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Oleksii SERHIEIEV
Postgraduate Student at the Department of System Analysis and Control, Dnipro University of Technology, 19, Dmytra Yavornytskoho Ave., Dnipro, Ukraine, 49005, serhieiev.o.s@nmu.one
***ORCHID:** 0000-0001-5781-5540*
***Scopus-Author ID:** 57220190743*

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APPLYING THE SYSTEMS APPROACH TO THE ANALYSIS OF REGIONAL-LEVEL MEDICAL LOGISTICS

The paper presents an in-depth analysis of the medical logistics system with a focus on improving decision-making processes for infrastructure development. The relevance of the work lies in the study of the system's robustness in crisis situations. The crisis revealed the inability of the system to meet the unprecedented demand for medicines and medical devices, emphasizing the need to create a more sustainable and adaptive logistics infrastructure.

The purpose of work. *To analyse and build a medical logistics system at the regional level. For this purpose, the key components and functions, including transport networks, regional and subregional centers and distribution hubs, should be additionally described. To analyse the legislative acts on the implementation of medical logistics, highlighting the general algorithm of actions for infrastructure development.*

Methodology. *A systematic approach was used to analyse the medical logistics system at the regional level. Using analysis and synthesis, the main components of the system are identified, and its organizational chart in times of crisis is presented. The process of providing assistance and organizing the relevant logistics infrastructure is considered using the IDEF0 notation, where inputs, outputs, controls, and mechanisms are identified. The process of opening regional, subregional and distribution centers is analysed separately and a methodology for its organization was proposed.*

Scientific novelty. *A methodology for opening regional, subregional and distribution centers is developed, which involves making appropriate decisions based on the results of solving the two-stage location-activation problem using software. The article details specific steps for organizing some processes of the regional medical logistics system that are potentially at risk of human factor influence in decision-making. The algorithm provides for the location of centers of different levels and determination of the transportation strategy. The author proposes to improve this process by automating some of the steps. Most of the steps can be optimized by applying the developed methodology and software for solving multi-stage location-activation problems. The application of the proposed modifications will allow taking into account more qualitative and quantitative indicators when making decisions on scaling the infrastructure in the field of medical logistics.*

Conclusions*. The proposed methodology and software make it possible to optimize some elements of the regional medical logistics system, improving their ability to adapt during emergencies, make more effective management decisions, achieve effective indicators by reducing costs and meeting the needs of the population.*

Key words: *system analysis, medical logistics, optimal solutions, business process, methodology.*

Олексій СЕРГЄЄВ
аспірант кафедри системного аналізу та управління, Національний технічний університет «Дніпровська політехніка», просп. Дмитра Яворницького 19, Дніпро, Україна, 49005
***ORCHID:** 0000-0001-5781-5540*
***Scopus-Author ID:** 57220190743*

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ЗАСТОСУВАННЯ СИСТЕМНОГО ПІДХОДУ ДО АНАЛІЗУ МЕДИЧНОЇ ЛОГІСТИКИ РЕГІОНАЛЬНОГО РІВНЯ

У роботі представлено поглиблений аналіз системи медичної логістики з основним акцентом на вдосконалення процесів ухвалення рішень щодо розвитку інфраструктури. Актуальність роботи полягає у дослідженні робастності системи в кризових ситуаціях. Під час яких була виявлена нездатність системи задовольнити безпрецедентний попит на ліки та вироби медичного призначення, підкресливши необхідність створення більш стійкої та адаптивної логістичної інфраструктури.

Мета роботи. *Проаналізувати та побудувати систему медичної логістики регіонального рівня. Для неї додатково навести ключові компоненти та функції, що включають транспортні мережі, регіональні та субрегіональні центри та розподільчі хаби. Проаналізувати законодавчі акти щодо впровадження медичної логістики із висвітленням загального алгоритму дій для розвинення інфраструктури.*

Методологія. *Застосовано системний підхід для аналізу системи медичної логістики регіонального рівня. За допомогою аналізу та синтезу виділено основні компоненти системи, наведено її організаційна діаграма в кризові періоди. Процес надання допомоги та організації відповідної логістичної інфраструктури розглянуто з використанням нотації IDEF0, де виділено входи, виходи, керування та механізми. Окремо було проаналізовано процес відкриття регіональних, субрегіональних та дистрибуційних центрів та запропоновано методику щодо його організації.*

Наукова новизна. *Розроблена методика відкриття регіональних, субрегіональних та центрів дистрибуції, що передбачає ухвалення відповідних рішень базуючись на результатах розв'язання двоетапної задачі розміщення-активації із застосуванням її у вигляді програмного забезпечення. Деталізовано конкретні кроки з організації деяких процесів регіональної системи медичної логістики, що потенційно перебувають під ризиком впливу людського фактору під час ухвалення рішень. Алгоритм передбачає розміщення центрів різних рівнів та визначення стратегії транспортування. Автором запропоновано вдосконалити цей процес шляхом автоматизації деяких процесів. Більшість кроків може бути оптимізована за допомогою застосування розробленої методики та програмного забезпечення для розв'язання багатоетапних задач розміщення-активації. Застосування запропонованих модифікацій дозволить враховувати більше якісних та кількісних показників при ухваленні рішень щодо масштабування інфраструктури у сфері медичної логістики.*

Висновки. *Запропоновані методологія та програмне забезпечення дозволяють оптимізувати деякі елементи регіональної системи медичної логістики, покращуючи їх здатність до адаптації під час надзвичайних ситуацій, ухвалення більш ефективних управлінських рішень, досягнення результативних показників шляхом зменшення витрат та задоволення потреб населення.*

Ключові слова: *системний аналіз, медична логістика, оптимальні рішення, бізнес-процес, методологія.*

Introduction. The last few years have shown us the weaknesses and areas for improvement of the medical logistics system. The global pandemic of 2020 unreadiness to meet the demand for medicines and immunobiological products in large quantities. This also highlights the strain on the system when we had to move quickly and efficiently during a crisis. The situation got worse with the full-scale invasion in 2022 which created an additional demand for moving large quantities of medicines as part of humanitarian aid. This unprecedented demand put a lot of pressure on the existing infrastructure, we need a robust and resilient medical logistics system that can adapt to crisis. The above-mentioned circumstances also introduced new challenges that require modernization and optimization of medical logistics transportation.

At the state level, one of the major challenges is to provide medicines to remote and underserved areas. To address this need we need to establish new regional, sub-regional and distribution centers in unserved areas. The continuous strain on the system also showed us the importance of developing adaptive strategies and leveraging technology to improve the efficiency and responsiveness of medical logistics.

The logistics industry is crucial for economic and social development. The paper (Lu, 2022) explores the challenges and strategies for optimizing logistics management from a supply chain perspective, emphasizing the importance of logistics optimization for sustainable industry growth. The work (Umoren, 2021) proposes a computational framework using fuzzy logic to optimize healthcare logistics, addressing resource constraints and improving the quality of care and quality of experience in Nigerian hospitals. The research (Mykhalchuk, 2020) introduces a new logistic model for Ukrainian healthcare, focusing on optimizing financial, material, human, and informational flows. It discusses the implementation of logistics concepts like enterprise resource planning, total quality management and others to enhance medical service quality and efficiency. The paper (Yaspal, 2023) addresses the increased production of infectious medical waste due to COVID-19, proposing a data-driven framework for optimizing reverse logistics in medical waste management. The article (Gadiiak, 2021) highlights the significance of

logistics in healthcare management, focusing on optimizing resource flow processes. It outlines the benefits of applying logistic approaches in medical institutions for effective resource control and quality improvement in medical services. From mathematical side, the problem of logistics is wildly researched as well. The paper (Koriashkina, 2023) presents mathematical models for the distribution of material resources related to preventive measures in case of technogenic emergencies. It examines optimal zoning tasks, assigning areas to social service objects with the possibility of overlapping zones when the nearest center cannot fully provide services. The study also considers the optimal location of new emergency logistics centers and the redistribution of loads across all structural elements, as well as the selection of locations for structural subdivisions based on existing objects. The criteria for optimality include minimizing the service time to the farthest object or the total distance to the nearest centers from consumers densely distributed in the given territory. Organizational costs for establishing new centers are also considered. The study (Koriashkina, 2024) focuses on enhancing the efficiency of evacuation logistics in regions affected by emergencies through a systematic approach. It highlights the importance of mathematical modeling and optimization theories in ensuring the rational distribution of transport and material resources. The research delves into two-stage evacuation logistics, emphasizing the role of first-stage centers (initial reception) and second-stage centers (further aid). The proposed models address optimal partitioning and resource allocation, aiming to minimize evacuation time and maximize coverage. The practical application of these models provides valuable insights for developing preventive measures and planning effective rescue operations.

The goal of this research is to conduct an in-depth examination of the existing state of the medical logistics system, evaluate the current procedures in place, and identify potential areas for improvement. Through this analysis, the author aims to offer recommendations for enhancing the logistics system, thereby increasing its quality and resilience. Ultimately, the objective is to ensure that the medical logistics system can effectively manage both routine operations and unforeseen emergencies, thereby safeguarding public health and welfare.

Key components of the medical logistics system. Healthcare systems need to be adaptable and strong in the face of uncertain crises like pandemics and floods. One key aspect of a strong healthcare system is the transportation network that helps distribute drugs effectively across emergencies. We see the effects of insufficient transportation infrastructure in distributing drugs across crises like pandemics and wars. On the other hand, we see the lives saved and cures contained across crises when healthcare systems have robustly structured transportation networks. While there are logistical and economic issues in setting up a transportation network in healthcare systems, the lives saved and the cures contained never cease to outweigh the costs. The key components of the Medical Logistics System are:

– Verkhovna Rada of Ukraine;
– Ministry of Health of Ukraine;
– suppliers designated by the MOH of Ukraine;
– regional centers;
– subregional centers;
– distribution centers.

The key components are illustrated in Figure 1.

Therefore, it is critical to focus on and invest in these health systems to ensure that they are resilient in times of crisis and can do their job effectively to protect the public. Lives saved are the goal and public health protection is the immediate effect across crises. To ensure this effect and goal, we shall first focus on the processes and current state of the medical logistics system across crises. We describe the decision-making process and the organization of the medical logistics system across a crisis. The process of medical logistics system organization in a crisis is shown in Figure 2. The Ukraine governments laws and orders are used for compiling the diagram: resolutions of the Cabinet of Ministers of Ukraine (No. 228 from 2024, No. 1805-p from 2021, No. 333-p from 2014); order of Ministry of Health (No. 232 from 2015); letter of the National Bank of Ukraine (No. 12-13780 111/1922 from 2004).

We will use the elements of the medical logistics system in Figure 2 to build a model for business processes. A context diagram in IDEF0 notation for medical logistics will be created depicting high-level functions and interactions only. The diagram has four types of arrows:

– Inputs: emergency; requests for medical assistance.
– Outputs: meeting the end-customers' needs.
– Elements of control: legislative acts; regulatory instructions for utilization and storage; internal regulations and orders.
– Mechanisms: Verkhovna Rada of Ukraine; Ministry of Health of Ukraine; regional health departments; regional centers.

Let's decompose Diagram A0 into the following elements:

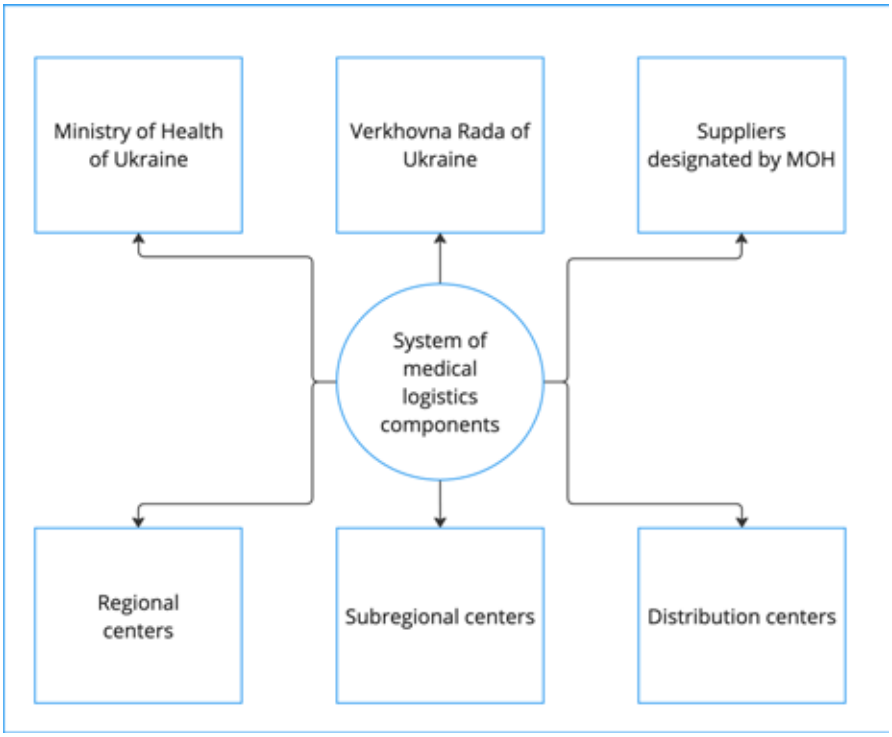

Fig. 1. Key components of the system of medical logistics

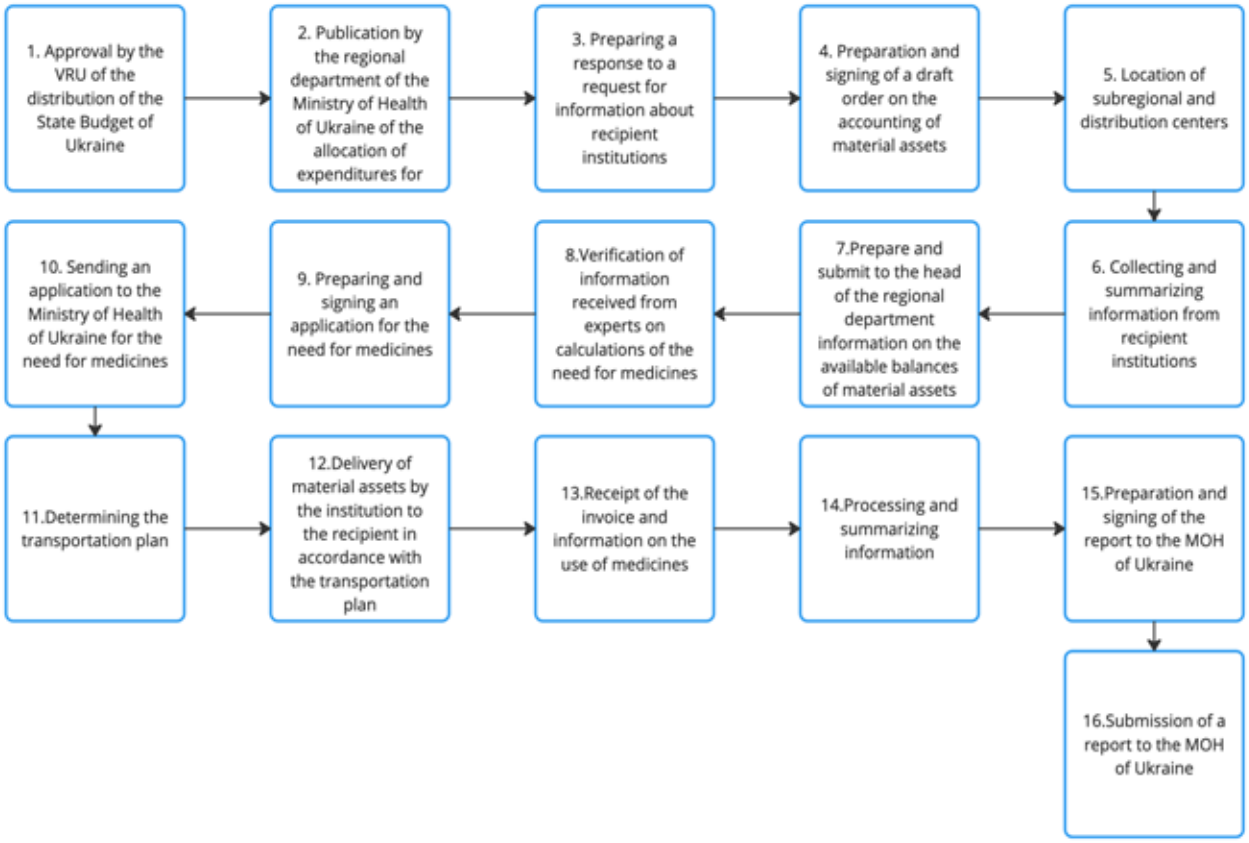

Fig. 2. Organization of the medical logistics system in a crisis

– Adoption of the legislative initiative of the Verkhovna Rada and preparation of orders of the Ministry of Health;

– identification of subregional centers and distribution centers;

– collecting and summarizing information from recipient institutions. Expert research;

– working with experts to calculate the need for medicines and medical supplies;

– determining the transportation strategy;

– receiving of material assets by the recipient institution in accordance with the transportation strategy;

– reporting by regional departments to the Ministry of Health.

The decomposed context diagram, that visualizes IDEF0 notation is shown in Figure 3.

The medical logistics system at the regional level performs the following functions through subsystems:

– Basic: ordering; supply; distribution.

– Key: purchasing management; transportation; inventory management; physical distribution.

– Additional: storage; cargo handling; IT support; accounting.

Moreover, the medical logistics system can be represented by several subsystems: legal, medical, IT, supply chain management and finance. When it comes to the legal system, it covers laws, regulations, and ethics, including contractual agreements and healthcare regulations. The medical one focuses on the clinical aspects of ensuring that drugs and medical supplies are appropriate, safe, and meet the needs of healthcare professionals and patients. The IT subsystem uses technology to manage information, automate processes and communications to improve the efficiency, accuracy, and reliability of logistics operations. The next one is supply chain management – it procures, stores, and distributes pharmaceuticals and supplies to ensure they are available on time and in good condition. The final one is the finance subsystem that manages the accounting aspects, including budgeting, cost tracking and optimization, invoicing and financial reporting. The mentioned functions and classifications for subsystems can be visualized in the form of the diagram in Figure 4.

It is worth highlighting some specific steps from the medical logistics organization steps from Figure 2 that potentially might contain lots of manual decision-making processes. These steps are the following:

– Step 5: Location of subregional and distribution centers.

– Step 6: Collecting and summarizing information from recipient institutions.

– Step 11: Determining the transportation plan.

These steps can be represented as certain algorithm of how a decision-making person runs the process of determining geographical locations for centers of different stages. An algorithm

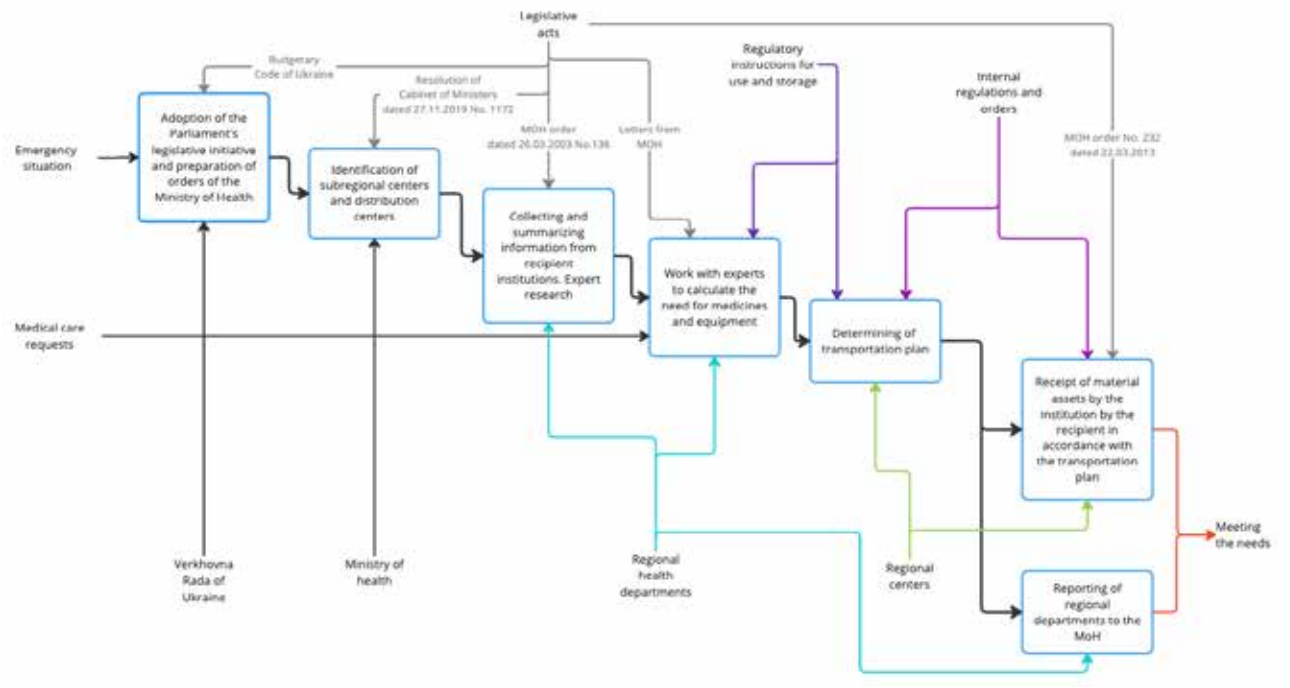

Fig. 3. Decomposition for diagram A0 for medical logistics

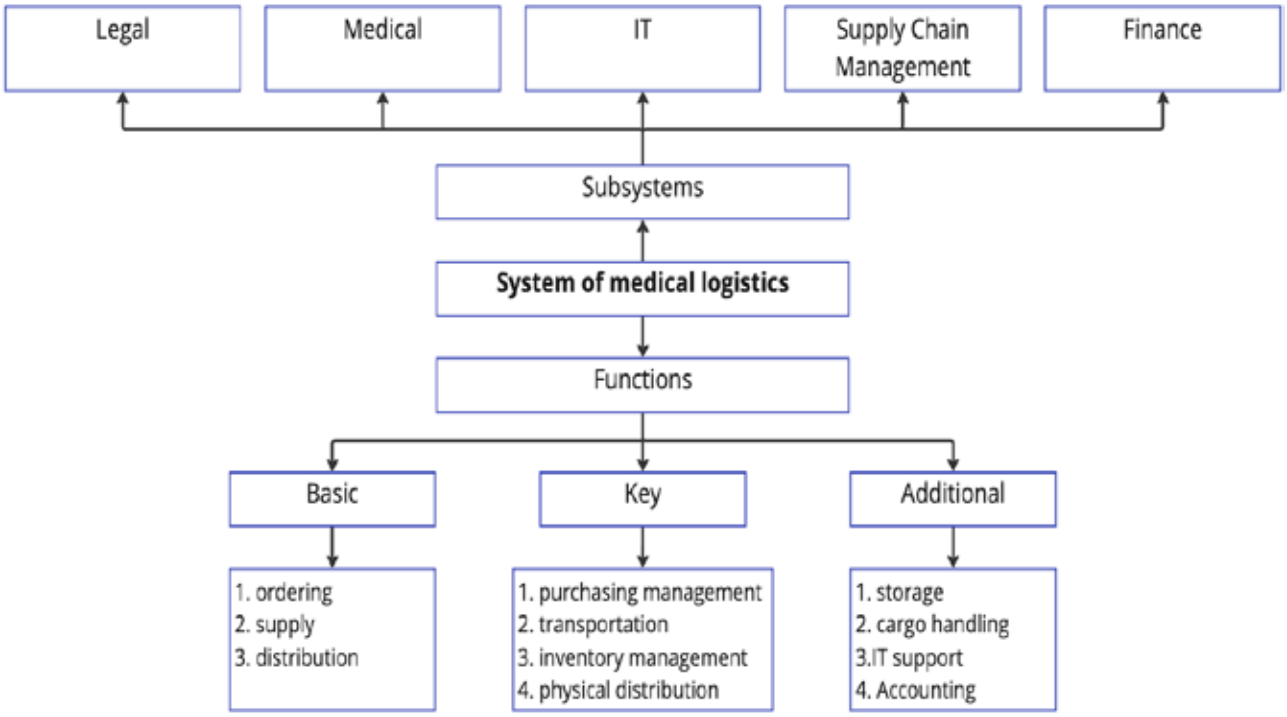

Fig. 4. Structure of medical logistics system

for opening regional, sub-regional and distribution centers and organizing transportation can be formulated as follows.

Step 1. The Ministry of Health submits a request for medicines and medical supplies from the regions to the relevant regional departments.

Step 2. The regional departments collect data on health needs, population and infrastructure capacity of different regions.

Step 3. Based on the information provided by the regional departments, the Ministry of Health decides which regional centers to open. This decision is made at the government level and considers factors such as geographic coverage, population density and specific medical needs. As a result, a report is prepared for the Ministry of Health.

Step 4. The Ministry of Health identifies potential sub-regional centers from the set of existing oblast medical institutions.

Step 5. The regional department evaluates the potential sub-regional centers proposed by the MoH to determine their suitability on the basis of the local healthcare demands and logistical needs.

Step 6. Detailed analysis of potential demand for medicines and planning for potential demand is carried out by the planning service of the regional department.

Step 7. Based on the demand planning, the regional department selects a certain number of sub-regional centers to be activated from the MoH list.

Step 8. Following the demand requests and the projected demand plan, medicines and SMEs are categorized:

– Immunobiological medicines;
– humanitarian aid;
– Medical products
– medical equipment;
– consumable materials.

Step 9. For each category of medical supplies, the regional department will determine whether the approach to aiding will be stationary or mobile:

– The need for stationary and mobile immunization sites is determined.

– Determine the need for stationary and mobile humanitarian distribution points.

– Medical supplies may be sent to stationary medical facilities or mobile points.

Step 10. Activation or location of distribution centers:

– For inpatient care, the department either activates existing facilities or establishes new ones as distribution centers (DCs) if existing facilities are insufficient.

– For mobile healthcare, the department determines the locations of mobile DCs.

Step 11. The regional department continuously monitors the efficiency of work and demand in the centers and makes the necessary adjustments to meet the changing needs of the population for medical care.

Step 12. The regional department assigns responsibility to the regional centers for developing a transportation plan in accordance with existing and planned needs.

The described algorithm is depicted in Figure 5.

It is proposed to improve this process through the implementation of certain automation measures. Most stages will be either eliminated or optimized, and new stages will be introduced. The Ministry of Health will organize the operation of a unified information system called MedData. The regional departments will use software to automate decision-making regarding the location and activation of centers. As a result, sub-regional centers, distribution centers, and transport schemes will be activated and placed. Regional centers will utilize the provided logistics software, which includes recommended transport schemes. The visualization of the improved process diagram is shown in Figure 6.

A more detailed description and formulation of the problem including mathematical models, solution approaches, and software implementation proposed by the author are detailed in (Us, Serhieiev, 2023; Serhieiev, Us, 2023). These elements are designed to integrate seamlessly to address the identified challenges.

Conclusions. This study analyzed the medical logistics system to improve decision-making processes for infrastructure development. The analysis highlighted several critical areas that require optimization and modernization to meet the increasing demands and challenges of both routine operations and unforeseen emergencies, such as the global pandemic and humanitarian crises. The key functions and components of the systems are described to emphasize their importance. The organization of the medical logistics system in a crisis situation is detailed according to steps derived from legislative documents. In addition, the vision of a medical logistics system with the use of a systematic approach is proposed. The medical process is presented in the form of IDEF0 notation to highlight the main steps during this process.

The main steps that could potentially contain a lot of manual decision-making processes are selected. For these steps, a more detailed algorithm is provided, where the reader can observe the set of actions for opening and locating centers of different stages. Improvements to the aforementioned algorithm have been proposed to eliminate manual decisions and replace them with the use of methodology and software implementation: it is proposed to make better use of the unified information system, MedData, managed by the Ministry of Health, which will centralize data management and improve coordination between health departments and centers. By using advanced

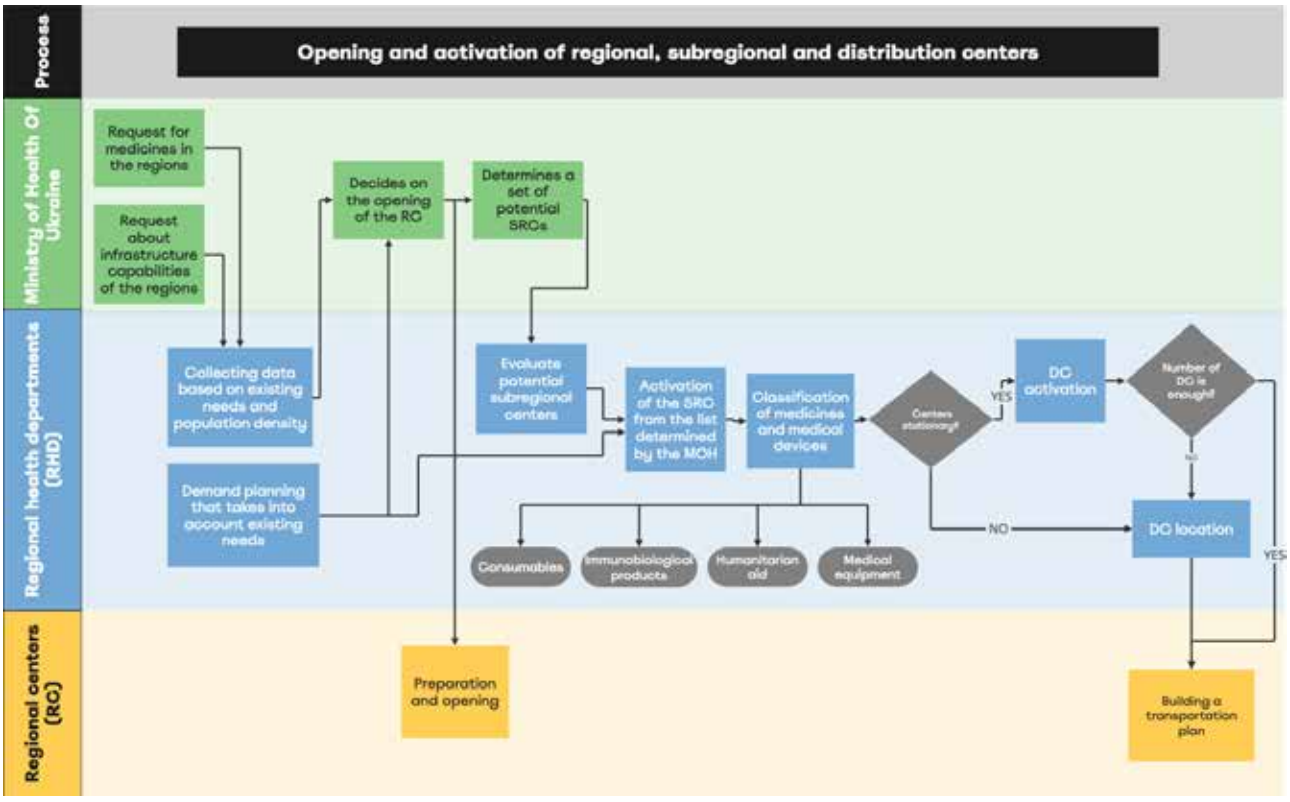

Fig. 5. Opening and activation of regional, subregional and distribution centers

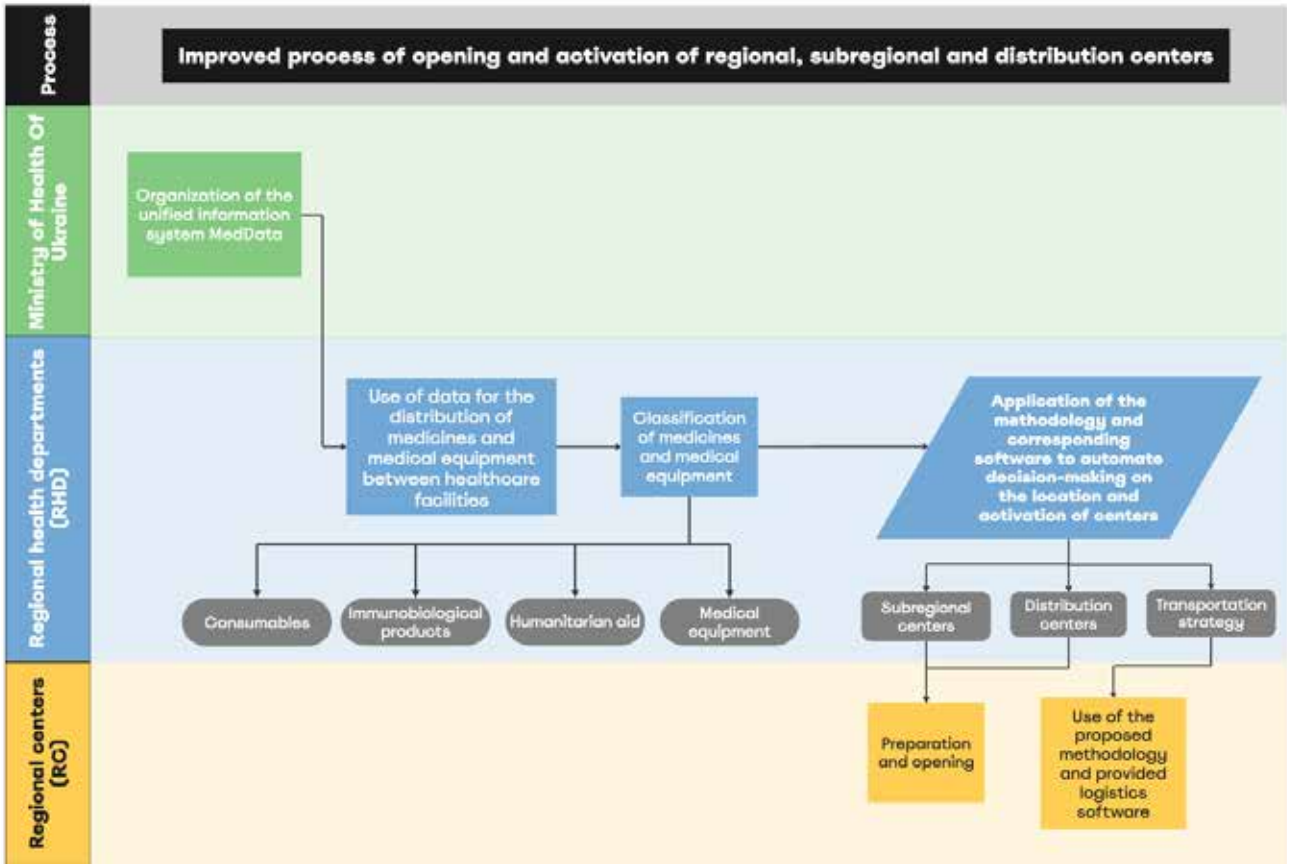

Fig. 6. Improved process of opening and activation of regional, subregional and distribution centers

software to automate decision-making processes, regional departments can streamline the location and activation of sub-regional and distribution centers. This will not only reduce human error and increase efficiency, but also ensure a rapid response in times of crisis. Ultimately, the provided improvements aim to build a more efficient, reliable, and responsive medical logistics system that can safeguard public health by effectively managing both routine and emergency medical logistics operations.

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