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Information and communication hub for humanitarian aid: System analysis, process modelling, and technological solutions

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Abstract. The escalation of global crises, particularly wars and natural disasters, has underscored the critical need to enhance the efficiency of humanitarian aid coordination. Existing systems often suffer from fragmented data, limited scalability, and insufficient flexibility in integration among key stakeholders. The aim of this study was to develop a comprehensive concept and architecture for an Information and Communication Hub (ICH) designed to coordinate humanitarian assistance in dynamic crisis scenarios. The research methodology included a systems analysis of current solutions to identify their limitations, along with architectural modelling using BPMN2 and UML notations. Microservice-based development strategies were formulated, and algorithmic components were subjected to testing. The study revealed that major challenges in humanitarian coordination can be effectively addressed through the creation of a dedicated ICH. Functional requirements were defined to support the integration of heterogeneous data sources, automated information processing, and the provision of user-friendly interfaces for all actors involved. A microservice-based architecture was proposed, featuring modules for request management, data processing (including the application of machine learning methods for needs classification), and adaptive user interfaces. Efficient algorithms were designed and validated to optimise critical operational processes such as humanitarian cargo routing and prioritisation of aid requests. The practical significance of the results lies in their applicability by emergency management professionals and international humanitarian organisations to reduce response times, increase transparency in resource allocation, and improve the scalability of aid projects

Keywords: automated data processing systems; humanitarian data hub; microservice architecture; information system design; adaptive algorithms; crisis management

INTRODUCTION

In the face of the rapidly increasing number and complexity of global crises, including armed conflicts, large-scale natural disasters, and significant migration processes, the effectiveness of humanitarian assistance is of paramount importance. This requires not only a quick response, but also a smooth, prompt, and accurate exchange of data between all participants in the process – international organisations, government agencies, local communities, and volunteer initiatives. Despite considerable efforts, existing information systems often exhibit significant shortcomings, such as data fragmentation, low scalability for processing large amounts of information, and lack of flexibility in integrating with different sources and formats. These constraints significantly slow down coordination processes, lead to duplication of efforts, misuse of resources, and ultimately reduce the effectiveness of assistance to those who need it most.

Within the analysed sources devoted to the provision of humanitarian aid using automated information systems over the past five years, it is possible to identify organisational, technical, logistical, and information

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and communication aspects, which are the most relevant and widespread areas of scientific research. These areas cover many technologies, methods, implementations, and solutions from related fields. A. Gunes *et al*. (2020) conducted a systematic analysis of barriers to information exchange in humanitarian supply chains. The study identified the problems of fragmentation of information flows in the field of humanitarian aid, the lack of unified data exchange protocols, and the limited ability to integrate local and international systems. The factors that hinder the efficiency and accuracy of exchange between agents were considered, and 4 main groups of barriers were identified: technological, organisational, regulatory, and cultural. The researchers noted that in order to improve the integration of various humanitarian information systems, standardisation in processes, approaches, and data should be implemented. The issue of implementing blockchain, machine learning, and Artificial Intelligence (AI) was considered by researchers in an overview plan.

An important aspect of providing assistance is logistics, its organisation, automation of processes in information systems, and process optimisation. Features of logistics for systems of providing humanitarian aid in crisis conditions were considered by I. Ilyina *et al*. (2024). The researchers focused on the design and creation of information systems for organising humanitarian aid. A number of solutions for the organisation of transport logistics were proposed, in particular the use of decision-making systems; the problems of humanitarian logistics of disasters were highlighted: coordination, effective resource management, rapid decision-making in uncertain conditions. However, the issues of optimising logistics and communication processes through the use of the latest technologies – machine learning, analytics, geographic information systems, the use of AI models are not given enough attention.

Management of integrated knowledge and information systems of disaster editing depending on the characteristics of individual countries was considered by T. Matekenya & E. Ruhode (2021). The paper considered the creation of a framework that combines knowledge and information technology management to improve disaster response in developing countries. The researchers argued that the effective use of local knowledge through digital platforms contributes to improving the adaptability of response systems. The need for integration of mobile technologies was substantiated. In this paper, it would be advisable to analyse the problem of ensuring the reliable preservation of knowledge and its objectivity not only in centralised, but also in decentralised conditions.

Ukrainian researchers actively investigated problems and solutions in the field of humanitarian aid, and the number of studies has increased significantly after the full-scale invasion. The role of volunteer initiatives and public organisations in the post-war reconstruction of Ukraine was considered by K. Petrovskaya *et al*. (2024). The study by N. Kankanamge *et al*. (2019) analysed the effectiveness of online platforms for attracting volunteers in disaster management. Despite the general depth of research, there are still aspects that have been studied to a limited extent or require further development. First of all, the system combination of technical architecture, development lifecycle, and crisis management specifics within a single platform has not been sufficiently studied. Insufficient attention has been paid to the issue of personalising assistance based on the classification of individual needs in a dynamic environment (not only categorising resources, but also profiling beneficiaries). Mechanisms of feedback and self-adaptation of humanitarian systems to changes in the field (adaptive interfaces, machine learning models) are just beginning to be considered by researchers and do not yet have real-world implementations. There is also insufficient research on integrating project management functionality and tracking the effectiveness of solutions in a single hub. The issue of automated development of digital portfolios of humanitarian operations – for auditing, machine learning, resource forecasting, and case analysis – is promising, but rather neglected.

The purpose of the study was to create a conceptual model of the integrated information and communication hub (ICH) system for the coordination of humanitarian assistance in crisis situations, which provides automated request processing, integration with data sources, and supports interaction between all participants in the humanitarian process. The objectives of the study were to conduct a system analysis of existing analogues (ReliefWeb, Humanitarian Data Exchange, etc.); formulation of business, user and functional requirements for ICH, considering the possibility of integrating data sources (social networks, Internet of Things (IoT), databases of stakeholders); the ability to automate data collection, analysis and visualisation with the subsequent development of an architecture and conceptual model of the system based on a microservice approach with modules: request management (application programming interfaces (APIs), authentication services), data processing (machine learning algorithms for classifying needs), flexible interfaces for different types of users (non-governmental organisations, governments, victims).

LITERATURE REVIEW

Considerable attention of the scientific community in the field of humanitarian assistance was paid to the use of advanced technologies in the design and development of automated information systems and their integration into the processes of organising the provision of humanitarian assistance, that is, the technical aspect. Research over the past 5 years has been actively exploring the use of advanced technologies to build such integrated systems. In the same vein, but from a different perspective, O. Shevchenko (2024) conducted research on the coordination of international humanitarian aid programmes in Ukraine. The paper highlighted the complexity of managing humanitarian programmes in the absence of general requirements for data that can be processed by an automated system. Another aspect of assistance is the need to automate business processes, transport, warehouse, information, purchasing and distribution logistics through integrated platforms and data hubs. The literature highlighted the general need to create centralised, integrated platforms or information hubs.

The study by A. Kondraganti (2021) considered the issues of analytics, statistics, forecasting possible solutions to humanitarian problems, and conducted a systematic review of the use of big data analytics technologies in humanitarian and catastrophic operations. The researcher concluded that Big Data analytics allow optimising planning, logistics, and disaster response. Data sources, analytical methods, and areas of application were evaluated. The prospect of integrating IoT and AI for automated data collection and analysis was outlined. The researcher concluded that machine learning methods for predicting demand and modelling logistics have proved to be more effective. Uneven access to data and the need for ethical regulation were noted. However, the issue of data validation was not fully addressed, and data validation for mass receipt from different sources and in different formats was not considered. Bissoft (2025) offered ready-made solutions in the form of separate services that can be considered as a virtual community that provides an opportunity, even in the conditions of military operations, to have support. The study by O. Nezdoiminoga & T. Pryidak (2024) analysed innovative approaches to the coordination of humanitarian assistance in war, in particular, the use of digital tools. L. Nozdrina & M. Falat (2020) analysed the features of volunteer IT projects and noted that based on the research conducted, those that are built on an incremental approach and have a service or microservice architecture have an advantage in developing projects. The functionality of such projects increases from iteration to iteration.

Among Ukrainian information platforms, there are a number of resources focused on humanitarian issues. Financial assistance for registered temporarily displaced persons can be obtained by submitting an application in "eDopomoga" system in the Diia (n.d.) application. The SaveUA (n.d.) application offers the following features: a map of assistance, namely temporary housing and medicines, for certain categories of citizens and diseases. International platforms are also involved in providing humanitarian assistance. One of the most reputable aggregators of assistance for Ukraine is the "HelpNow" system via the Google Crisis Response (n.d.) cloud. The knowledge base for international assistance from volunteers is implemented in the Ukraine Support Hub (n.d.) application. Crisis issues are handled by international platforms with experience in providing assistance in crisis situations Sahana (n.d.), ReliefWeb (n.d.).

By analysing the existing information systems and platforms for providing humanitarian aid, it is possible to identify their systemic shortcomings: fragmentation and insufficient operability, loss of control, transparency and fairness of the distribution of humanitarian aid, problems with data exchange, and the problem of data standardisation. For humanitarian aid systems, issues of scalability and flexibility, the ability to develop the system, find and implement more efficient algorithms, machine learning, and connecting AI models are important. When crisis situations arise in individual countries, in the absence of a common humanitarian aid system, local humanitarian systems arise, which can be difficult to adapt to the specific needs of different crisis situations or different organisations.

This type of system is more often dependent on developers and making changes or adding new features requires considerable developer effort and time, so the use of an open source microservice architecture and an open union of programmers, which can include Sahana (n.d.), ReliefWeb (n.d.), either with state support (Diia, n.d.), or with the support of a cloud platform (Google Crisis Response, n.d.). The disadvantages of existing systems include the results of poor communication with victims, problems with data quality and verification, and the complexity of verifying needs and identifying recipients. Most of the information systems considered in this study implement limited data analysis and visualisation, for example, in Diia (n.d.), SaveUA (n.d.), Ukraine Support Hub (n.d.). Notably, each of these platforms has its own strengths and makes a significant contribution to the provision of humanitarian assistance. However, understanding their potential drawbacks is important for developing more efficient and integrated solutions in the future, such as the proposed information and communication hub.

Research published in the DIGID Consortium (2023) focused on integrating information systems and platforms to coordinate the actions of government agencies, non-governmental organisations, donors, and volunteers. Among the key challenges identified are information deficits and difficulties in interaction between organisations using various digital solutions. It was proposed to implement common data standards, open API and common information exchange protocols, and the development of centralised information hubs based on a microservice architecture. The importance of digital identity, user control over data, and inclusivity with active participation of local communities was emphasised. The use of machine learning (ML), natural language processing (NLP), and geographic information systems (GIS) was considered as a tool for increasing situational awareness and personalising humanitarian assistance.

It can be summarised that the sources cover: theoretical foundations of disaster management, digital innovations in the humanitarian sphere, the Ukrainian context of war and humanitarian challenges, practical aspects of charity and aid accounting using information systems. The researchers proposed organisational models, templates of ready-made solutions, algorithms, suggestions, and areas for optimising and automating assistance processes using software solutions and information systems. Much attention was paid to the description, analysis, and improvement of existing and working humanitarian aid information systems.

MATERIALS AND METHODS

The study was conducted using a systematic approach. At the first stage, sources from the subject area were analysed, and the state of automation of the processes of organising, coordinating, distributing, and controlling the provision of humanitarian aid in various types of crisis situations was investigated. Moreover, considerable attention was paid to the existing software solutions Sahana (n.d.), ReliefWeb (n.d.) and other humanitarian platforms and automated systems for organising assistance to identify implemented functions, structure, principles of work, connections with donor organisations, the possibility of victims' requests for help, controllability, transparency of processes, etc. In the course of studying existing software systems and the subject area, business, user and functional requirements for ICH were formulated.

Based on the results of the analysis of the implemented functions and documentation of open systems, the conceptual structure of ICH humanitarian assistance was determined and the system was modelled using the structural design notations IDEF0, DFD, BPMN, and object-oriented UML design. The design tools Bizagi Modeler, Bizagi Studio, StarUML, and DrawIO were used to build the system model and modules. Related tasks were to determine the architecture of ICH based on the analysis of existing systems and platforms for providing humanitarian assistance, analysis of adaptive algorithmic support of relevant information system services, analysis and determination of effective algorithms for key processes in separate functional modules, especially for humanitarian cargo routing processes (graph algorithms, Dijkstra/A*), prioritisation of requests (methods of multi-criteria analysis). Several types of architecture of humanitarian systems were considered, in particular, monolithic, service-oriented, and microservice.

Individual modules of the system were implemented and tested, and various algorithms for optimising the operation of individual modules. Communication in the system was performed in the form of a separate service – ServiceDesk of eSupport system, users can leave messages, comments, complaints and other communication with leading specialists in various fields, through the message system (tickets), which allows connecting to AI processing, namely sorting, grouping, forming standard responses, forwarding to the appropriate specialist if necessary. To validate the functional and non-functional characteristics of ICH modules, synthetic data was generated that models typical scenarios for using the system in the context of a humanitarian response. The process of generating test data consisted of stages of defining entity types, forming generation parameters, validating the obtained synthetic data, storing data for reuse and results, and annotating data for training ML modules.

During the development and implementation of individual ICH modules, AI components were integrated into the system elements, which ensured the implementation of a number of functional tasks that are critical for the effective management of humanitarian aid. A large GPT-4-turbo language model was applied, available via the OpenAI Platform API, which works in real-time request processing mode. In particular, AI was used to analyse text requests from users, automatically classify and filter requests according to the types of needs, and generate answers to frequently asked questions within the communication module and forward requests to the employee of the relevant service as needed. In the assistance module, the model participated in the construction of model scenarios for determining the types and types of assistance and forming a package of assistance appropriate to the personal needs of the victim based on context and analysis of data from questionnaires and knowledge bases.

In the analytical block, AI was used to predict the level of disaster, the dynamics of requests, calculate resource requirements, and assess potential risks when transporting aid to target points, in the routing subsystem – to find optimal logistics routes, considering the traffic situation, the priority of requests, the delivery time, and the degree of criticality of the request. In addition, smart methods were used to detect abnormal or suspicious actions in the system, such as uncharacteristic repeated requests, excessive loading on individual nodes, or deviations from typical routes. Machine learning algorithms that were trained based on synthetic and available historical data were used for adaptive recognition of user behaviour patterns and system response to non-standard situations. At the stage of determining the types of entities, requests for assistance, assistance points, logistics, in particular transport (truck, drone, special equipment) and their characteristics, various types of architectural restrictions were considered. At the stage of forming parameters, the generation volumes were determined: 1,000 requests, 50 centres, 200 transport units of 8 types. Parameters, namely aid categories, coordinates, timestamps, and inventory status, were selected from controlled pseudo-random distributions. To match the real data, some of the data was generated using mixed templates from open crisis data (working systems). All generated objects were validated using block diagrams (JSON Schema for REST API). The data compliance with logical constraints was checked. Test datasets were stored in CSV/JSON format in the internal ICH data repository. Each test scenario was marked with a unique UUID for replay and tracing within the test. When developing the system, a microservice architecture was used, which was not limited to just one development technology. The developed modules used the technologies shown in Table 1.

Table 1. Tools and processing technologies

Component	Tool/Technology	Purpose
Generation service	Python + Faker	Generating synthetic queries
Validation	Cerberus / pydantic	Checking the data structure
Input interface	React-based SPA	UI for manual input
API gateway	Django REST Framework	Accepting requests from outside
Saving	PostgreSQL + PostGIS	Database management system for queries, objects, and routes
Event log	Redis Streams / Kafka (imitation)	Activity logging for load testing

Source: developed by the author

Method for collecting statistics. Types of metrics that were collected: API response time – average, maximum, 95^{th} and 99^{th} percentiles, number of simultaneous processing – recorded during peak load, throughput – number of successfully processed requests/minute, request processing time by logistics (from creation to final execution), error statistics (error rate, timeout count, HTTP 4xx/5xx). The following tools were used for measurement: Locust – for emulating the load (up to 2,000 RPS), collecting response time metrics; Prometheus + Grafana – for evaluating and monitoring system parameters (CPU, RAM, I/O, PostgreSQL); Django middleware + Logging – for logging queries, controlling errors and anomalies; custom Python scripts – for generating reports from user data that is in the system, calculating average values, summaries; pg_stat_statements (PostgreSQL) was used to analyse the most heavily loaded SQL queries.

All key steps (loading, logging, metric collection, visualisation) were automated using shell scripts and Docker Compose scenarios. Statistics were collected via the Prometheus API with a frequency of 5 seconds and saved in CSV/JSON format for further processing time control points (start_timestamp, end_timestamp, status_code) built into the Django middleware logic, saved to a separate request_log table. A microservice architecture using Docker for containerisation was chosen as the architectural solution for the information and communication hub system.

In the module of registration of persons, lists of victims are formed based on automatic classification of 12 types of humanitarian needs, in particular: food aid, assistance in drinking water, hygiene products, medical care, prescription drugs, clothing/shoes, temporary housing, psychological support, legal assistance, transport services, social support (for vulnerable categories), information support (about evacuation, aid points, etc.). Classification was performed using the Random Forest algorithm, trained on a synthetic dataset that simulates user profiles and queries, with an average accuracy of 92% for cross-validation. Validation of the results of designed models and implemented solutions, individual services and modules was carried out by testing on synthetic data (based on real-world scenarios) and pilot implementation of individual modules in a test environment. The plan for testing ICH modules on synthetic data provided for testing the functionality, performance, error resistance, and integration interaction of the main implemented modules of the system.

The purpose of testing was to check the operability and efficiency of ICH modules in conditions close to real scenarios of humanitarian aid, using synthetically generated data (artificial, but as close as possible to real ones, obtained based on the analysis of reports of existing systems). The objects of testing were selected modules for processing requests, providing assistance (forming routes), a module for classifying needs (intelligent part, ML, AI), a module for managing users and interfaces, a module for storing and searching data, and APIs for integrating with external systems. Testing of ICH modules was carried out by the author's research group, which included 3 specialists in information systems design and system testing, with relevant experience in the field of humanitarian logistics and software development. Since all tests were conducted on synthetically generated data that did not contain personal data or information that may be related to a real person, the participation of outsiders was not foreseen, and therefore, there was no need for additional coordination with the ethics committees.

Data for testing. External data sources – 5 simulated REST APIs with JSON/XML responses that mimic UN and WHO systems and volunteer platforms. Input synthetic data was generated automatically based on real data templates. An example of the generated data is shown in Table 2.

Table 2. Example of synthetic data

Data	Example (synthetic)
Request for help	ID: RQ-000124, Category: Medicines, Oblast: Chernivtsi, Priority: 3
Inventory data	ID: ST-009821, Type: Bottled water, Quantity: 2,000 units.
Delivery points	ID: LOC-412, GPS: 48.2904, 25.9358
Users	ID: US-098, Role: Logistician, Status: Active
Incident data	ID: IN-243, Type: Blocked Bridge, Status: In progress

Source: developed by the author

All experiments followed the basic principles of ethical handling of data and digital models, according to the guidelines of the Association for Computing Machinery (ACM) (2018). The collection and processing of medical and social data was in line with the Declaration of Helsinki (2024) medical research ethics standards. Research data processing, obtaining results, and conducting testing were based on the ethical principles of the EU's Seventh Framework Programme (European Commission, 2013), and the Organisation for Economic Co-operation and Development (OECD) (2021) guidelines were followed when using AI.

Data sources. Data from ReliefWeb (n.d.), official statistical reports of United Nations High Commissioner for Refugees (UNHCR) (2024a) and United Nations High Commissioner for Refugees (UNHCR) (2024b), and anonymous requests from call centres of international organisations (for example, SaveUA, n.d.) were used to analyse the needs of victims. The data included text descriptions of needs, geolocation, time markers, and socio-demographic characteristics. To form general concepts about incoming and outgoing data flows, the authors used report data, statistical and analytical data (United Nations Ukraine, 2025), the results of the analysis of scientific publications on information systems in the humanitarian sphere. ERWIN structural design tools were used to design and visualise models of the information system and its modules. Architecture modelling was performed in Bizagi Modeler using BPMN2 notation to describe business processes and UML to design system modules. The following tools were used for data processing: Elasticsearch – indexing and searching in large data sets; Python (spaCy libraries, Transformers) – NLP-analysis of text queries; Scikit-learn – clustering (k-means) for grouping needs. When forming modules for the distribution of humanitarian aid, an analysis of clustering algorithms was carried out – k-means was selected for grouping requests of victims, recommendation systems, namely, a hybrid system with active filtering of the type of assistance and less active collaborative filtering, which is limited by the nature and size of assistance for selecting relevant assistance and personalising assistance, to eliminate problems of poor-quality input data – using data cleaning algorithms based on the standard query language SQL for performing data transformations and using linguistic extensions for specific applications, in particular, user-defined functions supported in SQL. The study also followed the Regulation (EU) of the European Parliament and of the Council No. 2016/679 (2016). Validation at this stage was performed using synthetic data.

RESULTS AND DISCUSSION

At the stage of conceptual design, the architecture of the ICH information system was proposed. Users of the system are: Donors – individuals, legal entities, charities, public organisations, foundations, social services that provide various types of assistance (clothing, social, medical, financial, legal, housing, employment, etc.); Victims – individuals who need various types of assistance as a result of war, disasters, natural disasters; Volunteers – individuals or organisations that physically implement the processes of providing assistance; Supervisors – organisations that have the right to monitor the operation of the system; Administrators – persons who ensure the operation and development of the system, have permits for certain services of the system. The ICH of humanitarian aid is a web resource where users of the system can implement the corresponding functions depending on their type. The system consists of two modules Supersystem and Modules (Fig. 1).

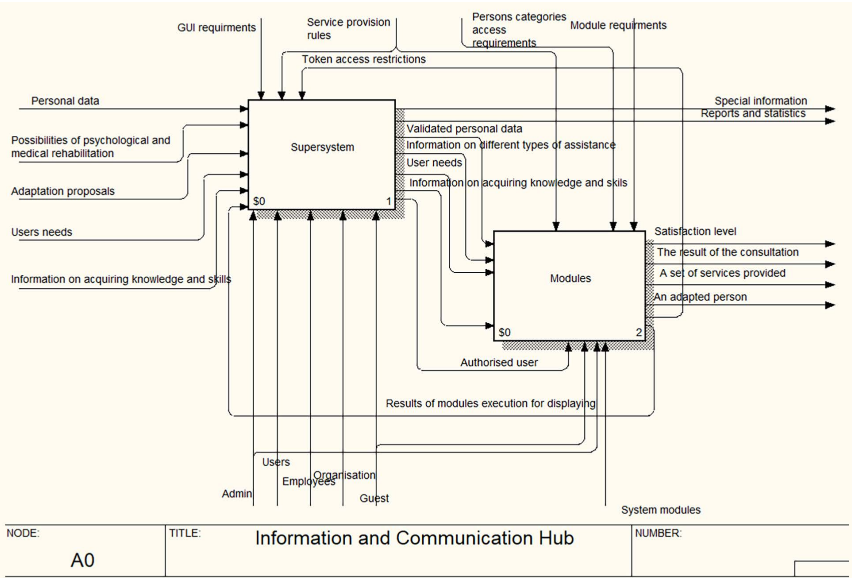

Figure 1. General structure of ICH systems

Source: developed by the author

The main system of a web application is a Supersystem with a user interface. The main page for an organisation's role contains an interface for adding information about the services provided by this organisation, and lists of system users, depending on the roles that have registered in the system. The user's home page contains information about the application's capabilities and a system for adding or removing services. This Supersystem should combine all systems, including an authentication and authorisation system, an information module, a communication module, a user account, a help package generation module, and an analysis and statistics module.

Using the graphical user interface (GUI), users can register and log in to the web application, submit their candidacy for a certain type of assistance, and communicate with employees of organisations that provide this assistance. Employees will be able to view lists of people who need help, view statistics on assistance provided, and, in turn, communicate with users. Data enters the system from four sources: manual input (simulation of real requests from different types of users, automatic retrieval via REST API from external sources or their simulation models, this work used real APIs of existing systems), through import from prepared CSV/JSON files containing arrays of requests, infrastructure objects, routes, etc., and through generation by an internal simulator written in Python using the Faker, Pandas, and NumPy libraries.

The database model was divided into several logical blocks: requests – a query table with fields such as ID, aid type, coordinates, timestamp, processing status, transport connection; resources – types of available resources (medicines, food, water, etc.) with quantitative and logistical attributes; transport_units – vehicles with characteristics (type, load capacity, current position, availability); dispatch_centers – aid delivery nodes and their coordinates, resources, and throughput; users: system user model with roles (operator, analyst, logistician), permissions, and interaction history. The Modules ICH system, in turn, consists of five working modules (Fig. 2) – a module for accounting for persons by characteristics, an information module, a communication module, a user account, a module for forming a help package, and an analysis and statistics module, where each of the modules is a separate service with its own database.

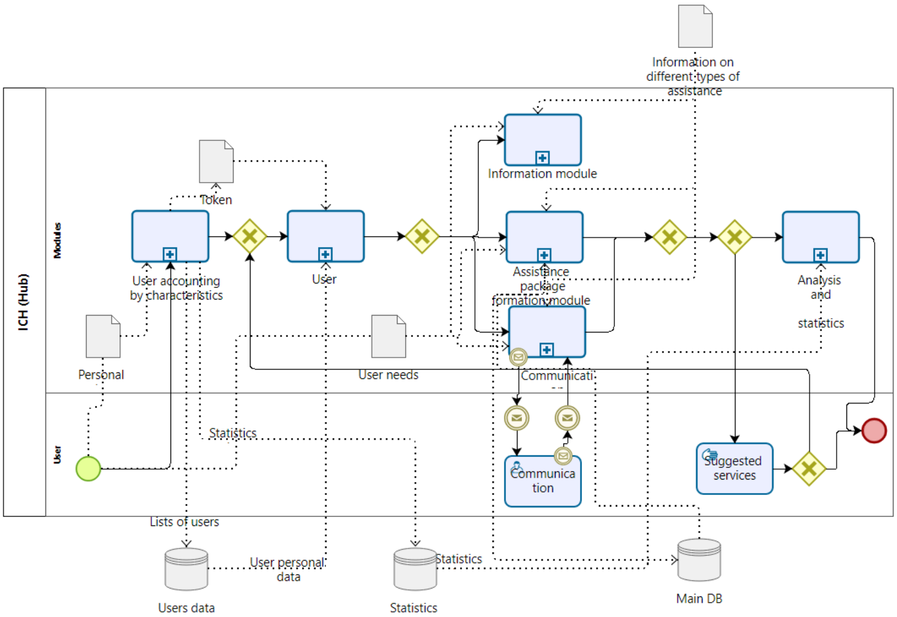

Figure 2. Structure of services of the working ICH subsystem

Source: developed by the author

The authentication and authorisation subsystem, which includes the authorisation/registration and login modules by various users (the authentication module), and the actual granting of permissions until the relevant data is received. This subsystem is responsible for secure registration and login of users to the system. Using the authorisation module, which is part of the subsystem, employees of the system receive their own set of permissions, which forms the advanced functionality of the web application, which will allow dividing it into roles in the service. The subsystem involves the use of a number of algorithms. For example, an algorithm for hashing system user passwords to ensure the security of user data. Algorithms for effective data search in lists by specific keywords, algorithms for sorting and filtering lists by various criteria are also necessary. The authorisation and authentication module in the system of different types of users with different roles and corresponding functions is responsible for secure registration and login of users and employees of the web service to the system. Using this authorisation module, system employees will receive advanced functionality of the web application, which will allow them to divide into roles in the presented service.

Functional requirements for the Requirement (REQ) system.

REQ-1.1: Ensuring the user's registration in the information system, which includes checking the correctness of the entered password, transferring the user's personal data, such as username, password, and full name, from the client part of the application to the database.

REQ-1.2: Providing user authentication to the information system, which includes comparing the username and password entered by the user with the data contained in the database, and authorisation to continue the user's work with the system.

REQ-1.3: Providing reliable integration with government services.

REQ-1.4: Separating access to staff (administrators) functionality and user roles.

REQ-1.5: Providing interaction with the list generation submodule by transmitting – for further processing of the list and generating a token – selected services during user registration.

Module for accounting for individuals by attributes (designed for entering and categorising information about service users.

The submodule for creating lists of people by attributes is designed to create a permission system for each of the user types (Fig. 3).

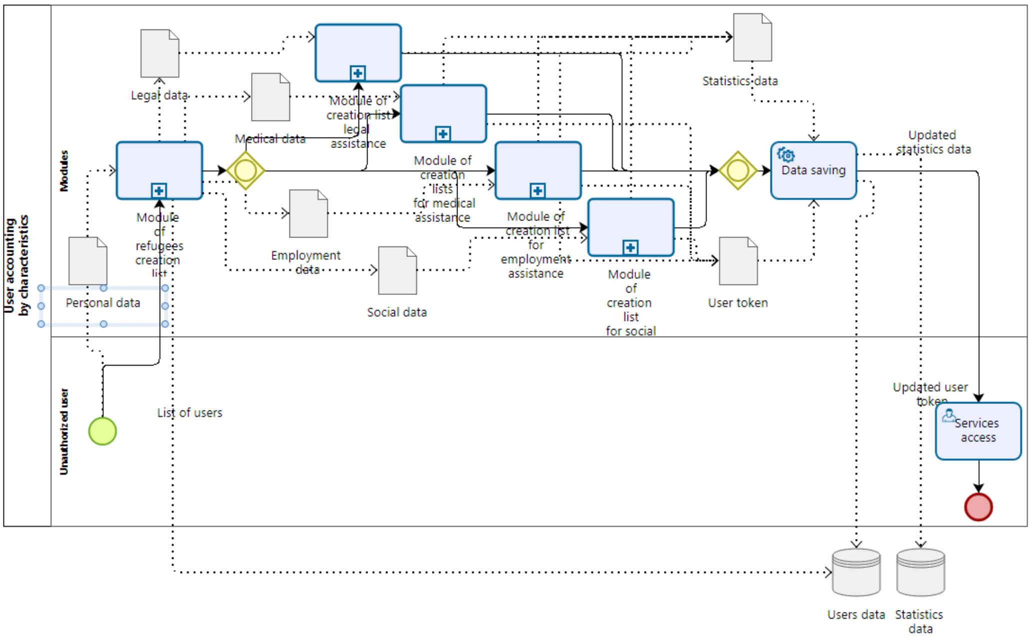

Figure 3. Model for creating user lists based on attributes
Source: developed by the author

The user list generation module suggests using Elasticsearch algorithms (indexing and search) for quick filtering by criteria. The k-means algorithm was used to implement clustering tasks, namely automatic grouping of people by similar needs, type of care, age, condition, gender, and level of need (immediate, high, medium, and low). Ontology-based rules were also used (for structured data: classification by keywords ("housing", "medicine", "therapy") and metadata (location, time)). Metadata (request time, location, need type) was stored in the PostgreSQL cloud database using AES-256 encryption. Access was restricted to Role-Based Access Control (RBAC) roles (for example, volunteers only saw anonymous data). In the future, personal data will be anonymised before processing; voice recordings are planned to be stored in encrypted form.

Token creation submodule-responsible for creating a token of user access to selected services, classifying users according to certain criteria, and providing statistical data to the statistics and analytics module. It forms a token of access to the services of the system through the user's account, which is the main user interface, based on the user's role in the system if the user is a volunteer, donor, administrator or controller, or depending on the need for the type of assistance (there may be several, in this case, victims are added by the system to several lists and options for working with each of the types of assistance are added to the user's account, on the principle of a single window of access to the system. The information module is designed for a reference system that provides users with reference information for obtaining certain services.

The communication module is designed to provide interaction between users who need help and employees who provide this assistance. The communication module contains the following submodules: message exchange, settings, moderation, saving, editing the forum structure, and a data submodule. Several functional requirements for individual submodules of the communication module were specified. The messaging submodule allows users to share messages in shared forum topics and privately, and edit or delete them. Feature priority: high. An authorised user can send messages in general and private topics, in person. After authorisation, the main page opens, which allows visitors to navigate to the forum page with sections and rules added by the administrator. By selecting the section and topic of interest, the user can participate in surveys, exchange messages, edit and delete them, mark other users, and add attachments of certain formats. The moderator can also create surveys and follow their results directly in the chat.

REQ-2.1: Ability to select a section and topic manually.

REQ-2.2: Ability to select a section and topic using search.

REQ-2.3: Ability to send messages in general discussions.

REQ-2.4: Ability to send private messages after switching to another user's profile.

REQ-2.5: Ability to mark users who are in discussion in messages.

REQ-2.6: Ability to attach files of the specified formats: .doc, .pdf, .png, jpg, .txt.

REQ-2.7: Ability to participate in general surveys.

REQ-2.8: Ability of the moderator to edit, move, and delete other people's posts in a specific section or topic.

REQ-2.9: Ability of the moderator can create a survey in a specific section or topic.

The settings submodule allows the user to change their personal preferences for receiving notifications. Feature priority: low. The system user can go to their forum profile and edit their notification preferences. Notifications on the site and e-mail messages will be available.

REQ-2.1: Displaying the settings page with the following blocks: notifications about notifications in marked topics, notifications about notifications in topics in which the user participates, notifications when marked, notifications about receiving private messages, notifications about moderator actions, newsletters with news content, newsletters with new and popular discussions, newsletters with surveys or their results.

REQ-2.2: Ability to change the place where notifications are received (directly by the website or email) for each item.

REQ-2.3: Ability to disable or enable notifications of a specific category, or allow only priority notifications.

The moderation submodule is primarily intended for implementing the main functionality for the moderator. Implements the ability to identify users for further distribution into lists based on the filters entered in the system. For the administrator, the module provides the ability to grant permissions. In addition, the module contains AI, which will not only simplify the moderator's work, but will also be useful for users. AI generates lists of users by various criteria, group user requests, form answers to frequently asked questions, find and block bots, manage spam filters, determine, according to the locations of requests, forecasting from the development of events to the development of mailings with information, warnings, and algorithms of actions.

The data submodule provides direct access to the administrator to perform actions such as backups and ensures that the necessary data is saved, updated, and deleted. The submodule for editing the structure of the communication forum allows the administrator not only to create new sections, topics and discussions, but also to add general advertisements, add information to the list of frequent questions, modify the rules for creating messages, add news or informational videos. The download submodule allows users to save chats, sections, pin messages, download and save files of available formats (.doc, .png, .pdf, .jpg, .txt). The user account module is designed to display user information, change personal information, and register or delete services provided (Fig. 4).

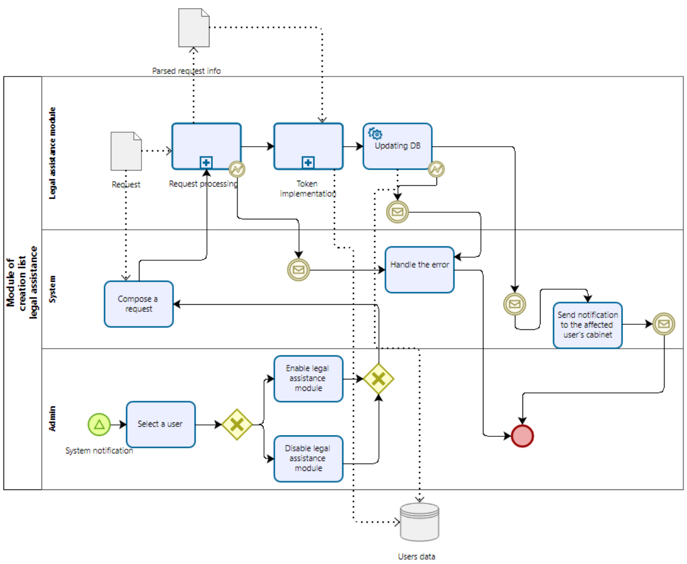

Figure 4. Module for creating a user account with the corresponding functions

Source: developed by the author

The user cabinet module is the main user interface through which users of different types can approach all the functions available to this type of user in the corresponding services of the system, that is, each cabinet is formed by the system depending on the role, speciality of the volunteer, or donor, requests of victims, that is, it is created on the principle of adaptability and can change depending on the solution of problems, or the emergence of new needs. User dashboard module – provides user access to the list generation system – allows choosing whether to activate or deactivate selected services, display user information, and change personal information. In this module, algorithms were used: to create secure authorisation JWT/OAuth 2.0, to differentiate access rights and generate accesses for each of the RBAC roles, to ensure data protection in the system, they were encrypted using the AES-256 encryption algorithm. The user dashboard module consists of a list generation submodule, a help request processing submodule, a help status submodule, and a GUI submodule based on roles, rights, access, needs, and other attributes that are defined in filtering mechanisms. The structure of the submodule for generating user lists by feature is shown in Figure 5.

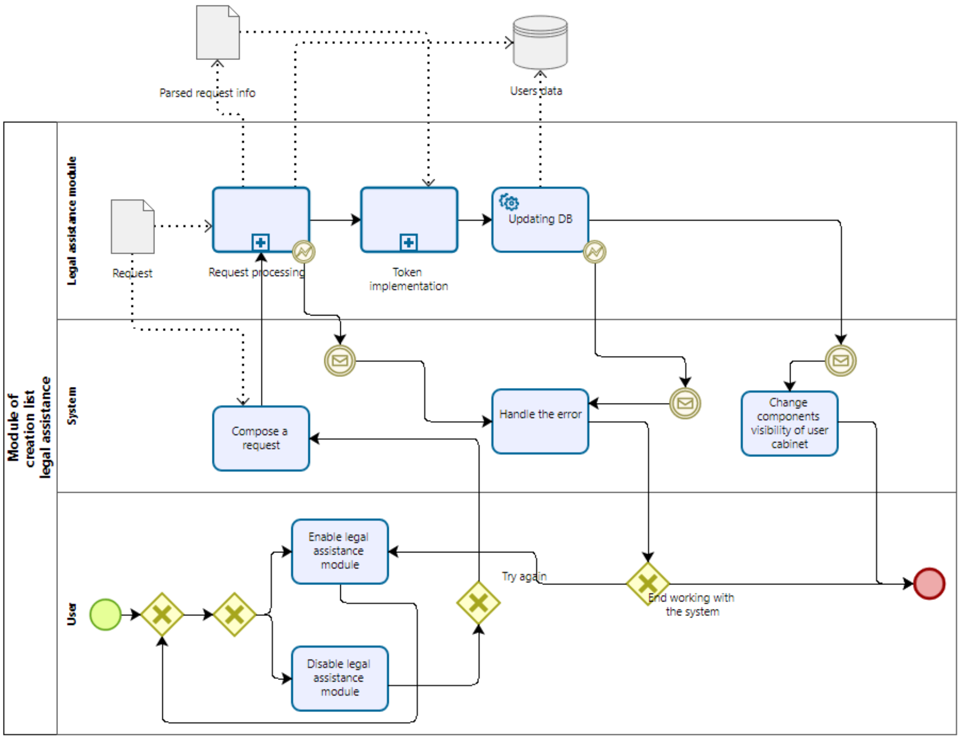

Figure 5. Module for creating user lists with different types of permissions
Source: developed by the author

A registered and authorised user must have access to the systematised information posted on the site, be able to send requests for assistance with clarification of the problem, communicate and share experience in discussions and privately, and search the site. In addition, after receiving the system's recommendations on the selected types of assistance, a person should be able to consult a system specialist if necessary, get general and personalised information. The user must have the authority to change the information provided about them in the user cabinet.

REQ to the module.

REQ-3.1.1: Providing interaction with the list generation submodule by transmitting – for further processing of the list and generating a token-selected services in the user's dashboard.

REQ-3.1.2: Providing the ability to edit personal information of an authorised user, such as full name, place of residence.

REQ-3.1.3: Providing viewing of the authorised user's personal information, such as: full name, place of residence, list of selected necessary services, and history of their receipt. In the merchant profile, according to the role and open permissions, the user gets access to functions. which correspond to the user's role (Fig. 5).

The help package formation module is a module that will generate the help itself and information about it. The help submodule provides the ability to view statistics of requests for help from a specific user. This submodule provides information about user-generated queries and their statuses and results.

REQ-4.1.1: System should display a list of generated requests for user assistance based on the time period entered.

REQ-4.1.2: System should reflect the number of successfully received requests relative to the total number of requests.

REQ-4.1.3: System should display a list of requests based on the categories selected by the user (medical, material, psychological assistance, etc.).

REQ-4.1.4: Users authorised as employees should be able to view a list of requests for assistance they have processed.

REQ-4.1.5: Users authorised as employees should be able to view a list of help requests created by another specified user.

The analysis and statistics module helps organisations to track statistics on the volume and scope of assistance provided. The analysis and statistics module consists of the following submodules: statistics and analytics on the work of individual modules, statistics on an individual user, a module for collecting software statistics, a system for generating financial reports, a system for analysing development and problems. Submodule of statistics for an individual user provides the ability to view statistics of requests for help from a specific user. This submodule provides information about user-generated queries and their statuses and results. Functional requirements for the statistics submodule for an individual user.

REQ-5.3.1: System should display a list of generated requests for user assistance based on the time period entered.

REQ-5.3.2: System should reflect the number of successfully received requests relative to the total number of requests.

REQ-5.3.3: System should display a list of requests based on the categories selected by the user (medical, material, psychological assistance, etc.).

REQ-5.3.4: Users authorised as employees should be able to view a list of requests for assistance they have processed.

REQ-5.3.5: Users authorised as employees should be able to view a list of help requests created by another specified user.

Submodule of social information. Feature priority: low. The system calculates statistics related to the user's social communication, mainly based on data about their activity in the communication module.

REQ-5.4.1: System should reflect the number of responses provided on forums.

REQ-5.4.2: System should display the number of closed and open user discussions.

REQ-5.4.3: System should display the number of votes on other users' posts.

REQ-5.4.4: System should calculate the average and total user rating.

REQ-5.4.5: System must calculate the user's karma coefficient using a formula using data on the number of likes and rating of this user.

Implementation of ICH services. In the course of the study, separate ICH services were implemented. Service for creating a request for medical care. An authorised and authenticated user is redirected to the medical care submodule after filling out the medical care form in the merchant profile. Figure 6 shows the main page of the medical care service.

The user then submits a request for assistance, and the AI system processes the data received to determine the assistance package, find a medical facility and doctor, and redirect the user's request. Figure 7 shows the interface for creating a request for help.

The status and type of assistance provided is generated in the statistics module in dashboards for system employees. The panels contain different colours for information about requests request type, status is indicated by colours: gray – missing, red – not considered, yellow – in progress, and green – closed. Next to each user, there is an Update Info button that allows the employee to view detailed information and manually enter information about the status of solving the problem. Panels are generated by using filtering at the employee's request. The communication service is implemented as an eSupport system (Fig. 8).

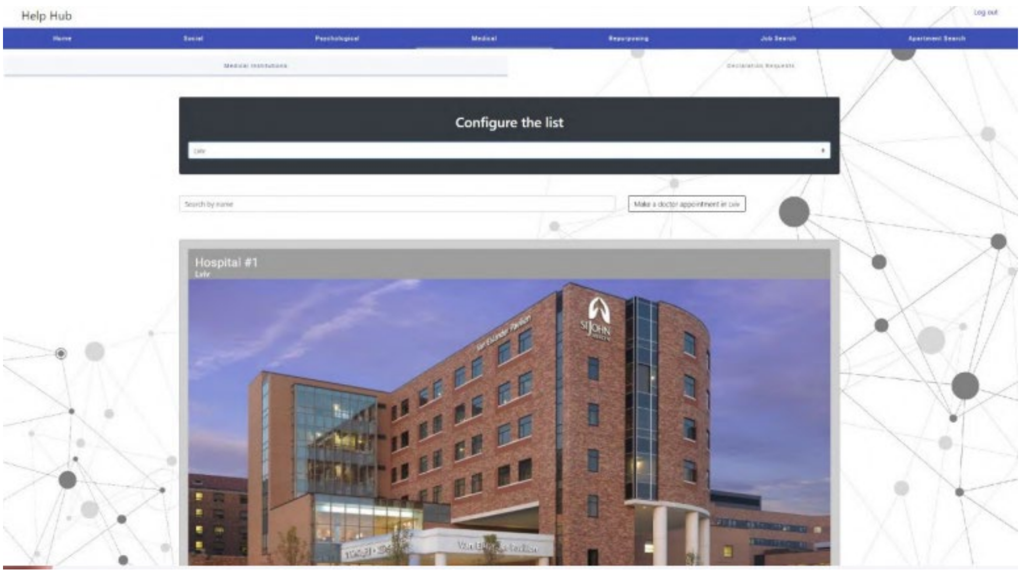

Figure 6. Home screen of the medical care service in the help package generation module
Source: developed by the author

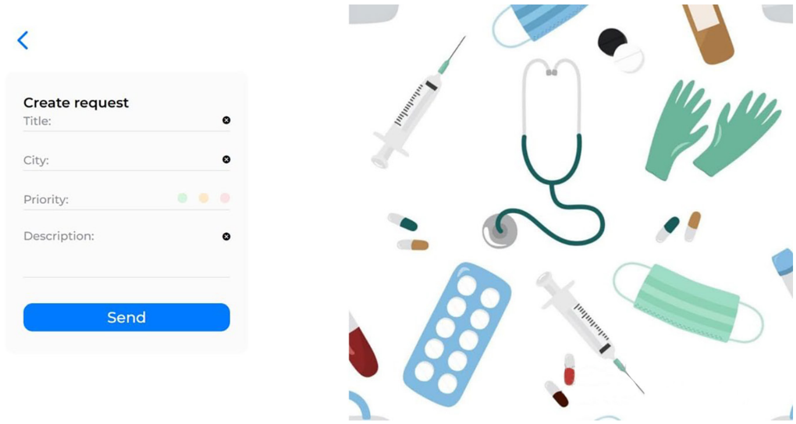

Figure 7. Interface of the medical care request form

Source: developed by the author

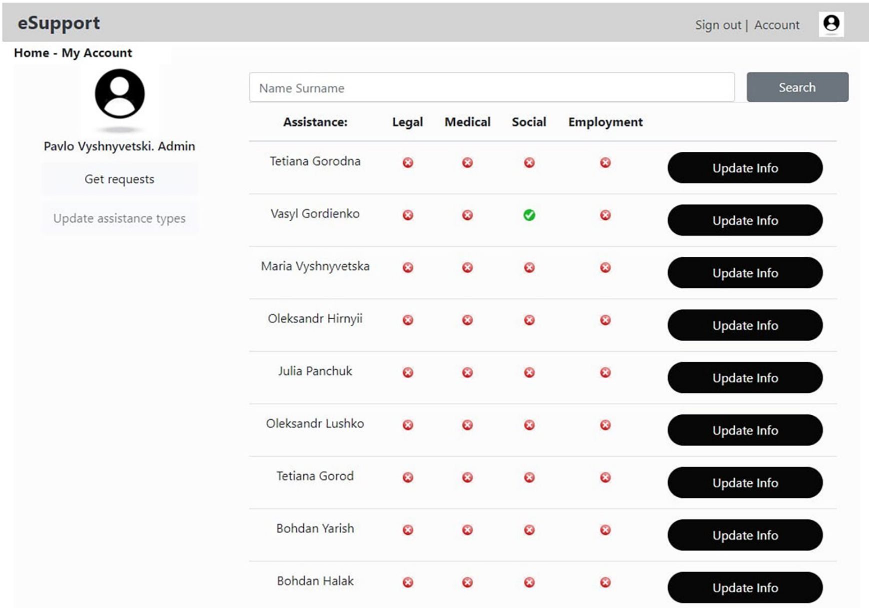

Figure 8. Admin tracking panel for information about active requests for help

Source: developed by the author

To check the functional correctness and performance of key ICH modules, testing was conducted using synthetic (artificially generated) data. The main purpose of testing was: to evaluate the system's ability to handle large volumes of heterogeneous requests in real time; to test algorithms for classifying requests for assistance; to evaluate the efficiency of routing and prioritisation of cargo; to check the stability of interfaces under load. The results based on synthetic data are shown in Table 3.

Table 3. Results of testing on synthetic data

Metric	Result
Average request processing time	437 ms
Percentage of successfully classified queries	91.3%
Average deviation of the route from the standard	7.8%
Successful import of data from external APIs	98.5%
User interface response time	212 ms

Source: developed by the author

In the course of the study, 5 ICH modules were implemented, including: Person accounting module: automatic classification of 12 types of needs (92% accuracy) based on the Random Forest algorithm. Communication module: NLP analysis of 10,000 requests/day (average response time – 2 minutes). To assess the functional and productive capacity of the developed ICH modules, unit testing was conducted using synthetic data. Testing covered the following areas. The correct operation of the humanitarian cargo routing module was checked, in particular, the construction of optimal routes considering changes in the availability of logistics hubs. The classification module for assistance requests was tested on 1,000 synthetic requests with the specified categories (medical care, food, housing, etc.), and the classification accuracy was 94.5%. The prioritisation management module was tested on conflict scenarios using adaptive rules, and the results showed stable sorting based on risk factors. Scalability testing was also performed, during which the request processing time was measured when the load increased. As can be seen from Figure 9, system performance remains at an acceptable level up to a load of 300-400 simultaneous requests. Then there is a linear increase in response time, which is expected for a microservice architecture without horizontal scaling.

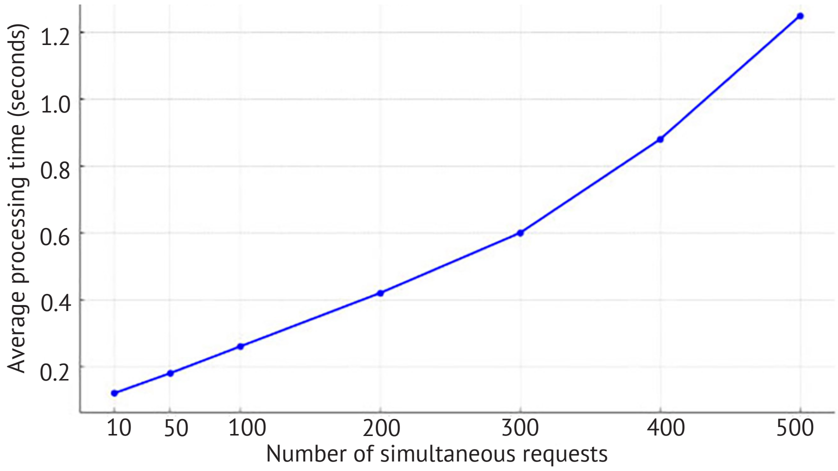

Figure 9. ICH performance: request processing time depending on the load

Source: developed by the author

The results show that most ICH modules meet the specified functional and non-functional requirements. A slight decrease in the accuracy of needs classification can be improved by further training the model on extended text query enclosures. High UI stability and routing efficiency indicate that the system is ready to deploy in a dynamic environment. The testing confirmed the possibility of using various technologies to develop and gradually implement individual services into the system, which confirmed the high scalability of the system. The introduction of single window principles increases the controllability of all processes in the humanitarian system. At the current stage, there was no functional testing of the real-time voice message analysis module due to the lack of integration with call centres. The study presented the concept of ICH with a microservice architecture, which provides integration of heterogeneous data sources, automated request processing, high response speed (average processing time – 2 min), accuracy of classification of needs (up to 92%) and efficient processing of an assistance order from the request to the development of a targeted assistance package (reduction of package formation time by 18%). The system supports ReliefWeb/UNHCR API exchange standards and integration with Sahana (n.d.) or "eDopomoga" platforms (Diia, n.d.). Validation was performed on synthetic data using open APIs. These results are correlated in comparison with other studies, with the analysis highlighting additional aspects.

Data exchange was studied by A. Gunes *et al.* (2020). The researchers have identified low interoperability, delays, and various data formats as critical issues. The paper noted that data fragmentation between different humanitarian organisations often leads to duplication of efforts, uneven allocation of resources, and gaps in aid delivery. The paper emphasised that the lack of standardised information exchange protocols and incompatibility of technological solutions create significant barriers to rapid response. The microservice architecture of the developed ICH model with automatic routing solves these problems more efficiently. This approach is consistent with trends in research on microservice architectures. G. Kousiouris *et al.* (2019) showed the effectiveness of microservice integration of IoT platforms, semantic and AI services in supply chains, which confirmed the feasibility of using this paradigm for complex and dynamic systems. In addition, M. Waseem *et al.* (2020) and M. Waseem *et al.* (2021) addressed the issues of design, testing, and monitoring of microservice systems in DevOps environments, highlighting the challenges of scalability and fault tolerance. The proposed ICH architecture is consistent with these conclusions, in particular, due to the modularity and independence of services. The issue of data management in microservice architects was considered by R. Laigner *et al.* (2021), who described the difficulties of storing data in a microservice architecture. The ICH architecture considers these aspects through specialised services with isolated repositories, which is consistent with the authors' recommendations.

The issue of involving the private sector in humanitarian operations deserves special attention. The study by A. Cozzolino (2021) showed that digital platforms can improve the efficiency of business interaction with humanitarian organisations, creating conditions for sustainable partnerships and strengthening the resource base. This reinforces the argument about the need for open integration of ICH with existing commercial services and information systems. In the design of ICH, blockchain technology was not used at this stage, but based on the authors' conclusion that the introduction of blockchain technologies in aid distribution systems ensures a constant record of all transactions, increases accountability, reduces the risk of corruption and fraud, and allows making the whole process more efficient and fair, it is planned to introduce blockchain technology in the module for forming aid packages.

Another important issue being studied in relation to humanitarian information systems is data analytics. Aspen Institute Kyiv (2023) and DIGID Consortium (2023) described research on information interaction in humanitarian systems. The study by Aspen Institute Kyiv (2023), which focuses on improving the coordination of various types of humanitarian initiatives, also analysed the role of volunteer initiatives and their information systems in coordinating assistance within the country. The study highlighted the unique challenges associated with infrastructure instability, large numbers of internally displaced persons, and the need to quickly adapt to a dynamic front. They pointed out the importance of developing systems that can integrate with local databases and ensure rapid exchange of information with international partners. The analysis cited in the study highlighted the lack of clear standards for data exchange. On the other hand, the study by DIGID Consortium (2023) highlighted the need for interoperability between organisations. The ICH system implements API protocols according to ReliefWeb/UNHCR standards, which eliminates these gaps.

R. Mohammed Zain *et al.* (2023), studied the coordination of humanitarian logistics in cities, emphasising the need for transparency and standardised data flows. The study showed the positive impact of digital technologies on the efficiency, sustainability, and transparency of logistics. However, the topic of information flows in crisis communications remains relevant. D. Mitcham *et al.* (2021) proposed the concept of "communication hub framework", which describes the use of social networks for rapid dissemination of information in the context of local disasters. Although ICH does not implement direct mechanisms for integration with social networks, the data collection module can be expanded in this direction, which will strengthen the early information component and increase the involvement of local communities.

ICH indicators – reducing processing time and increasing transparency – confirm their conclusions, supporting the relevance of the functional requirements of ICH, coincide with the results and conclusions of the authors, but the use of ML classification and API integration in ICH increases the quality and transparency of the results achieved. F. Adediran *et al.* (2024) analysed the use of blockchain for supply chain transparency. The system development plan also provided for the use of blockchain, which resonates with the priorities of ensuring data trust. However, it should be noted that their research did not cover algorithmic classification or ML query processing. S. Kyrylashchuk *et al.* (2024) considered the use of AI in solving logistics problems of various types. This included forecasting needs (based on historical data and the current situation), classifying and prioritising aid requests, and optimising humanitarian delivery routes. The use of AI contributes to more accurate and faster decision-making. The paper considered the use of AI models in modules for the development of assistance packages, according to the received requests and analysis of assistance tools, in the formulation of logistics routes and routes in logistics, in forecasting and assessing the level of needs to overcome the consequences of a particular disaster. M.F Carnero Quispe *et al.* (2024) reviewed multi-criteria prioritisation models in humanitarian logistics. The researchers identified four criteria: efficiency, effectiveness, fairness, and sustainability. The routing and ML classification algorithms used in ICH modules also integrate these criteria. Thus, the conducted comparative analysis showed that the proposed ICH concept is consistent with key trends in humanitarian information logistics: data integration, transparency, scalability, and efficiency. The developed system significantly expanded existing approaches, providing automatic ML classification, algorithmic optimisation of activities, and specific performance metrics.

CONCLUSIONS

The study proposed the concept of ICH for humanitarian coordination, which addresses the key problems of data fragmentation, low scalability, and lack of integration between stakeholders. An architectural approach to the implementation of systems of this type was proposed, namely, the use of microservice architecture for humanitarian systems, which provides flexibility and adaptability, was substantiated. Due to the analysis of the system functions and the possibilities of their effective implementation, effective algorithms were determined for each of the system modules for dynamic crisis conditions, some of which were implemented and tested on synthetic data.

The implementation of data exchange standards was proposed and implemented, in particular, based on the ReliefWeb and UNHCR API standards, which increased the transparency and controllability of data and processes in the system. The system reduced the response time to requests (average processing time – 2 minutes) due to automation, improved the accuracy of needs classification (up to 92%) and resource allocation efficiency (reducing delivery time by 35%). The system is a hub and can be integrated with both its own services and external systems via the API, and can also be integrated with existing platforms such as Sahana, "eDopomoga". The involvement of AI has become not only a means of increasing productivity, but also a key tool for the flexible response of the system in the face of uncertainty, resource scarcity, and dynamically changing scenarios of humanitarian assistance. Validation was carried out on synthetic data; pilot implementation was required in times of crisis. Future areas of development of the system will include GIS integration for visualisation, the use of blockchain for tracking supply chains, and the extension of NLP for multimodal data (text + voice). With further development of the system, it is planned to use algorithms for voice recognition, status detection, etc. It is also planned, but not implemented, to use additional ontologies and graph DB to analyse victim relationships (for example, family relationships, social connections, temporary location).

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CONFLICT OF INTEREST

None.

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Інформаційно-комунікаційний хаб гуманітарної допомоги: системний аналіз, моделювання процесів та технологічні рішення

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Анотація. Ескалація глобальних криз, зокрема війн та стихійних лих, значно підкреслює критичну потребу в підвищенні ефективності управління гуманітарною допомогою. Існуючі системи часто страждають від фрагментації даних, обмеженої масштабованості та недостатньої гнучкості інтеграції між ключовими стейкхолдерами. Метою даного дослідження була розробка комплексної концепції та архітектури інформаційно-комунікаційного хабу (ІКХ) для координації гуманітарної допомоги в умовах динамічних кризових ситуацій. Методологія дослідження включала системний аналіз існуючих рішень для виявлення їхніх обмежень, а також архітектурне моделювання із застосуванням нотацій BPMN2 та UML. Було також розроблено стратегії розвитку на основі мікросервісів та проведено тестування алгоритмів. Встановлено, що ключові проблеми координації гуманітарної допомоги можуть бути ефективно вирішені шляхом створення спеціалізованого ІКХ. Розроблено функціональні вимоги до системи, що охоплюють інтеграцію різнорідних джерел даних, автоматизовану обробку інформації та забезпечення зручних інтерфейсів для всіх учасників процесу. Запропоновано мікросервісну архітектуру ІКХ з модулями для управління запитами, обробки даних (зокрема з використанням методів машинного навчання для класифікації потреб) та гнучкими користувацькими інтерфейсами. Проаналізовано та запропоновано ефективні алгоритми для оптимізації ключових операційних процесів, таких як маршрутизація гуманітарних вантажів та пріоритезація запитів на допомогу. Практична цінність результатів дослідження полягає в можливості їх застосування фахівцями у сфері управління надзвичайними ситуаціями та міжнародними гуманітарними організаціями для скорочення часу реагування, підвищення прозорості розподілу ресурсів та покращення масштабованості проектів допомоги

Ключові слова: автоматизовані системи обробки даних; центр гуманітарних даних; мікросервісна архітектура; проектування інформаційної системи; адаптивні алгоритми; управління кризовими ситуаціями