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Design and Implementation of Software Platform for Orthopedics and Traumatology Coordination Among Health Institutions in Disaster Situations in Turkey

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Abstract

In large-scale disasters that disrupt societal functions, the expertise of orthopedic and traumatology specialists plays a critical role in managing a substantial proportion of injuries. However, the effective and efficient utilization of available resources in the aftermath of such events necessitates the establishment of a rapid and dynamic organizational framework among healthcare institutions, tailored to the specific characteristics of the disaster. Despite the existence of disaster management regulations issued by relevant ministries, particularly the Ministry of Health, as well as earthquake monitoring and information systems developed by AFAD, there is currently no actively utilized system capable of coordinating and informing healthcare institutions and medical professionals within minutes following a disaster. A systematic approach that involves the identification, categorization, and prioritization of healthcare institutions' needs, the definition of inter-institutional coordination mechanisms, and the early notification of volunteer orthopedic and traumatology specialists has the potential to enhance resource optimization in disaster response efforts. In this context, the coordination and management software platform is developed in order to facilitate the rapid coordination of healthcare institutions upon disaster occurrence, ensuring timely communication with specialists and minimizing the time required to deliver critical healthcare services in the affected areas. Featuring a map-based interface, the platform is designed to be user-friendly and incorporates rule-based assignment algorithms to effectively address the healthcare needs of disaster-stricken regions.

Keywords: Disaster management, healthcare coordination, multi-layer architecture, NET framework, orthopedics and traumatology

1. Introduction

In large-scale earthquakes, musculoskeletal system injuries constitute a significant proportion of traumatic injuries [1]. Following the earthquakes centered in Kahramanmaraş on February 6, 2023, a portion of the affected individuals received medical care at Adana City Hospital (ACH), which remained operational due to being relatively less impacted by the disaster. During the first week after the earthquake, ACH admitted a total of 3699 patients with earthquake-related injuries, of whom 1092 required treatment for musculoskeletal system injuries [2]. Notably, musculoskeletal injuries accounted for 29.5% of all injuries treated at ACH, highlighting their substantial prevalence in such disasters.

During a disaster, the healthcare system becomes a high profile element, critical to the immediate health response and recovery phase. The immediate response of orthopedic and traumatology

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specialists in disaster-affected areas is critical, particularly given the high incidence of musculoskeletal injuries among victims. Disaster situations pose significant challenges for health institutions, particularly in the fields of orthopedics and traumatology, where rapid coordination between various entities is crucial for effective patient management and recovery. However, previous disaster responses have demonstrated persistent challenges in the efficient allocation and utilization of resources. In this regard, the development and implementation of software platforms dedicated to facilitating this coordination can greatly enhance the resilience and responsiveness of health services in times of crisis.

As defined by Zhong et al., hospital disaster resilience encompasses a health institution's ability to maintain core functions while absorbing and responding to the shocks of disasters, ultimately enabling a return to normalcy or a new adaptive state [3]. Resilience is particularly vital in contexts where multifunctional coordination of medical services is essential. Evidence from a variety of disaster management scenarios highlights the need for robust planning and the lack of specific disaster protocols as significant impediments to effective health services coordination [4]. For example, the utilization of mobile integrated health providers illustrated the importance of efficient communication and coordinated response in handling flood-related health emergencies [5].

The capacity for digital networks and health care providers to collaborate effectively is another critical aspect of disaster response. As emphasized in the research in [6], collaborative frameworks between digital volunteer networks and formal health organizations enhances data sharing and facilitates a more organized response to catastrophic situations. Additionally, the equitable distribution of resources during disasters reinforces the need for effective data management technologies to streamline access to crucial medical information [7]. In order to support emergency aid responders, an e-health platform providing drug calculations, case management guidelines, and a deep learning model for pediatric X-ray analysis was introduced in this study. Furthermore, integrating predictive, preventive, and personalized medicine into emergency medical responses, as elucidated in [8], can optimize the management of field hospitals and enhance the delivery of orthopedic and trauma care during disaster scenarios. This modern approach facilitates better outcomes by addressing the unique needs of patients immediately affected by disasters while supporting the operational efficiency of health institutions. Ultimately, software platforms dedicated to orthopedic and trauma coordination during disasters should not only focus on immediate clinical needs but also incorporate systems for psychological interventions, resource distribution, and inter-institutional collaboration. In this paper, we introduce an interactive and map-based software platform for coordination among healthcare organizations, which could be used in the aftermath of a disaster. The platform provides category assignments of health organizations for effective and timely provision of healthcare services in affected regions.

2. Framework and Definitions of Health Organization Structures in Disaster Situations

The developed software platform serves as an inter-institutional coordination system designed to efficiently allocate resources and facilitate the rapid and effective delivery of healthcare services to disaster-affected areas. One of the primary objectives of this platform and coordination system is to address the healthcare needs of the affected community to the greatest extent possible until state-led emergency response operations become fully functional.

To achieve resource optimization following a disaster, the system identifies the epicenters on a digital map of Turkey and categorizes healthcare institutions located within these regions or at specific distances from the epicenters. This categorization is performed using an algorithm that evaluates multiple criteria and assigns healthcare institutions to one of four distinct categories based primarily on geographical proximity and hospital bed capacity. The categories and their definitions are as follows:

Red Zone Healthcare Institution (KASK): Refers to healthcare institutions situated in areas where fundamental needs such as daily living, shelter and protection cannot be met following a disaster.

Yellow Zone Healthcare Institution (SASK): Denotes healthcare institutions that are geographically adjacent to red zone institutions, located within the nearest unaffected areas within national borders where social life remains stable.

Green Zone Healthcare Institution (YASK): Comprises healthcare institutions within national borders that can provide immediate personnel and equipment support to red zone institutions that have been severely impacted and rendered inoperable. Green zone institutions are geographically the closest to yellow zone institutions.

Blue Zone Healthcare Institution (MASK): Encompasses all healthcare institutions within the country that do not fall into the KASK, SASK, or YASK categories. Following a disaster, MASK institutions, in coordination with SASK institutions, provide the necessary personnel and equipment support to KASK, SASK and YASK institutions while also addressing the medical needs of referred patients.

Public, private, and university hospitals operating within the platform are pre-registered into the system before active usage. This registration process includes essential data such as geographical coordinates (latitude and longitude), bed capacity and the list of orthopedic and traumatology specialists affiliated with each institution. Furthermore, as these attributes change over time, system administrators are responsible for continuously updating them via the platform's user interface.

3. Health Institution Category Assignment Algorithm

Once the disaster definition has been established, the process of assigning healthcare institutions to the KASK, SASK, YASK, and MASK categories is initiated. The flowchart of the algorithm is given in Figure 1. The assignment process begins with the classification of institutions into the KASK, SASK, and MASK categories, followed by the reassignment of specific MASK-category institutions as YASK, depending on the capacity of KASK institutions. The detailed methodology for these assignments is outlined below:

KASK Assignment: Healthcare institutions classified as KASK are determined based on the number and radii of the markers defined on the map. All healthcare institutions located within the areas covered by these markers in the disaster definition are designated as KASK.

SASK Assignment: SASK institutions are identified as those situated within a maximum distance of 100 km from the perimeter of the disaster-affected area. However, during this assignment, the total bed capacity of KASK institutions is also taken into account. If the cumulative bed capacity of KASK institutions reaches a predetermined threshold at a shorter distance, the SASK assignment process is terminated.

MASK Assignment: Before the designation of YASK institutions, all healthcare institutions within Turkey that have not been categorized as KASK or SASK are initially classified as MASK.

YASK Assignment: YASK institutions are selected from among the MASK institutions that are geographically closest to KASK institutions and have not yet been assigned as YASK.

YASK Assignment Algorithm:
Step 1: The algorithm begins by calculating the distance between each KASK and every MASK institution, generating a KASK/MASK distance matrix.

Step 2: Using the distance matrix, the closest MASK institutions to each KASK are identified. However, due to geographical proximity, a single MASK institution may be the nearest candidate for multiple KASK institutions.

Step 3: The MASK institutions identified in Step 2 are grouped based on their proximity to the corresponding KASK institutions. Within each group, the closest MASK institutions to a given KASK are reassigned as YASK.

Step 4: Following the KASK-YASK pairings, healthcare institutions designated as YASK are removed from the KASK/MASK distance matrix.

Step 5: The assignment criteria for each KASK institution are evaluated to verify whether they have been met. If a KASK institution satisfies its assignment criteria, it is also removed from the KASK/MASK distance matrix. The primary assignment criterion for each KASK is the allocation of two YASK institutions per 100 hospital beds.

Step 6: The algorithm iterates through Steps 2–5 until all KASK institutions fulfill their assignment criteria.

This YASK assignment algorithm not only facilitates the pairing of KASK institutions with YASK institutions but also ensures that the process begins with the KASK institutions located at the outermost boundary of the affected region and systematically progresses inward. This structured approach enhances the efficiency of disaster response operations by enabling the initial group of specialists arriving at the disaster site to provide real-time updates and critical information to subsequent teams arriving from more distant locations.

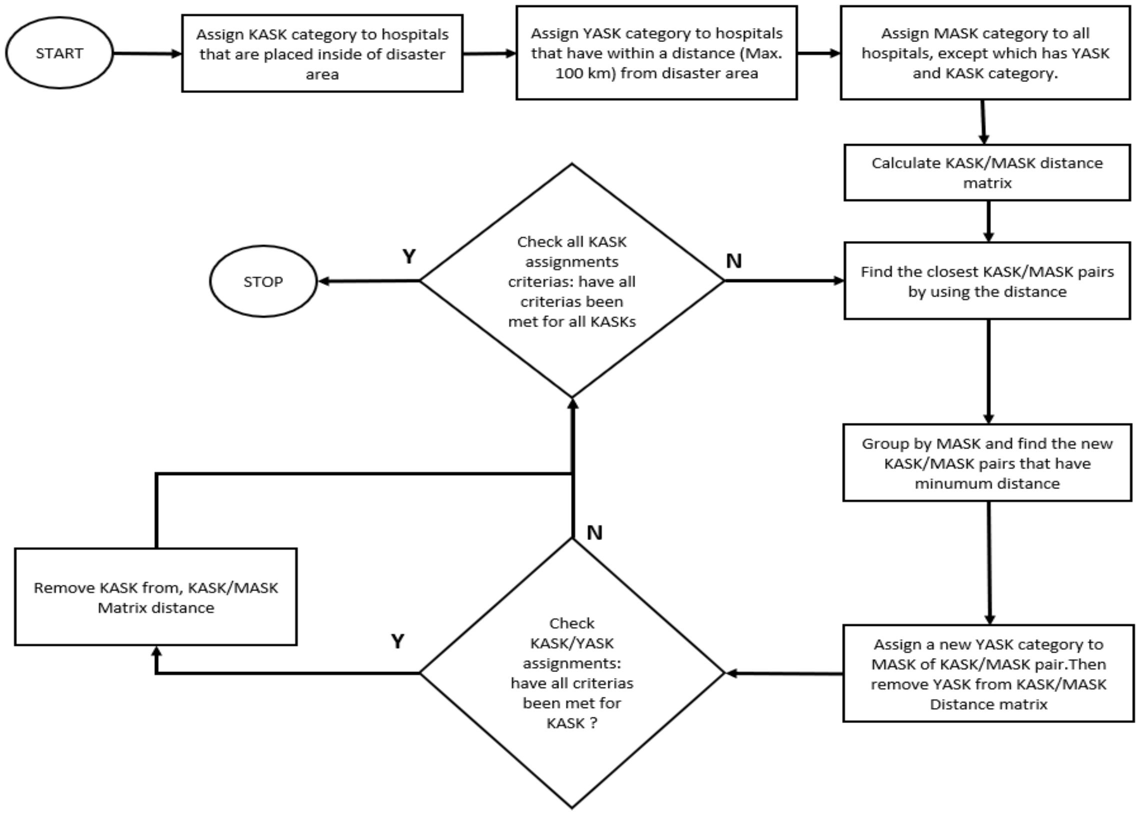

Figure 1. Flowchart of category assignment algorithm

4. Software Design Methodology

The application has been developed using a multi-layered architecture in accordance with the SOLID principles. To ensure that application layers remain loosely coupled, the Dependency Injection design pattern has been implemented. The architectural layers of the software and their respective responsibilities are outlined below:

WEB.UI.ADMIN: This is the user interface layer, positioned at the topmost level of the architecture and closest to the end-user. It has been developed using the ASP.NET 8 framework. Additionally, this layer hosts RESTful web APIs, which validate and process incoming requests from the user interface before forwarding them to the Logic Layer (BLL). The user interface components of the system are developed using HTML, JavaScript, jQuery libraries, CSS classes, and Razor Pages.

Business Logic Layer (BLL): This layer is responsible for executing the necessary rules and logic to process application data. The manager classes within this layer communicate with the Data Access Layer (DAL) to process and store application data in accordance with predefined rules. In the context of the developed application, algorithms and criteria used for the assignment of healthcare institutions are encapsulated within the manager classes of this layer.

Data Access Layer (DAL): This layer manages data exchange between the Logic Layer (BLL) and the database.

CORE: A shared application layer that contains fundamental classes utilized by all layers.

ENTITIES: This layer is responsible for storing software entities used throughout the entire application. It also includes entity objects used by Entity Framework Core.

The application has been developed using C# and .NET 8 Framework. The development environment utilized is Microsoft Visual Studio 2022 Community Edition, while GitHub has been used for source code management. The database management system employed is Microsoft SQL Server Express Edition.

5. Simulation Results

Initiation of the health organization category assignment process starts with the disaster event definition in the system. This process begins by marking one or more circular zones on the map, with radii ranging from 50 km to 100 km, depending on the scale and severity of the disaster. Figure 2 illustrates an example of a disaster definition applied to the February 6, 2023, Kahramanmaraş Earthquake When the algorithm steps outlined above are applied to the disaster area illustrated in Figure 2, the resulting assignment pattern is depicted in Figures 3 and 4.

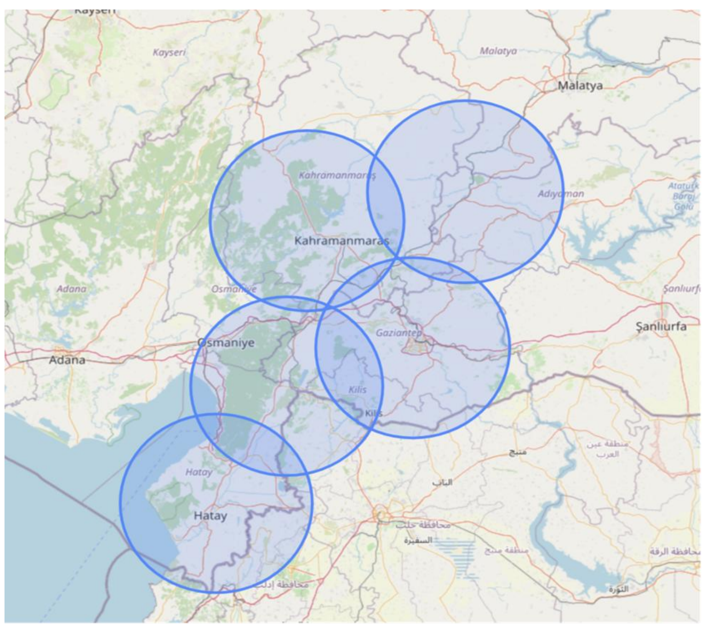

Figure 2. The example definition of the Kahramanmaraş Earthquake on February 6, 2023 on the map.

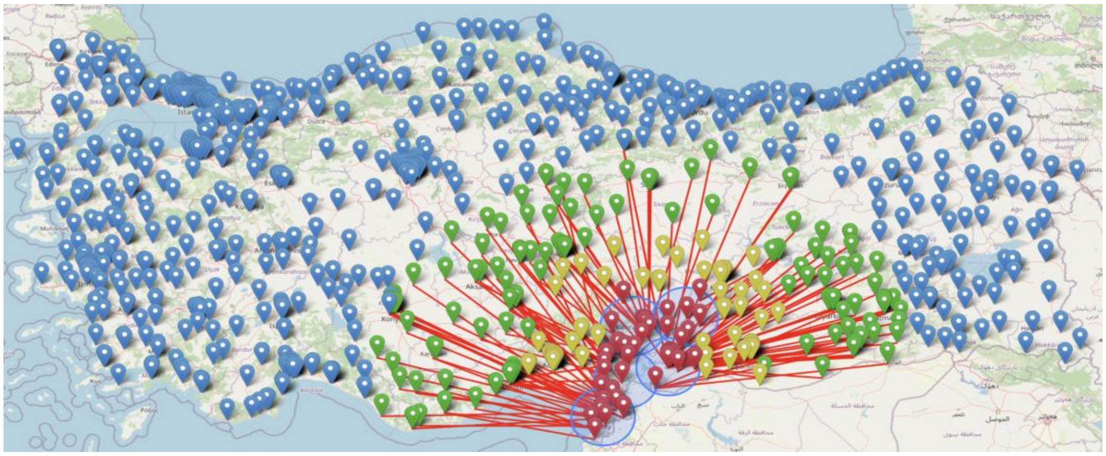

Figure 3. General view of health institution assignments after the definition of disaster.

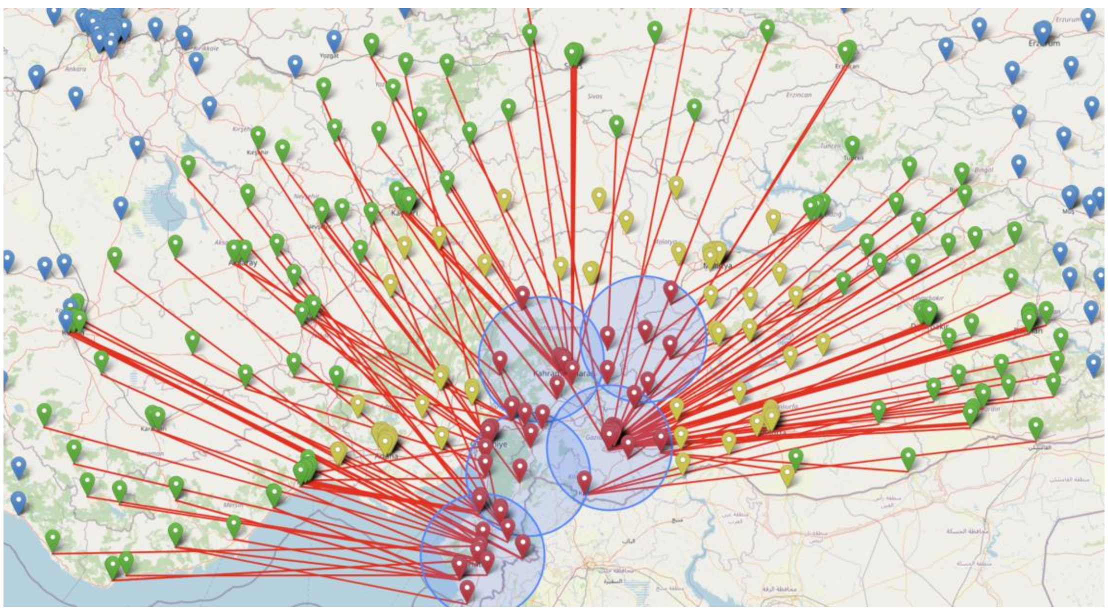

Figure 4. A closer look at KASK/YASK assignments.

5. Conclusion

In the present study, a coordination and management software platform has been developed with the objective of enhancing the prompt coordination among healthcare institutions in the aftermath of a disaster. This initiative aims to ensure timely communication with pertinent specialists and to reduce the time required for the provision of essential healthcare services in affected regions. The software platform is equipped with a map-based interface, which is intentionally designed to optimize user accessibility. Furthermore, it incorporates rule-based assignment algorithms that are specifically tailored to effectively meet the healthcare demands of areas impacted by disasters.

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