examples of information systems for logistics support of enterprises for planning freight transportation, including road transport, have been developed, such as ERM and CRM transport management systems, but the orientation of such systems is aimed at profit and time, instead, volunteer tasks are aimed, first of all, at the safety factor, because they are not of a commercial nature.

Achieving the safety factor in the information system of logistical support of volunteer tasks (IS LSVT) depends on the completeness, relevance, verification and efficiency of the operation of logistical information flows, and the integration, coordination and synchronization of commodity and financial flows. For this purpose, IS LSVT is created as a system of interrelationships between volunteers, resource provision (vehicles and cargo) and relevant management procedures in order to provide an appropriate information base for planning, organization and control of logistics in the activities of volunteers in the conditions of military operations. The main function of IS LSVT is to ensure effective logistics decisions.

Supporting the functionality of international logistics chains on the territory of Ukraine, the IS LSVT concept proposed below is a comprehensive system of collective use by volunteers with a single information space. This information should be automatically transmitted to the relevant response services (Figure 2).

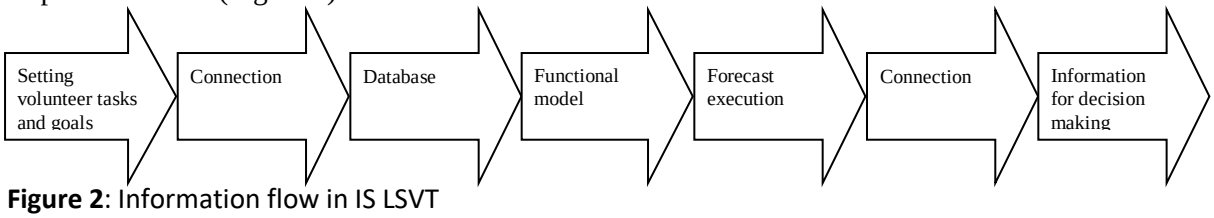

Figure 2: Information flow in IS LSVT

The main function of IS LSVT is to ensure the adoption of effective logistical decisions based on volunteer tasks and defined goals. Supporting the functionality of logistics chains on the territory of Ukraine, the IS LSVT concept proposed below is a complex system of collective use with a single information space.

However, IS LSVT being developed should have a wide range of functionality for controlling the main warehouse operations: loading and unloading operations, cargo acceptance, marking and bar coding, registration of arrival and departure, repacking, assembly, etc. The IS LSVT transport functionality should provide the main functions of transport logistics in wartime conditions: receiving and forming orders, managing planned and actual routes, drawing up an optimal traffic schedule, the time of stay and completion of each stage of transportation, planned and actual costs along the route, calculation of transportation costs at each stage, tracking cargo on the way.

Therefore, taking into account the above, IS LSVT should consist of orderly interdependent elements and possess some set of synergistic qualities and be divided into functional and supporting subsystems. The functional subsystem consists of a set of tasks to be solved, grouped according to the common goal [24]. The support subsystem should include the following elements: technical support, that is, a set of technical means that ensure processing and transmission of information flows; information support, which contains various directories, classifiers, codifiers, means of formalized description of data; mathematical support, that is, a set of methods for solving functional tasks. IS LSVT must have the following characteristics:

1) synchronization and coordination between financial, informational, logistical and material flows;

2) coherence, sequence and complexity of actions of different time periods, different levels of management;

3) the reality of tasks, correct use of information, optimal logistical decision-making.

For the construction of IS LSVT, it is necessary to always pay great attention to the principles of its construction. The ability not only to localize IS LSVT, but also to the parallel operation of information systems and technologies makes it possible to approach the management of material flows from a systemic perspective, ensuring the processing and exchange of large volumes of information between various participants in the logistics process. This includes the monitoring audit of resources (availability of actual and planned orders, content of production main and intermediate warehouses) and terms (delivery, processing, waiting, downtime, meeting deadlines).

Thus, the information subsystem of making a separate decision regarding IS LSVT should consist of four interconnected blocks, namely:

1) a block of input information that is accumulated in the form of a database based on retrospective and forecast information for a certain date and is relatively unchanged over time;

2) a block of operational information that comes directly from the production sites of the enterprise and constantly changes as the production process progresses;

3) the unit for forming a volunteer task, in which, on the basis of analytical models, input and operational information is processed and justified by the expediency of making this management decision and its parameters (in particular, the terms of making it);

4) block of management decision-making, which contains the corresponding fragment of the organizational structure of enterprise management, i.e. subdivisions, officials who participate in the development of management decisions, and the relationships between them;

5) a block of source information, which represents the resulting information provided to the manager (in accordance with his powers, job rights and functional duties) about the state or activity of this or that object in the form of information about the availability of personnel at the enterprise by category personnel and structural divisions as of a certain date, which includes regulatory and planning, actual and special information.

It is worth paying attention, in the context of the design and development of IS LSVT, the statement that the development of logistics systems is determined by a system of economic, informational and organizational, technical) technological and social measures, the implementation of which allows comprehensive improvement of the organization and management of an economic object with the aim of saving resources with simultaneous compliance with safety and ecological and economic efficiency [25], while the role of the safety factor is dominant over the profit factor.

In Figure3 presents the system of parameters of the external environment of IS LSVT functioning, taking into account the aspects described above.

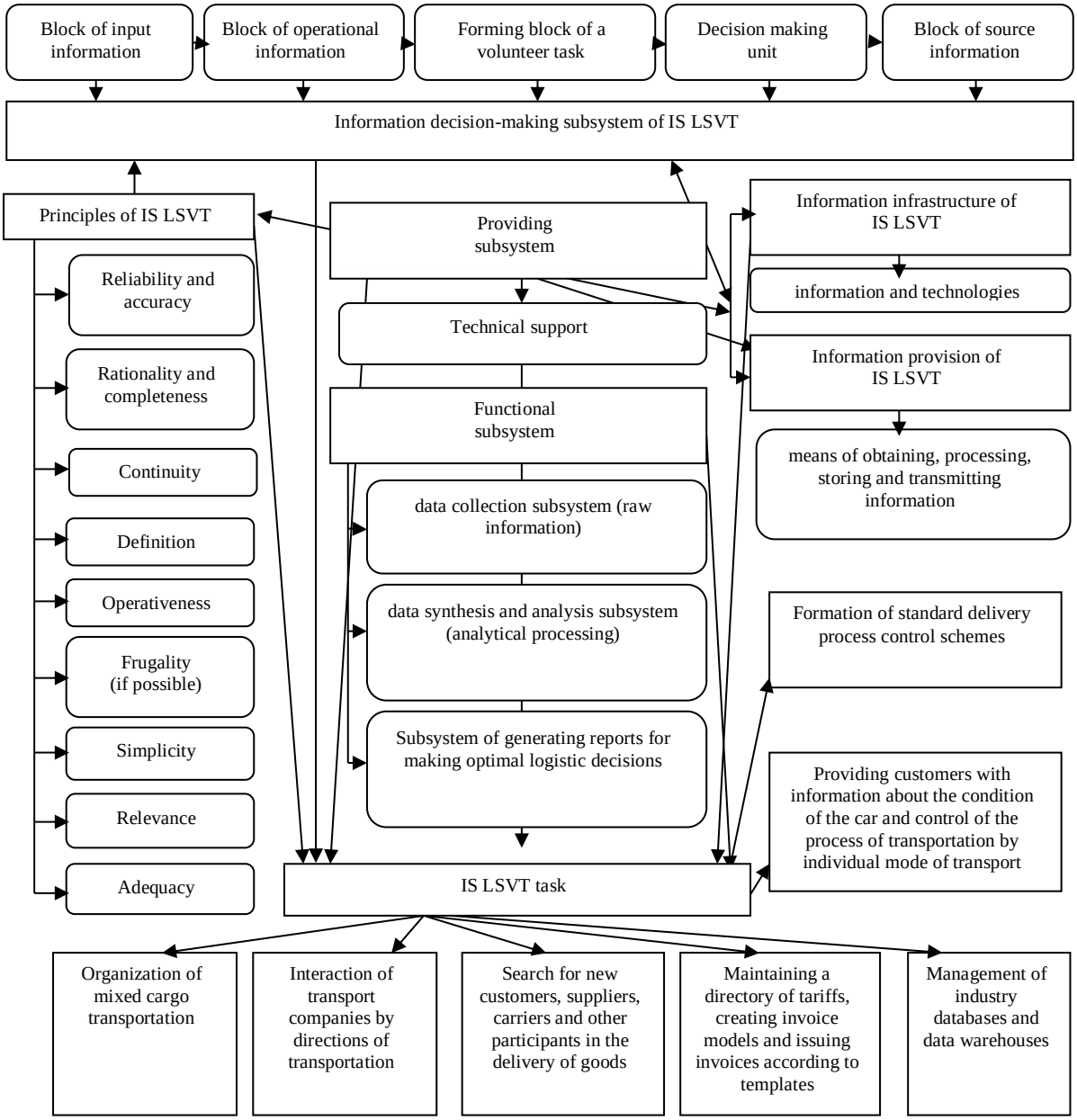

Figure 3: The system of parameters of the external environment of the functioning of IS LSVT

In the case of ensuring the operation of IS LSVT, taking into account all parameters of the external environment, presented in Figure 3 achieves the fulfillment of the set goals defined in Figure 1. In order to improve the structure of decision-making, it is necessary to conduct a preliminary in-depth study of existing information flows, to determine the contradictions formed between the content of task-setting functions and their organizational forms, between the organizational structure and the quantitative composition of people, the establishment of a unified system in the work of the coordinating volunteer center or headquarters, regulations functional duties of each volunteer.

4. Creation and implementation of a functional model of the information system for logistical support of volunteer tasks

Determining the components of the external information environment of IS LSVT implementation

made it possible to formulate requirements for the types and attributes of input information:

$$L = L_1 \cup L_2 \cup L_3 \quad (1)$$

where L_1 are the parameters of the volunteer task regarding cargo delivery, which is the direct or indirect source information of the monitoring system and includes a list (set) $\alpha=\{ \alpha_1, \ldots, \alpha_n\}$ of settlements in the zone of military operations, each of which is characterized by a T^{WA}, $tw = 1,\ldots,$ K_{wa}, regarding the amount of necessary cargo, such as basic necessities, food, medicine, etc., and the need T^G , $G = 1,\ldots, K_G$ for the evacuation of victims, K_{wa}, $K_G \leq H$, and also assessment of the duration *D* of active hostilities in the zone of hostilities;

L_2 – parameters of the territory of military operations, in particular, the level of activity of conducting hostilities, the condition of the roads along the route to the affected points, the announcement of an air alert, weather conditions, etc.;

L_3 – parameters of the resource provision of the process of delivery of necessary goods from volunteer organizations, i.e. coordinates of the locations of *W* warehouses (goods storage places, including essential items, food, medicine, etc.), locations of bomb shelters $Sh = \{ Sh_1, Sh_2, \ldots, Sh_n\}$, characteristics vehicles - road transport and special equipment.

One of the main logistical tasks when carrying out work on the delivery of volunteer goods to military operations zones under conditions of shelling should be the tasks of transporting goods and essential items, etc., as well as the evacuation of victims - the return route. They belong to the class of multi-criteria optimization problems of management decision-making regarding the logistics of volunteering with additional restrictions (for example, time and safety priorities), which necessitates modeling taking into account the possibility of changing the time of volunteer work in order to:

– reducing the time of delivery of goods and essential items;

- reduction of population evacuation time;

– reduction of vehicle maintenance costs by minimizing their number on the basis of carrying capacity calculation;

- reducing the movement of vehicles in the reverse direction without fulfilling the tasks of cargo delivery or evacuation in idle.

Thus, the time of delivery of goods and essential items, the time of evacuation, the costs of maintaining vehicles and the length of idle movements determine a set of partial criteria for the effectiveness of volunteer work.

The nature and peculiarities of the flow of logistical tasks during the delivery of volunteer cargo to the war zones determined the choice of road transport as an important component of the set of vehicles for cargo delivery and evacuation. The prerequisite for the use of this type of transport is: mobility in countering air threats, maneuverability during shelling, speed and variability in delivery, the possibility of combining and combining with special equipment.

The main characteristics of motor vehicles are as follows:

$$C^g = (CC^g , CV^g, PC, DR , CU, CF), g = 1,\ldots n \quad (2)$$

where CC^g - carrying capacity,
CV^g - maximum cargo volume,
PC - maximum passenger capacity,
DR - maximum daily traffic, limited by the rules of safe speed,
CU - cost of using vehicles for the period *[1, D]*,
CF - fuel consumption.

The above-mentioned partial criteria for the effectiveness of logistical tasks of volunteer work can be combined into three groups: task parameters (L_1), parameters of the territory of military operations (L_2), resource provisioning parameters (L_3), which allows, in accordance with them to formulate the three main tasks of logistical support in the information system (Figure 4): evaluation of the effectiveness of measures for the fulfillment of volunteer work tasks in the zone of military operations; optimal loading task; routing task.

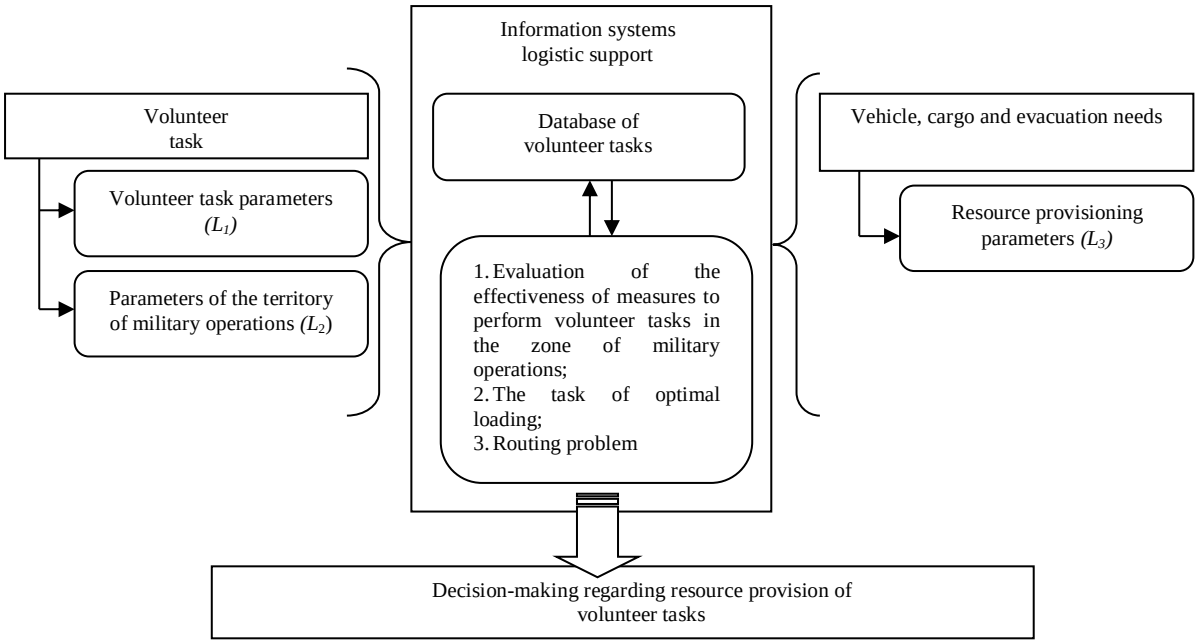

Figure 4: Functional model of IS LSVT

The given range of tasks of the logistics information system sets requirements for the hardware and software of the processes of designing and functioning of the system. The general scheme of methodical provision of defined tasks consists of six stages.

Stage 1. Determination of the parameters of the set α, the planning horizon D (according to the data of the volunteer point).

Stage 2. Determination of initial estimates of T^{WA} and T^{G} values, priorities for their implementation, i.e. task of intervals $[t\ min_g, t\ max_g]$.

Stage 3. Determination of the evaluation of the sensitivity analysis of the effectiveness of measures y regarding the performance of volunteer tasks in the zone of military operations based on the application of fuzzy logic - the task of evaluating the effectiveness of measures regarding the performance of volunteer tasks in the zone of military operations.

Stage 4. Solving the iterative problem of finding a rational placement of T^{WA} tasks for evacuation on the planning horizon *[1, T]*. Under the accepted assumptions, the placement of the order determines the route of its execution.

Stage 5. Determination of a rational plan for the execution of T^{G} orders for the delivery of goods in the location α n.

The optimization method for solving the problems of the 4th and 5th stages is a modification of the method of rational placement of rectangular objects in a limited rectangular area, taking into account the difference of the 5th stage, which consists in the possibility of using one road transport for the simultaneous execution of several T^{G} orders (multiplicative order).

Stage 6. It is performed in the presence of multiplicative orders and contains a search for the route of execution of T^{G} orders for each time cycle $t = 1,...T$, taking into account the conditions of the combat situation and the presence of air alarms.

The output information of the information logistics system is the logistical support of volunteer work, which contains data on the number of motor vehicles used, a plan for optimal loading of cars and special equipment for them, a schedule of evacuation measures and cargo transportation.

5. Completeness and approval of the functional model of the information system of logistical support of volunteer tasks

From the positions of fullness of the IS LSVT structure, the presence of the following components is assumed:

– a description of the logistical task of the volunteer point – an interface to the database on the

characteristics of populated areas where hostilities are taking place and emergency response maps of potentially mined areas [26], which allows you to quickly choose a possible route, prepare information on the parametric identification of mathematical models of the main tasks of the logistics information system;

- visualization - mapping the contours of the locations where volunteer delivery and/or evacuation tasks will be performed;

– available resources – structured information on resource provision for logistical support of volunteer tasks;

- calculation - an interface with software for solving the main optimization problems of the logistic information system for planning and resource provision of volunteer tasks in the conditions of military operations, which generates the necessary input information for building the problem of resource optimization.

The numerical implementation of the general scheme of the method of resource minimization [27] for the implementation of logistical support for volunteer tasks in the conditions of military operations was carried out on the example of volunteer initiatives of the Volunteer Support Staff of the Union of Consumer Societies of the Khmelnytskyi Region, which were implemented in the territory of the Kharkiv Region in 2022. The initial characteristics are given in Table 1.

Table 1

Parameters of volunteer logistics tasks in the Kharkiv region in May 2022 in wartime conditions

Data	Parameters	
Parameters of the volunteer task ($L_{1)}$	Area of military operations, km^2	285
	The number of settlements in need of volunteer cargo	5
	The number of persons declared for evacuation	7
	Number of affected/evacuated population, persons	12/3
Parameters of the area of military operations (L_2)	Number of bridges: destroyed/damaged	3/15
	Length of highways, km: destroyed/damaged	2/4
	Curfew hours	-
	Air alarm, number per day	3
	Within one region	Kharkiv
Resource provision parameters (L_3)	Number of special equipment	2 trailers, 1 unloader, 1 loader
	Number of human resources (volunteers), persons	8
	Cargo, including food, i.e	3,2
	Drinking water, i.e	2,3
	Provision of vehicles	3

The results of the modeling of volunteer logistical support tasks, taking into account the fulfillment of the goals of evacuating victims and delivering humanitarian goods to the military operations zone, are presented in Table 2.

Table 2

Results of simulation of volunteer tasks using the information system of logistic support

Indicator	Decision-making time, h	Time of cargo delivery, hours	Total time of the volunteer task, hours	The number of volunteers	Number of vehicles and special equipment, units
Basic option	3.00	23.00	10.00	8.00	6.00
After optimization	0.75	18.50	6.30	5.00	5.00
Relative effectiveness, %	25.00	80.43	63.00	62.50	83.33

Thus, the key factor in the optimization of volunteer tasks with the application of the logistics support information system is the total time, which depends on the time of decision-making and delivery of goods. Such parameters as the curfew time and the duration of the air alert are the maximization values of the duration of the volunteer tasks, which must be taken into account during the development of the IS LSVT functional model. Identification and modeling of the parameters of volunteer logistics tasks based on parameters: volunteer task (L_1), territory of military operations (L_2) and resource support (L_3) provides an opportunity to optimize the volume of volunteer personnel, transport and special equipment taking into account effective distribution.

The presented numerical experiments on the approval of IS LSVT based on the method of resource minimization taking into account the proposed set of criteria, in addition to the implementation of volunteer initiatives on the territory of the Kharkiv region, were positively tested by the Volunteer Support Staff of the Union of Consumer Societies of the Khmelnytskyi Region in the Kherson and Mykolaiv regions, which is a confirmation of the successful implementation of the proposed approaches .

6. Acknowledgements

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7. Conclusions

The presented theoretical and analytical studies proved the expediency of creating a functional model of the information system of logistical support of volunteer tasks based on the following:

1. Based on the study of open scientific sources of information, the lack of a solution to the urgent problem of building effective and economical logistics for the needs of volunteers in wartime conditions was identified. For this purpose, the creation of an information system for logistical support of volunteer tasks, which will ensure the achievement of goals from the positions of: ensuring and improving coordination of logistics and access of the humanitarian community to current operational information, is substantiated; facilitating access to sufficient and reliable common logistics services where logistics gaps are identified; expanding the opportunities of volunteers in logistics through the use of modern IT solutions.

2. The parameters of the external environment of the operation of the information system of logistical support of volunteer tasks have been identified in the context of its design and development on the basis of a systemic approach, where the role of the safety factor is dominant over the profit factor from the standpoint of the functioning of the supply and functional subsystems in order to achieve the set goals and objectives.

3. The conceptual principles of building a functional model of the information system for logistical support of volunteer tasks have been defined, taking into account the structure of the external information environment, which is based on the parameters of: the volunteer task, the data of the territory of military operations, and the indicators of resource provision, taking into account the criteria for the optimal load of road transport and routing.

4. The elements of the IS LSVT structure have been established, which should include: an interface to the database on the characteristics of settlements where hostilities are taking place and emergency response maps of potentially mined areas, visualization, a description of available resources, and an interface with software for solving the main optimization tasks of logistics information a system for planning and resource provisioning of volunteer tasks in the conditions of military operations, which generates the necessary input information for building the resource optimization task.

5. Numerical experiments determined that the key factor in the optimization of volunteer tasks with the application of the information system of logistic support is the total time, which depends on the time of decision-making and delivery of goods. The curfew and the duration of the air alert are parameters that increase the duration of volunteer tasks.

At the same time, further research should be focused on the development of measures that take into account the scientific intelligence presented in this publication in combination with the use of artificial intelligence methods to process expert information on the parameters of volunteer tasks depending on the season and type of terrain.

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