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Application of a Hybrid MCDM Model for Locating a Humanitarian Logistics Center

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Abstract: When the word "disaster" is used, it usually refers to both human-caused situations that have a negative impact on the community and its environment as well as natural disasters like hurricanes, earthquakes, floods, and similar phenomena. Good logistics management is crucial to reducing the bad effects of these kinds of circumstances. This typically entails tasks like planning, organizing, acquiring, moving, and other associated duties. The distribution of supplies to impacted individuals in an effort to save lives is the main objective of humanitarian logistics. The location of humanitarian goods and equipment, which are kept in makeshift humanitarian logistics centers, is crucial for ensuring prompt response in such circumstances. As a result, when deciding where to locate these centers, it is crucial to take into account particular local factors. Numerous factors might impact this kind of selection, which is why finding a location for a humanitarian logistics center is considered a multi-criteria challenge. This research suggests using the ADAM (Axial-Distance-Based Aggregated Measurement Method) and SWARA (Stepwise Weight Assessment Ratio Analysis) techniques to solve this kind of issue. An example of their application is provided by a case study that centers on where Serbia's humanitarian logistics hub is located. The creation of a framework and a special set of standards for choosing the locations of humanitarian logistics centers are the main results of this study. This can help decision-makers, authorities, individuals, non-governmental groups, and logistical service providers make well-informed decisions that have the potential to save countless lives.

Keywords: Logistics; Humanitarian logistics; Logistics centers; MCDM problem; SWARA method; ADAM method

1 Introduction

The last decade of the 20th century pivotal for the development of logistics, as awareness of its significance grew. Logistics evolved from a set of activities into a critical component of every supply chain, necessary for the seamless integration of procurement, production, transportation, and sales on a global scale. A major factor in this development was the rise of logistics service providers, whose role is to execute logistics operations for companies that lack internal resources. This evolution also led to an increase in the number of stakeholders within the supply chain, each playing a vital role in the delivery of products to the end consumer [1].

As in many areas, logistics is also a key component in humanitarian activitiesHumanitarianism represents the actions of one person towards another, aimed at providing assistance in situations where support and solidarity with those in need are required. Humanitarianism is not only a moral principle but also a business sector that develops under the influence of market factors and organizations aiming to increase their market share [2]. There are various perspectives on what constitutes humanitarian action, but three fundamental principles are often highlighted: humanity, neutrality, and impartiality. These principles are crucial for defining humanitarian operations. When it is stated that an activity must embody humanity, it implies the necessity of providing assistance whenever and to whomever it is needed. Neutrality entails that aid should be delivered without discrimination against any community, with a particular focus on those who are in urgent need of support. In any humanitarian action, it is essential for humanitarian organizations to maintain impartiality and refrain from favoring one group over others that may be deemed less "close" to them [1].

Initiating humanitarian action requires complete and up-to-date information about the current situation. Historically, information flow was slower and less efficient compared to today's real-time information access. The speed of information exchange today is unprecedented. This fact has directly influenced the heightened expectations of public for humanitarian organizations to respond to emergencies as swiftly and effectively as possible. The public's expectations place additional pressure on humanitarian organizations and their capacity to respond in accordance with their capabilities and expertise. Due this pressure, errors within the supply chain are significantly more visible and less accepted [1].

Following the devastating earthquake in Haiti, there was a significant increase in global awareness regarding the importance of humanitarian logistics. This event had a profound impact on reforms within humanitarian and government organizations, particularly in terms of their preparedness, response mechanisms, and reconstruction efforts [3]. The primary distinction between commercial logistics and humanitarian logistics lies in the fact that the latter aims to provide a rapid response to urgent and often unforeseen events, delivering aid to those in need, while costs are considered secondary. To ensure a swift response, the method of supply distribution plays crucial role, and this is largely dependent on the location of the humanitarian logistics center [4].

The aim of this study is to identify the optimal location for establishing a humanitarian logistics center within the territory of the Republic of Serbia. By analyzing factors and circumstances specific to the given territory, key criteria were selected that will have a decisive impact on locating the center. The paper will begin by introducing the concept of humanitarian logistics. This section will cover terms related to humanitarian organizations and humanitarian supply chains, as well as the challenges that frequently arise and should be considered when selecting a location. Additionally, the concept of logistics centers will be highlighted, with a focus on those serving as humanitarian centers. After covering the fundamental characteristics of these concepts, the subsequent chapter will address the problem of locating a humanitarian center. Initially, the criteria for selecting a location will be defined, followed by an evaluation of alternatives representing the most suitable locations for establishing the center. Once the criteria and alternatives are defined, the SWARA method will be applied to determine the weight of each criterion and then the ADAM method will be used to solve by ranking the alternatives in descending order.

2 Background

In humanitarian operations, selecting the right location for a logistics center is critical for ensuring the efficient distribution of aid. This background section covers two key topics: the principles and challenges of humanitarian logistics, and the role and functions of logistics centers. A thorough understanding of these areas is crucial for analyzing and solving this complex multi-criteria problem in the most effective manner.

2.1 Humanitarian Logistics

Disasters, regardless of their origin, can have devastating consequences for affected communities. The recovery process, often lengthy and arduous, requires diligent planning and preparedness to minimize disruptions and facilitate a more efficient return to normalcy. Some organizations distinguish between "disasters" (resulting from natural phenomena) and "complex emergencies" (arising from armed conflicts or large-scale violence) [5]. Although the term "logistics" originally pertained to military procedures involving the procurement, maintenance, and transportation of materials, facilities, and personnel, it now has practical applications in civilian life. In situations that require urgent response, the effectiveness of the reaction largely depends on logistical organization. Given the necessity of delivering assistance in the form of specialized personnel, equipment, and humanitarian supplies as quickly as possible and with minimal losses, it is crucial to approach the organization and management of the logistical system appropriately to achieve optimal success [5]. The origins of humanitarian actions can be traced back to the Middle Ages, when the first volunteers began to care for the wounded, the sick, and others in need of assistance. Given that donations and support from other organizations and states are essential for humanitarian efforts, the initial examples of such collaborations emerged in the 18th century, particularly in response to the devastating earthquake that stuck Lisbon [6]. During the Second Italian War of Independence in 1859, Henry Dunant distinguished himself as a prominent humanitarian by providing aid to wounded soldiers. For this reason, he is considered a humanist who laid the foundation for modern humanitarianism and organizations such as Red Cross and Red Crescent [7].

To be considered humanitarian, an action must be characterized by specific attributes. First and foremost, it should aim to provide assistance to all individuals in need of help while maintaining a completely neutral stance. In the context of war or any armed conflict, humanitarian organizations face the challenging task of delivering aid to everyone affected without discrimination, regardless of their affiliations or backgrounds. The neutrality is essential to uphold the integrity of humanitarian efforts, ensuring that assistance reaches those who require it most, irrespective of political, ethnic, or social considerations. The commitment to neutrality enables these organizations to navigate complex situations and effectively address the needs of diverse populations impacted by crises [1].

The assistance provided by humanitarian organizations and the methods employed to deliver it largely depend on their logistical organization. Without logistics and its experts, these activities would be inconceivable, especially in

emergency situations where the emphasis on effective logistical organization is even greater. Given the heightened pressure to execute operations flawlessly, the costs associated with logistics in humanitarian contexts are significantly higher compared to those in the business sector. The considerable uncertainty in both supply and demands, as well as the unpredictability regarding the timing and location of disasters, coupled with severely inadequate infrastructure, contribute to the increased complexity of organizing and implementing services in humanitarian logistics [7].

Humanitarian organizations refer to agencies that assist people who are suffering, particularly victims of armed conflicts, hunger, and natural disasters. These organizations are occasionally also referred to as relief societies. This may include rescuing migrants and ensuring their safety, providing shelter and food for the homeless, or offering assistance to individuals affected by natural disasters or civil unrest [4]. The ability to rapidly identify needs and engage in resource mobilization, supply, transportation, distribution, and provision of supplies and services to individuals in need is one of the key competencies of humanitarian organizations [4].

Disasters that most severely impact people in Europe and cause the majority of economic damage are floods. Heatwaves and storms also affect a large number of Europeans, but droughts have the greatest impact on agriculture and human well-being. The vulnerability of the Republic of Serbia to natural disasters is a consequence of its geographic location, as well as its natural and socio-economic characteristics. The most common natural disasters affecting Serbia are floods, earthquakes, droughts, fires, and landslides [8].

Humanitarian assistance typically includes essential supplies, such as water and food. In addition, clothing items and tents for temporary shelter are often delivered to those affected. For the most vulnerable populations, medications and specialized medical personnel are provided. Delivering these goods is far from simple, especially considering that they are sent to areas that are unsafe and devastated by disasters. For this reason, it is essential to continuously invest in the equipment and qualified personnel responsible for humanitarian logistics. Ongoing improvements will lead to a more efficient, reliable, and cost-effective delivery of humanitarian goods. As a result, this will enable a timelier and faster response to emergencies [6]. A specialized organization for logistics services in humanitarian situations defines logistics management in humanitarian organizations as "the process of planning, implementing, and controlling the efficient, economical flow and storage of goods, materials, and related information from the point of origin to the point of consumption in order to alleviate the suffering of affected individuals" [7].

The objective of logistics in all fields, including humanitarian efforts, is to ensure that goods or services are delivered based on the principle that the required quantity is provided at the time and place where the need arises, with satisfactory quality and at an affordable price [9]. Some of the fundamental characteristics of humanitarian logistics are urgency and uncertainty. Some crises occur with a degree of prior warning, while others arise suddenly. Today, technological advancement is improving the accuracy of natural disaster forecasting. In addition to the aforementioned characteristics, humanitarian logistics is also defined by the necessity to respond to events as swiftly as possible. Any delays can result in loss of human lives and an increase in the number of individuals at risk. That distinguishes humanitarian logistics from commercial logistics is that economic concerns are set aside, with the primary focus being on people and their lives [10].

From the perspective of humanitarian logistics structure, three main components are identified [9]. *Development Logistics* aims to manage long-term crises that lead to human suffering or economic damage, where the causes cannot be attributed to a single event. It involves ongoing activities in health, education, sustainability, poverty reduction, hunger alleviation, water supply, shelter provision, child protection, etc. *Relief Logistics* aims to mitigate the negative effects of various disasters. Disaster management includes risk management before a disaster and crisis management during and after a disaster. *Evacuation Logistics* involves activities and resources that facilitate the relocation of people and their property to safe location and their stay there until they can return to the original location.

In humanitarian logistics, five types of flows are managed (5B) [11]. *Flow of Bodies* refer to the movement of personnel, the evacuation of people from affected areas, humanitarian trips and travel, among other things. *Flow of Boxes* encompass the procurement, distribution and return of various products. *Flow of Brains* simply knowledge and skills of the workforce in humanitarian logistics enable the execution of service flows, including logistics services, construction services, household assistance and other services. *Flow of Bucks* involve the movement of funds from donors, sponsors and purchasers, the purchase of goods, financial assistance to affected individuals, etc. These flows include cash, electronic money and crypto-currencies. *Flow of Bytes* cover communication between humanitarian organizations and the public, promotional activities, calls for donations and sponsorships, transmission of orders, invoices and similar documents, coordination of other types of flows and other forms of communication and information exchange among participants in humanitarian logistics.

Humanitarian operations are time-limited processes. They start immediately after a disaster occurs and last from 1 to 3 months, depending on the scale of the disaster. Activities performed during this period are crucial and should be managed with appropriate methods [12]. Managing a humanitarian supply chain involves carrying out certain phases to maintain systematic supply chain routes during periods of hardship are emergency situations. The phases are as follows [13].

Assessment and planning – Logistical analyses assist professionals in assessing the effects of a disaster on the

ecosystem and its impact on the population and logistical operations. The conclusions drawn from these analyses are crucial for informed decision-making, as well as for developing plans and organizing responses to crisis events. The planning process includes the following phases: identifying key challenges, gathering relevant data, considering various solutions, evaluating options and making final decisions, implementing the chosen solutions, monitoring the execution, making timely adjustments, and formulating an exit strategy for the final phase of activities.

Procurement– Efficient procurement plays a key role in the overall success of emergency response efforts, depending on how it is managed. Procurement is a crucial component of the internal supply chain process, transforming request into tangible goods or services to meet essential needs. The fundamental principles of procurement in humanitarian logistics include transparency, accountability, as well as efficiency and cost-effectiveness.

Storage and Inventory Management – Emergency or humanitarian supplies refer to the goods, materials, and equipment that organizations use to provide aid during crises, especially to cover the essential requirements of impacted communities. To improve the management of humanitarian stocks during disasters, the Humanitarian Supply Management System (SUMA) was developed. The goal of the SUMA system is to address various issues that arise when large amounts of aid arrive in a disaster-affected region or country [5].

Transportation and Fleet Management – Transportation strategies are not solely dependent on organizational needs; they also vary among different organizations. Fleet management encompasses the oversight, coordination, and facilitation of various transportation activities. Efficient fleet management aims to reduce overall costs through the optimal and economical use of resources, including vehicles, fuel, and spare parts.

Cold Chain – Cold chain management encompasses all processes designed to ensure a consistent temperature-sensitive products, such as vaccines, serums, and pharmaceuticals, from the point of production until they are utilized.

Customs – In the humanitarian field, especially in crisis situations, it is crucial to comprehend the processes for importing and exporting goods as they are vital to the supply chain. All items entering or existing a nation are subject to certain governmental regulations and requirements. During emergencies, humanitarian organizations typically gain precedence, as the United Nations often facilitates negotiations with governments to secure swift access to essential supplies.

Distribution – In the realm of humanitarian efforts, the concept of distribution is viewed through three lenses: the transportation of items from the point of acquisition or transfer of ownership to the final recipient, the relocation of materials within the organization across different sites, and the phase when items are handed over to beneficiaries or collaborators.

Monitoring and evaluating – The process of monitoring entails ongoing evaluation of how well logistical tasks are carried out and whether the set objectives are met. This ongoing assessment facilitates necessary adjustments. Evaluation offers insights into whether objectives have been achieved, the factors contributing to either success or setbacks, and provides direction for subsequent initiatives.

In all of these stages of managing humanitarian supply chains, challenges frequently arise, including [13]: considerable unpredictability in demand, significant unpredictability in schedules, major uncertainty regarding geographical locations, various difficulties in supply logistics, challenges in cooperation among diverse stakeholders and decision-makers in the humanitarian supply chain, as well as the influence of political and socio-economic conditions in the area, insufficient telecommunications and information systems, and complications in assessing the effectiveness of humanitarian missions.

2.2 Logistics Center

The concept of a logistics center emerged about 50 years ago. During this time, logistics has undergone significant changes related to production, storage and transportation methods. As a result, the understanding of the functional and conceptual importance of logistics centers has evolved [14]. Logistics centers now offer not only traditional activities such as storage but also additional logistics services such as labeling, assembly, semi-processing and customization. Both logistics firms and freight forwarders recognize that value-added services at logistics centers are essential for effective supply chain management, and this trend is anticipated to persist in the coming years [15]: spatial planning with infrastructure rationalization, quality of transportation, and development of intramodality.

In humanitarian logistics, the characteristics of the disaster and its impact on the requirements of the affected regions dictate the suitable facilities for delivering assistance. Examples include temporary healthcare centers when there is a need for primary medical services and distribution hubs [16]. The selection of facility types is also influenced by the transportation methos employed. Truck, commonly used for road transport, frequently carry aid supplies. However, the advent of new technologies has introduced additional dynamic and decision-making considerations related to transportation modes. For instance, drones are increasingly being utilized in distribution networks. In such cases, the facilities involved must be equipped to operate with drones [16]. The strategic placement of a humanitarian logistics center is vital, as it significantly influences the effectiveness of disaster response following an incident. In recent years, the selection of warehouse locations within humanitarian logistics has garnered considerable interest,

capturing the focus of prominent global humanitarian organizations [10].

Logistics centers can be configured to provide various functions such as storage, transportation, distribution, assembly, direct delivery, cargo consolidation, sorting, transshipment and more [17]. In humanitarian logistics, the primary goal is to distribute goods to affected individuals to save lives. The inherent and uncontrollable nature of disasters makes humanitarian logistics unpredictable. This situation leads to an imbalance between supply and demand. While logistics supply may be abundant at one demand note, it may be insufficient at another. To tackle this challenge, it is essential to establish a humanitarian logistics center that can oversee the allocation of aid in the disordered circumstances created by extensive disasters [18]. The type of disaster and its effects directly influence the determination of the appropriate facility for providing support. Facilities that aid humanitarian efforts can be categorized based on their specific roles, resulting in six primary classifications [16]: supply facilities, distribution centers, nodes in the distribution network, shelters, field hospitals, and blood storage centers.

3 Problem Statement

Despite advancements in technology that have addressed numerous challenges, many communities still lack the necessary resources to manage the widespread destructive consequences of natural calamities. In 2018, a natural disaster led to nearly 12,000 fatalities and impacted over 68 million individuals globally. The growing effects of disasters in recent years have underscored the urgent need for effective and efficient emergency response operations [19]. A crucial factor in the pre-disaster phase is determining the optimal site for a humanitarian logistics center. Humanitarian agencies store vital supplies and resources at these locations. When a disaster occurs, pre-positioned items such as medications, food, water, and equipment can be quickly dispatched to those affected. As timely delivery of assistance is essential for victims, choosing the appropriate location for these centers is a critical aspect of aid operations [19]. Facility locations modeling serves as a strategic method for disaster management planning and significantly influences the effectiveness and efficiency of operations both before and after disasters. The challenges of location selection in disaster management focus on creating a network for distribution water, food, medical supplies, equipment, and other necessary humanitarian assistance [19].

3.1 Locating a Humanitarian Logistics Center

While most of these disasters cannot be avoided, significant improvements in the number of casualties and reported property losses can be achieved through effective distribution of supplies. Efficient supply distribution can be achieved through a well-managed humanitarian logistics system. Therefore, it can be concluded that a prompt response is essential following unforeseen disasters and is significantly influenced by the placement of the humanitarian logistics center [20]. Choices regarding the placement of facilities have a considerable influence on the effectiveness of humanitarian efforts. The quantity and positioning of distribution hubs, along with the volume of aid resources, play a crucial role in determining response times and the expenses involved in the humanitarian supply chain. Nevertheless, the intricate and unpredictable nature of the operational landscape makes it difficult for humanitarian organizations to create efficient and effective networks for delivering assistance [21].

Numerous non-governmental organizations (NGOs) tend to steer clear of utilizing pre-positioned supplies due to the associated complexities and expenses, Instead, these organizations often depend on local and international procurement, which may fall short of addressing urgent needs. The lack of widely developed or applied quantitative methods and principles tailored to the specific characteristics of the aid environment can lead humanitarian organizations to make facility and supply location decisions based on ad hoc approaches. This can result in inefficient outcomes, such as elevated costs, duplicated efforts, and wasted resources, as well as ineffective results like delayed responses and unmet demands [21]. Additionally, there are no universal systems for the placement of aid supplies within humanitarian logistics that provide data on the quantity, quality, geographic location, and ownership of these supplies. Consequently, the absence of a systematic framework and the necessary infrastructure for structuring the humanitarian supply chain may hinder organizations from accurately evaluating their response capabilities and effectiveness [21].

3.2 Characteristics of the Territory of the Republic of Serbia

This study focuses on location a humanitarian center in Serbia. Serbia is a landlocked nation located in Southeast Europe, at the heart of the Balkan Peninsula, with a total area of 88,509 km^2. The northern region, known as Vojvodina, is situated in the Pannonian Plan and is predominantly flat. Other flat areas can be found in Mačva, Posavina, Pomoravlje, Stig, and Negotin Krajina in eastern Serbia. The central portion of the country and the hilly area of Šumadija lie to the south of the Sava and Danube rivers, while further south, the hills gradually rise into mountainous terrain [22]. Serbia is notably prone to a significant number of different types of natural disasters, with varying frequencies and intensities. With an average of 100 disasters per decade since the early 19^{th} century, the number of natural disasters reached up to 2800 per decade by the end of the predicted in advance. However, based on experience, statistics, modeling methods and the typical locations where they occur, it is possible to anticipate

their potential occurrence [22]. Serbia is vulnerable to various natural and anthropogenic hazards. Risk levels differ throughout the country and fluctuate based on the type of hazard and the evaluated potential for harm There is a noticeable lack of capacity among local authorities, specialized services and consultants to engage in modern disaster risk management approaches. The overall disaster protection system in Serbia is inadequate, particularly concerning these spatial aspects of disaster risk management [23]. Table 1 shows the area of the Republic of Serbia susceptible to natural disasters, covering 57.33% of the country's total area (88 509 km^2) [22].

Table 1. Areas prone to natural hazards in the Republic of Serbia [22]

Natural Hazard	Area (km^2)	Percentage of the Total-Area of the Republic of Serbia (%)
Seismic Hazard VIII-IX MCS	16,388.59	18.55%
Seismic Hazard IX-X MSC	1,109.71	1.26 %
Areas with Excessive Erosion	3,320.80	3.76%
Landslide-Prone-Areas	13,327.60	15.08%
Drought-Prone-Areas	18.306 .93	20.72%
Potential Flood-Prone-Areas	15,198.07	17.20 %
Highest Risk of Forest Fires	3,154.95	3.57%
Vulnerable-Areas in Serbia	50,659.87	57.33 %

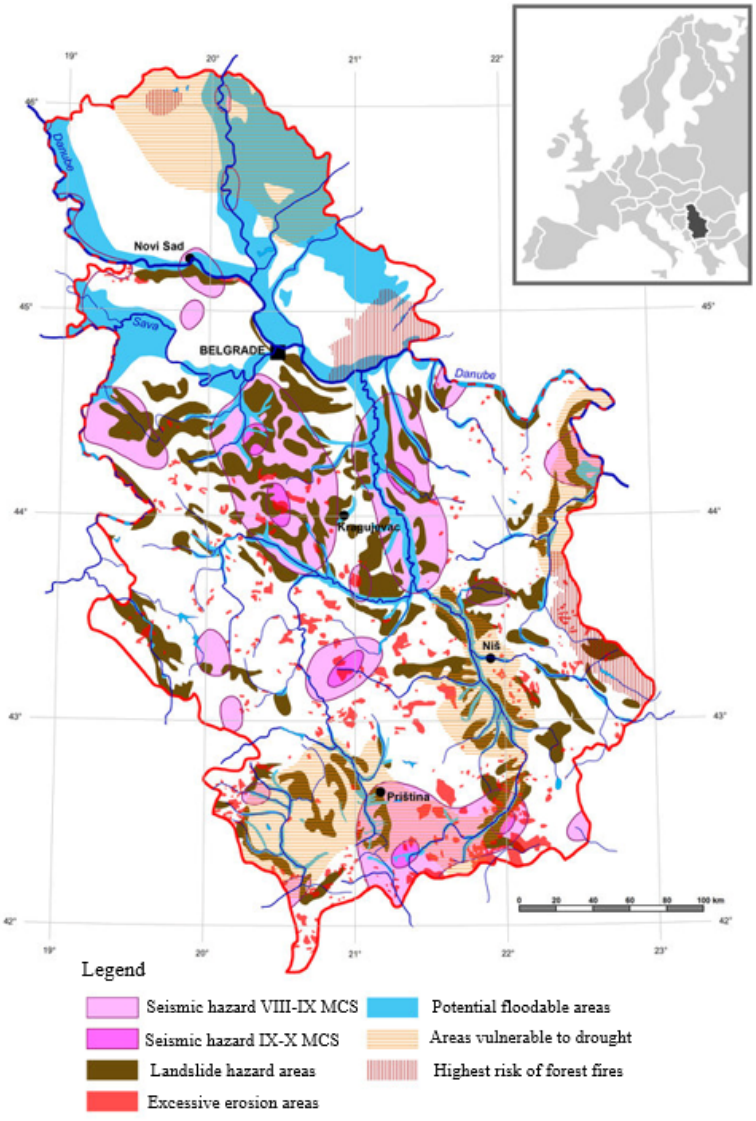

Figure 1. Map of potential natural disasters in Serbia [22]

There is a trend of increasing numbers of fires in Serbia, as well as higher rates of fatalities and injuries. According to official data, the number of fires in increased by 50% compared to the previous year. The highest fire risk is in eastern and southeastern Serbia [23]. Serbia is situated in an area characterized by moderate seismic activity in terms of occurrence, frequency, and intensity of earthquakes. According to available information, there have been about 180 earthquakes with epicenters in Serbia and the surrounding area, which, in addition to material damage at 89 locations in Serbia, have also resulted in loss of life. Figure 1 shows a map of Serbia with marked areas at risk of natural disasters [22].

The majority of experts contend that climate change will result in a rise in the frequency of extreme weather occurrences, including floods, landslides, and wildfires. The growing trend of devastating and unfavorable natural events is especially noticeable in incidents that are reliant on weather conditions [22]. Considering the various types of natural disasters occurring in Serbia, there is a need to establish a humanitarian logistics center to ensure an efficient response to unforeseen hazards. A number of challenges must be tackled to facilitate the efficient movement of aid logistics from the humanitarian center. Initially, the creation of an effective pre-positioning strategy is complicated by uncertainties regarding the occurrence, location, and severity of disasters. While having pre-positioned supplies in humanitarian logistics centers can be beneficial in certain scenarios, their effectiveness may be constrained by the substantial financial resources needed. The difficulty lies in selecting a site for humanitarian center that is situated outside potential disaster zones while remaining sufficiently close to ensure timely and effective assistance. Thus, identifying an appropriate location for a humanitarian logistics center presents a complex multi-criteria challenge [10].

3.3 Criteria for Evaluating and Comparing Alternatives

Criteria are tools used to assess and compare alternatives or possible solutions derived from clearly defined objectives (in this case, locating a Humanitarian Logistic Center – HLC). They are created based on one or more related attributes associated with the alternatives [24].

Based on the goals related to the specific decision-making problem, criteria are generated, with one goal potentially generating multiple criteria [24]. This paper focuses on the main problem of locating an HLC in Serbia and the following key criteria have been identified:

Proximity to Disaster-Prone Areas (C1) – This criterion is highlighted as a crucial factor in selecting a location for the Humanitarian Logistics Center, according to literature. The location of the HLC directly affects response speed and costs incurred in providing aid. It is important that the HLC is not situated in areas prone to natural hazards, emphasizing the need to assess the safety to the location.

Availability of Logistics Experts (C2) – The presence of qualified experts is another crucial element, as it guarantees that trained personnel are available. The successful functioning of the humanitarian logistics center relies heavily on the skills and qualifications of these individuals. With the increasing need for careful coordination in the humanitarian sector due to carious constraints faced by NGOs, it is essential to have skilled staff who can manage crises and humanitarian supply chains efficiently, even under conditions of constraints and unpredictable disasters.

Geographical Characteristics (C3) – Geographical characteristics encompass the physical attributes that define the natural environment of a location, including aspects such as topography and climate. They also take into account the sociopolitical and economic stability of the country in which the humanitarian logistics center is situated.

Transport Connectivity (C4) – Transport connectivity refers to the accessibility of transportation infrastructure linking the prospective site of the center to the disaster area. Transport connectivity involves access to transportation infrastructure between the potential location of the center and the disaster site. In providing aid to affected areas, the ability to quickly transport relief items within 24 to 48 hours of a request via airports, ports or major roads is crucial. Therefore, it is essential for the potential location to be close to international ports, airports and major roads.

Availability of Existing Facilities and Infrastructure (C5) – The availability of facilities for storing humanitarian supplies, as well as those that offer essential services like electricity, water, and vehicle maintenance, is crucial for supporting the operations of the humanitarian logistics center.

Land Costs (C6) – While humanitarian operations have a direct impact on people's lives, the cost factor may be viewed as less critical when compared to other considerations However, the amount of money allocated for the HLC may be determined by decision-makers or may be subject to strict budget limits. Therefore, efforts should be made to minimize the financial investment in the potential facility and the land on which it will be developed.

Reliability (C7) – Reliability is a key characteristic in planning humanitarian logistics under conditions of uncertainty, aiming to minimize the risk of failure in the network. Suppliers can also be impacted by potential disasters and are assigned varying levels of risk for each item they offer. The objective is to secure multiple sources of supply to enhance reliability.

Safety (C8) – Safety is essential for aid operations, especially in the chaotic and unpredictable conditions that follow a disaster. Humanitarian, operations frequently face the risk of theft attempts. Therefore, it is vital to ensure that the location of the humanitarian logistics center is secure for the storage of aid items and that measures are in

place to protect against theft. Choosing locations in proximity to emergency services, such as fire stations, police stations, and hospitals, is also important to address any incidents that may arise at the warehouse.

Number of Logistics Providers (C9) – The presence of logistics providers is important not only because they are available but also due to the essential collaboration required among them.

Proximity to Other Warehouses (C10) – This criterion refers to the proximity of warehouses not intended for humanitarian activities but used for commercial purposes. If the main warehouse for humanitarian supplies is damaged or becomes unusable, a nearby warehouse can serve as a backup location for storing critical supplies. Additionally, proximity to other warehouses allows for easy redistribution of resources between humanitarian and other warehouses, which can be useful for transferring supplies between commercial and humanitarian uses, or vice versa.

Shared Logistics and Partnerships (C11) – Proximity to other humanitarian organizations, NGOs, or agencies can be advantageous for humanitarian activities due to potential collaboration that could increase efficiency and reduce costs.

Political and Economic Stability (C12) – Choosing a location in regions with political and economic stability reduces the risk of unrest, changes in laws or economic crises that could negatively affect the operation of the humanitarian center.

4 The Hybrid MCDM Model

This part introduces a combined multi-criteria decision-making (MCDM) model that integrates the SWARA technique for establishing criterion weights and the ADAM method for evaluating alternatives. This strategy advantage of the benefits of both approaches to create a transparent and organized decision-making framework.

4.1 The SWARA Method

Since the main problem in this case is determining the location of a Humanitarian Logistics Center in Serbia, considering multiple (12) criteria, it can be described as a Multicriteria Decision Making (MCDM) problem. The criteria differ in the importance assigned to them in the decision-making process. The significance of the criteria is usually expressed through weight coefficients assigned to each criterion or by ranking them according to importance. In this case, the weights of the criteria are determined using the SWARA (Stepwise Weight Assessment Ratio Analysis) method.

The procedure for using the model is based on the following five steps [25]:

Step 1: Criteria (C_i) are sorted based on their expected importance in a descending order (subjective assessment).

Step 2: Starting from the second criterion in the sequence, the respondent provides a rating of the relative importance of that criterion compared to the previous one and then for each subsequent criterion. This relationship is also known as the comparative significance of the average value S_j.

Step 3: Next, the procedure for determining the coefficient K_j is followed:

$$K_j = \begin{cases} 1, j = 1 \\ Sj + 1, j > 0 \end{cases} \tag{1}$$

Step 4: Next, the determination of the adjusted weights Q_j is carried out:

$$Q_j = \begin{cases} 1, j = 1 \\ \frac{Qj-1}{Kj}, j > 0 \end{cases} \tag{2}$$

Step 5: Finally, the relative weights of the evaluation criteria are calculated, where W_j represents the relative weight of C_j, following the formula provided below:

$$W_j = \frac{Qj}{\sum_{K=1}^{n} Qk} \tag{3}$$

4.2 The ADAM Method

To identify the optimal site for a humanitarian logistics center in Serbia, the ADAM (Axial-Distance-Base Aggregated Measurement) method is employed. This innovative approach focuses on assessing distances from a central point and is categorized within a new class of Multi-Criteria Decision Analysis (MDA) methods known as geometric methods. The fundamental concept involves comparing alternatives that are ranked based on the values associated with complex polyhedral volumes that correspond to the specified options [26].

In the ADAM method, the process of ranking alternatives is based on determining the volume of complex polyhedral defined by points (vertices) in a three-dimensional coordinate system. Each point can be of one type (out of three possible types) [26]: coordinate origin – O, reference point – R, and weighted reference point – P. The

coordinate origin is a point with coordinates (0,0,0). Reference points are points with coordinates (x,y,0) that define the value of an alternative according to some criterion as the axial distance of the point from the coordinate origin in the xy-plane. Weighted reference points have coordinates (x,y,z), where the z coordinate is used to obtain the axial distance of the weighted reference point from the xy-plane. These distances correspond to the weights of the criteria [26]. By defining all the points that define a polyhedron, it is possible to calculate its volume as the sum of the volumes of k polyhedral (k=1,2, . . . , n-1). Each polyhedron consists of faces formed by the coordinate origin, with reference and weighted reference points of two consecutive criteria. The final ranking of alternatives is obtained according to the descending values of the calculated volumes of the polyhedral [26].

The steps of the method are [26]:

Step 1: Define the elements of the decision matrix E, which represent the score e_{ij} of alternatives i with respect to criteria j, that is, vectors that correspond to the score of alternatives with respect to the criterion:

$$E = [e_{ij}]_{m \times n} \tag{4}$$

where, m represents the total number of alternatives, while n represents the total number of criteria.

Step 2: Define the elements (s_{ij}) of the sorted decision matrix S, indicating the sorted scores e_{ij} in descending order according to the weight (importance) of the criteria:

$$S = [s_{ij}]_{m \times n} \tag{5}$$

Step 3: Define the elements of the normalized sorted matrix N, where the normalized scores n_{ij} are obtained:

$$n_{ij} = \begin{cases} \frac{sij}{\max_{Sij}}, zaj \in B \\ \frac{\min_{Sij}}{sii}, zaj \in C \end{cases}, \tag{6}$$

where, B is the set of maximization criteria and C is the set of minimization criteria.

Step 4: Find the coordinates (x,y,z) of the reference (R_{ij}) and weighted reference (P_{ij}) points that define the complex polyhedron in the following way:

$$x_{ij} = n_{ij} \times \sin \alpha_j, \forall j = 1, \ldots, n; \forall i = 1, \ldots, m \tag{7}$$

$$y_{ij} = n_{ij} \times \cos \alpha_j, \forall j = 1, \ldots, n; \forall i = 1, \ldots, m \tag{8}$$

$$z_{ij} \begin{cases} 0, \text{ for } R_{ij} \\ w_j, \text{ for } P_{ij} \end{cases}, \forall j = 1, \ldots, n; \forall i = 1, \ldots, m \tag{9}$$

where, α_j represents the angle that determines the direction of the vector that defines the value of the alternative solution, obtained as:

$$\alpha_j = (j-1)\frac{90^\circ}{n-1}, \forall j = 1, \ldots, n, \tag{10}$$

Step 5: Calculate the volumes of the complex polyhedral V_i^C as the sum of the volumes of the pyramids from which it is composed using the following formula:

$$V_i^C = \sum_{k=1}^{n-1} V_k, \forall i = 1, \ldots, m \tag{11}$$

where, V_k is the volume of the pyramid obtained using the following formula:

$$V_k = \frac{1}{3} B_k \times h_k, \forall k = 1, \ldots, n-1, \tag{12}$$

where, B_k is the base area of the pyramid defined by the reference and weighted reference points of two consecutive criteria and is obtained using the following formula:

$$B_k = c_k \times a_k + \frac{a_k \times (b_k - c_k)}{2}, \tag{13}$$

where, a_k is the Euclidean distance between the reference points of two consecutive criteria, obtained using the following formula:

$$a_k = \sqrt{(x_{i+1} - x_j)^2 + (y_{j+1} - y_j)^2} \tag{14}$$

While b_k and c_k are vectors corresponding to the weight of two consecutive criteria, namely:

$$b_k = z_j, \tag{15}$$

$$c_k = z_{j+1} \tag{16}$$

h_k represents the height of the pyramid from the defined base to the apex of the pyramid, which is located at the coordinate origin (O) and is obtained using the following formula:

$$h_k = \frac{\sqrt{s_k\,(s_k - a_k)\,(s_k - d_k)\,(s_k - e_k)}}{a_k}, \tag{17}$$

where, s_k is the semi-perimeter of the triangle defined by the x and y coordinates of two consecutive criteria and the coordinate origin and is obtained as:

$$s_k = \frac{a_k + d_k + e_k}{2}, \tag{18}$$

where, d_k and e_k are the Euclidean distances of the reference points of two consecutive criteria from the coordinate origin and are obtained as:

$$d_k = \sqrt{x_j^2 + y_j^2}, \tag{19}$$

$$e_k = \sqrt{{x_{i+1}}^2 + {y_{i+1}}^2}, \tag{20}$$

Step 6: Ranking of alternatives is based on the descending values of the polyhedral volumes V_i^C (i=1,. . . ,m). The best alternative is the one with the largest volume.

5 Results and Discussion

This section provides a detailed description of the alternatives considered, the results obtained from the analysis, and the discussion of these results, offering insights and interpretations that relate to the objectives of the study.

5.1 Alternatives

An alternative is a potential solution to a decision-making problem when there is interest either in its implementation or consideration. Therefore, deciding to choose an alternative does not necessarily mean it will be implemented. The identification of the set of alternatives from which a choice is made depends on the characteristics of the problem being solved, the desired outcome of the decision, as well as the existing constraints that determine whether an alternative belongs to the set of potential solutions [24].

In this paper, the focus is on solving the problem of locating a humanitarian logistics center in Serbia. By analyzing the history of natural disasters in Serbia, it is necessary to include location that are optimal in terms of transportation connectivity on one hand and safety from natural disasters on the other. Accordingly, the following cities have been selected as potential locations for the humanitarian logistics center: HLC1 – Novi Sad, HLC2 – Belgrade, HLC3 – Kragujevac, HLC4 – Niš, HLC5 – Zrenjanin, HLC6 – Kruševac, HLC7 – Subotica.

HLC1 – Novi Sad is a city of vital importance in Serbia. This is evident from the fact that, along with Belgrade and Niš, it has the best transportation connections in the national road network (highways A1 and E-75). Although Novi Sad does not have an airport, it has a port that allows for river transport. The feature would positively impact the efficiency and execution of humanitarian activities in the city and its surroundings. As shown on the map of potential disasters in Serbia (Figure 1), Novi Sad is not threatened by seismic hazards, unlike the other alternatives, but it is exposed to the risk of floods and landslides. Therefore, from a safety perspective, it is considered an area that requires special attention and preparation to minimize potential risks and consequences of such events. Currently, there is a Red Cross warehouse in Novi Sad where supplies for emergency interventions, including food, clothing and other necessities, are stored. Additionally, Caritas Serbia has a regional center in Novi Sad, equipped with emergency supplies. According to the latest analysis, the price of construction land in Novi Sad is around 150 €/m^2.

HLC2 – As the capital city of Serbia, Belgrade is the central hub with most important transportation routes, including road (highways), air (Nikola Tesla Airport) and water (ports) transport. However, due to its geographical location, the city is susceptible to risk from floods and landslides. Therefore, constant preparedness and adequate preventive measures are required to reduce the likelihood and impact of potential disasters. It is important to note that the availability of logistics experts is favorable in both Novi Sad and Belgrade, which further facilitates the organization and implementation of humanitarian activities. As the capital city, Belgrade hosts the largest number of humanitarian organizations. Some of them include the Red Cross, whose main center and warehouse are located in Belgrade. Additionally, Caritas Serbia has its headquarters in Belgrade, providing social assistance, healthcare support, educational programs and more. In Belgrade, there is also a warehouse belonging to the Serbian Ministry of Interior (Emergency Situations Sector) where equipment and supplies for rapid response are stored. Among these organizations, there is also "Help – HilfezurSelbsthilfee.V." which has its warehouses stocked with emergency supplies. Based on the current analysis, the price of construction land in Belgrade is approximately 200 €/m^2.

HLC3 – Kragujevac is the fourth-largest city in Serbia, with a population of around 180,500 residents. The transportation connectivity of Kragujevac does not reach the levels founds in other alternative cities. Kragujevac lacks access to waterways and does not have an airport. However, it is important to note that it is relatively close to airports in Belgrade, Kraljevo, and Caritas also has its capacities for interventions and a warehouse with essential supplies. Current analysis indicates that the price of construction land in Kragujevac is approximately 50 €/m^2.

HLC4 – Niš is the third-largest city in Serbia and is located on the Nišava River. The main road comes from Belgrade and continues south towards Thessaloniki and Athens. Another important road is E-80, which leads from the Adriatic Sea and Pristina to Dimitrovgrad, Sofia, Istanbul and further to the Middle East. Niš also has a road leading northwest (E771) towards Zaječar, Kladovo and Drobeta-Turnu Severin in Romania [27]. Thus, it can be said that Niš has an excellent geopolitical position. It has an airport with limited capacity but is highly frequented, which significantly contributes to its transportation connectivity. Additionally, Niš is home to the Serbian-Russian Humanitarian Center, which could provide necessary support if needed. The center was established based on an agreement dated October 20, 2009, and officially opened on April 25, 2012 [28]. In addition to this center, there are other organizations in Niš such as the Red Cross Niš, Caritas and Hilfe. The current market price of construction land in Niš is approximately 60 €/m^2.

HLC5 – Zrenjanin is located in the center of Banat, in Vojvodina and is the administrative center of the Central Banat District. It is the third-largest city in Vojvodina. The city is situated on the banks of the Begej and Tisa rivers, at an altitude of 80 meters [29]. The road routes are: Zrenjanin – Novi Sad (regional road connected to the E75 highway), Zrenjanin-Belgrade (regional road connected to the E70 highway) and Zrenjanin-Timisoara (international road towards Ukraine, Moldova and other former Soviet republics). Zrenjanin also has an airport. It is the largest Class C airport in the Balkans, with the necessary infrastructure, suitable for smaller passenger, agricultural and cargo planes. The location offers conditions for expansion and improvement. The river network is represented by the Tisa River, which is navigable throughout its length in the Zrenjanin area. The Begej River, as part of the Danube-Rhine-Main hydrosystem, is connected to the North and Black Seas. Additionally, Zrenjanin is one of the most important railway hubs in Vojvodina [30]. Regarding humanitarian organizations, only the Red Cross operations in Zrenjanin with its capacities. A disadvantage of this city's geographical location is the flooding of the Tisa and Begej rivers (in 2016 and 2024), The price of land in Zrenjanin varies, but the approximate price is 30 €/m^2.

HLC6 – Kruševac spans an area of 854 square kilometers and comprises 101 settlements, housing a population of over 145,000 people. It serves as the central hub of the Rasina District, which encompasses the municipalities of Aleksandrovac, Brus, Varvarin, Trstenik, and Ćićevac. The area is mostly hilly with some lowland areas. It lies in the valleys of the West Morava, Rasina, Pepeljuša and Ribarska rivers [31]. Due to its geographical location, Kruševac experiences floods, which is a disadvantage of this locaton. Thanks to the opening of the second section of the Morava Corridor, 10.9 km long from Makrešane to Koševo, Kruševac is more efficiently connected with Serbia's networks of highways and expressways [32]. Five and a half kilometers from the center of Kruševac is the "Rosulje" airport, which enables air transport in emergency situations. The Red Cross operates in the Kruševac area with its capacities. The price of construction land in Kruševac and its surroundings is around 30 €/m^2.

HLC7 – Subotica is situated in the northern part of the Republic of Serbia, positioned along key European corridors and nestled between two rivers, the Danube and the Tisa. It ranks as the second-largest city in Vojvodina in terms of population and serves as one of the most significant transportation hubs in Serbia. Near the city is the connection to the E-75 highway, which links Subotica with Hungary to the Northernand Southern Europe via Belgrade to the south. It is also connected by rail to all of Europe, which is a significant advantage for humanitarian activities [33]. Six kilometers southeast of Subotica is the "Bikovo" airport, used for sports, educational, and training flights of planes and gliders, as well as for parachute jumps [34]. Subotica's history includes natural disasters such as snowdrifts during winter and floods during spring. Regarding humanitarian organizations, Caritas and the Red Cross are present in Subotica. Research on the current market estimates the price of construction land in Subotica

at around 40 €/m^2.

5.2 Results

Decision-making represents a process of rational reasoning guided by some goal(s), resulting in a decision being made. Furthermore, this can be regarded as a component of the problem-solving process and can be characterized as the method of identifying a solution to a specific issue. Since this situation pertains to a multi-criteria decision-making challenge involving 12 criteria, it is essential to establish their respective weights. In this study, the SWARA method is utilized to determine the significance of each criterion. Initially, the criteria C_i is arranged in order of importance, from highest to lowest, based on a subjective evaluation. Subsequently, beginning with the second criterion on the list, the participant assesses the relative significance of that criterion in comparison to the preceding one, continuing this process for each subsequent criterion. This ratio is also called the comparative significance of the average value S_i. The third step of applying the SWARA method implies determining the coefficient K_i, followed by the determination of the weights Q_j. Finally, the relative weights w_j of the criteria are obtained from the Q_j values. All mentioned values are presented in Table 2.

Table 2. Criteria weights

	Criterion	Rank	S_j	K_j	Q_j	w_j
C1	Proximity to disaster-prone areas	1		1	1	0.294
C4	Transport connectivity	2	0.7	1.7	0.588	0.173
C2	Availability of logistics experts	3	0.3	1.3	0.452	0.134
C3	Geographical characteristics	4	0.6	1.6	0.282	0.083
C9	Number of logistics providers	5	0.1	1.1	0.257	0.076
C11	Shared logistics and partnerships	6	0.55	1.55	0.166	0.049
C10	Proximity to other warehouses	7	0.1	1.1	0.151	0.044
C6	Land cost	8	0.1	1.1	0.137	0.040
C12	Political and economic stability	9	0.15	1.15	0.119	0.035
C5	Availability of existing facilities and infrastructure	10	0.2	1.2	0.099	0.030
C8	Security	11	0.3	1.3	0.076	0.022
C7	Reliability	12	0.1	1.1	0.069	0.020
Σ					3.396	1.000

After applying the SWARA method, the next step is evaluating the alternatives based on the criteria. This is an important step before applying the multi-criteria decision-making method, in this case, the ADAM method. In Table 3, the ratings of the alternatives according to the criteria are presented, using the following ratings: 5 – excellent, 4 – very good, 3 – good, 2 – satisfactory and 1 – unsatisfactory. Table 3 is also known as the decision-making table.

Table 3. The decision-making table

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
HLC1	4	4	4	5	4	5	4	4	5	5	3	4
HLC2	4	5	4	5	4	5	5	5	5	5	4	3
HLC3	2	3	3	2	2	3	2	2	2	3	2	2
HLC4	3	4	4	4	3	3	3	4	4	5	5	4
HLC5	1	2	2	3	1	1	1	2	1	2	1	2
HLC6	2	2	1	2	1	1	1	2	1	1	1	2
HLC7	3	3	2	4	2	2	3	4	3	4	3	3
B/C	B	B	B	B	B	C	B	B	B	B	B	B

In this case, the first alternative, HLC1 (Novi Sad), has generally good rating for criteria such as transportation connectivity (C5), the number of logistics providers (C9) and proximity to other warehouses (C10). On the other hand, it is rated slightly lower for the criterion of shared logistics and partnerships (C11). HLC2 (Belgrade) has the highest rating for most of the criteria, especially for transportation connectivity (C4), reliability (C7), safety (C8), the number of logistics providers (C9) and proximity to other providers (C10). Both Belgrade and Novi Sad received the lowest ratings for the criterion of land price (C6), as these locations have the most expensive building land. Kragujevac (HLC3) has lower ratings compared to other alternatives in almost all criteria. Niš (HLC4) has solid ratings in most criteria, with the best ratings for proximity to other warehouses (C10) and shared logistics and partnerships (C11). The fourth alternative, HLC5 (Zrenjanin), is relatively poorly rated across all criteria, with transportation connectivity (C4) being rated slightly better. Kruševac (HLC6) mostly has poor rating, which is

attributed to its geographic location and the characteristics of the area. The last alternative, HLC7 (Subotica), has solid ratings, with its transportation connectivity (C4), safety (C8) and proximity to other warehouses (C10) standing out. In terms of land prices, the best-rated cities are Zrenjanin and Kruševac, followed by Subotica, Kragujevac, Niš and finally Novi Sad and Belgrade. However, land price is not decisive in this case, as the most important factor for the center is its location in relation to disaster areas and transportation connectivity.

The next step in the ADAM method involves sorting the data from the decision-making table (Table 4) in descending order according to the weight of the criteria.

Table 4. Sorted data

	C1	C4	C2	C3	C9	C11	C10	C6	C12	C5	C8	C7
HLC1	4	5	4	4	5	3	5	5	4	4	4	4
HLC2	4	5	5	4	5	4	5	5	3	4	5	5
HLC3	2	2	3	3	2	2	3	3	2	2	2	2
HLC4	3	4	4	4	4	5	5	3	4	3	4	3
HLC5	1	3	2	2	1	1	2	1	2	1	2	1
HLC6	2	2	2	1	1	1	1	1	2	1	2	1
HLC7	3	4	3	2	3	3	4	2	3	2	4	3

The next step of the ADAM method involves defining the normalized matrix. In Table 5, the data after applying the normalization formula are presented.

Table 5. Normalized data

	C1	C4	C2	C3	C9	C11	C10	C6	C12	C5	C8	C7
HLC1	1	1	0.8	1	1	0.6	1	0.2	1	1	0.8	0.8
HLC2	1	1	1	1	1	0.8	1	0.2	0.75	1	1	1
HLC3	0.5	0.4	0.6	0.75	0.4	0.4	0.6	0.33	0.5	0.5	0.4	0.4
HLC4	0.75	0.8	0.8	1	0.8	1	1	0.33	1	0.75	0.8	0.6
HLC5	0.25	0.6	0.4	0.5	0.2	0.2	0.4	1	0.5	0.25	0.4	0.2
HLC6	0.5	0.4	0.4	0.25	0.2	0.2	0.2	1	0.5	0.25	0.4	0.2
HLC7	0.75	0.8	0.6	0.5	0.6	0.6	0.8	0.5	0.75	0.5	0.8	0.6

By applying software for solving multi-criteria problems based on the ADAM method, the results were obtained (Table 6), showing that the optimal solution is the second alternative, that is Belgrade – HLC2.

Table 6. Ranking of alternatives

Alternatives	Result	Rank
HLC2	0.035	1
HLC1	0.041	2
HLC4	0.027	3
HLC7	0.018	4
HLC3	0.010	5
HLC5	0.007	6
HLC6	0.006	7

The results are presented in descending order. It is observed that after Belgrade, the best-rated location is Novi Sad (HLC1), followed by Niš (HLC4). The lowest-rated location is Kruševac (HLC6), which was somewhat expected after the criteria evaluation. Since the land price in Kruševac was the lowest, it is concluded that in this case, the price is not a critical criterion to consider when selecting the location for a humanitarian logistics center. Figure 2 presents the obtained polyhedrons, where the volume indicates the favorability of the alternatives (larger volume – better solution, and vice versa).

Assigning weights to the criteria is a crucial aspect of multi-criteria decision-making. These weights are a significant source of subjectivity and can greatly influence the outcomes of multi-criteria challenges. Therefore, conducting a sensitivity analysis is essential. This analysis examines how variations in the relative weights of the criteria affect the solution, which is common practice in verifying solutions and making decisions. In this instance, 21 scenarios (SC) were developed, each altering the weights of the criteria. The criteria with the highest weights included: proximity to disaster-prone areas (C1), transport connectivity (C4), and the availability of logistics experts

(C2). For each scenario, the weight of the selected criteria was decreased by increments of 15, 30, 45, 60, 75, 90, and 1000 precent. In scenarios 1-7, the weight of criterion C1 was modified, while the weights of the other criteria remained constant. In scenarios 8-14, the adjustments were made to criterion C4, and in scenarios 15-21, the changes were applied to criterion C2 (Table 7).

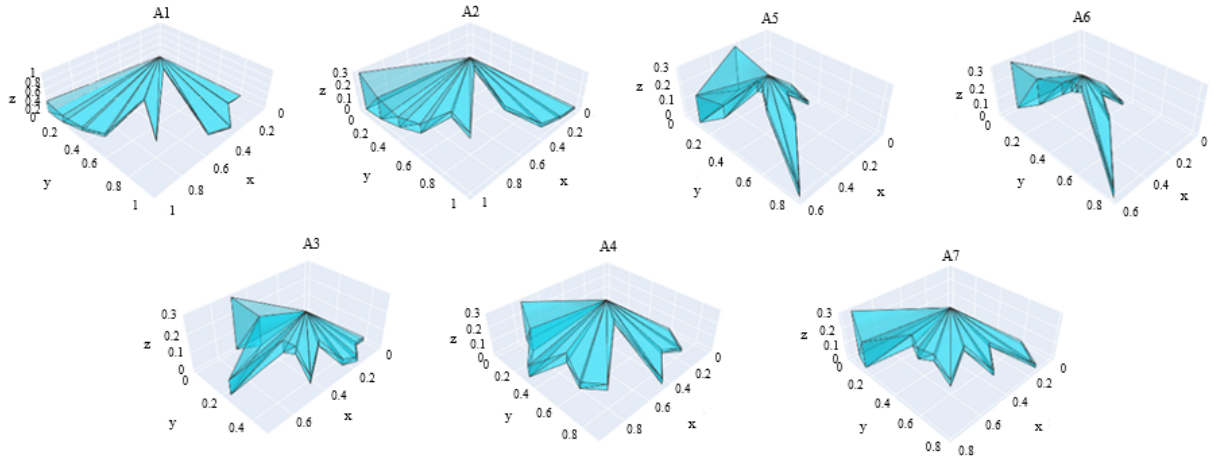

Figure 2. Polyhedral (ADAM method)

Table 7. Sensitivity analysis of the observed solution

	HLC1	HLC2	HLC3	HLC4	HLC5	HLC6	HLC7
SC1	0.033707	0.036994	0.010221	0.026964	0.005671	0.004724	0.017001
SC2	0.032663	0.03595	0.010012	0.026338	0.005515	0.004515	0.016375
SC3	0.031411	0.034645	0.010161	0.025265	0.004316	0.004544	0.015413
SC4	0.029105	0.032558	0.009483	0.023993	0.004333	0.003991	0.013911
SC5	0.027203	0.03048	0.009035	0.022895	0.004372	0.003246	0.012828
SC6	0.025049	0.028336	0.008558	0.021718	0.004252	0.003079	0.011782
SC7	0.026022	0.029635	0.009029	0.023022	0.00458	0.002987	0.01207
SC8	0.03364	0.036804	0.010158	0.026825	0.005588	0.00471	0.016961
SC9	0.031529	0.03557	0.010103	0.026004	0.00531	0.004517	0.015345
SC10	0.030419	0.034337	0.00977	0.025116	0.004977	0.004356	0.014802
SC11	0.029309	0.033137	0.010035	0.024444	0.004067	0.003962	0.013982
SC12	0.028009	0.03187	0.009761	0.023776	0.004009	0.003824	0.013368
SC13	0.026672	0.030708	0.009651	0.022797	0.003543	0.003652	0.012476
SC14	0.028546	0.03279	0.010455	0.024596	0.003778	0.003937	0.013251
SC15	0.033991	0.037088	0.010102	0.026907	0.005619	0.004809	0.017257
SC16	0.033232	0.03614	0.009775	0.026224	0.005411	0.004686	0.016887
SC17	0.033355	0.035205	0.009272	0.025909	0.005279	0.004262	0.016282
SC18	0.032748	0.034351	0.009045	0.025226	0.005203	0.004186	0.01594
SC19	0.031866	0.03327	0.00875	0.024738	0.005163	0.004146	0.015633
SC20	0.031418	0.032511	0.008392	0.02408	0.004946	0.003929	0.015317
SC21	0.033985	0.034876	0.009018	0.026056	0.005368	0.00425	0.016527

In every scenario, the prioritization of all alternatives remained consistent, preserving the same sequence as observed in the primary solution. This observation leads to the conclusion that the method exhibits a high degree of stability, as illustrated in Figure 3.

5.3 Discussion

The challenge of determining the optimal location for a humanitarian logistics center is not yet a widely discussed subject on a global scale, although there is a growing interest from specialists in this area. Given the distinct nature of this sector, it differs significantly from conventional and established scenarios. This paper seek to highlight the significance of setting up a humanitarian logistics center in regions where such facilities are essential. Given that the function of such a facility becomes critical during emergency situations, the focus is placed on defining the criteria

that must be considered when determining its location. Through an understanding of the concept of humanitarian logistics and logistics centers, the most important criteria identified are proximity to disaster-prone areas, transport connectivity, and the availability of logistics experts. Following these are geographical characteristics, the number of logistics providers, shared logistics and partnerships, proximity of other warehouses, land cost, political and economic stability, availability of existing facilities and infrastructure, and finally, safety and reliability. These criteria were selected subjectively, considering that for this type of facility, it is crucial to take all of them into account, with a particular emphasis on the first three.

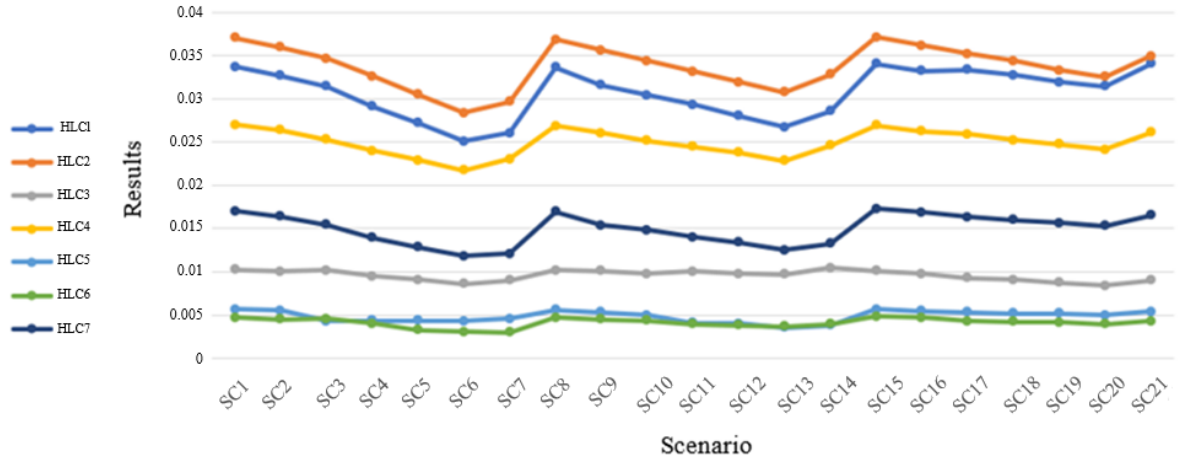

Figure 3. Sensitivity analysis

Utilizing the ADAM method for evaluating the proposed alternatives reveals that Belgrade emerges as the most appropriate location in Serbia for establishing a humanitarian logistics center. This research demonstrates that it is impossible to determine the location of a center without a detailed investigation of the territory's characteristics and the history of natural disasters, which is also recommended to other experts in this field of study. Sensitivity analysis confirmed the stability of the obtained results, which suggests that the conclusions are reliable and provide important guidelines for stakeholders in the field of humanitarian logistics.

6 Conclusion

Humanitarianism embodies the provision of assistance support, and a sense of empathy among individuals. It pertains to the altruistic traits inherent in people that drive them to help others without expecting personal gain in return. The very notion of offering help without any expectation of compensation forms the foundation upon which humanitarian organizations are built. Given the multitude of actors involved in humanitarian activities, it is crucial to effectively coordinate these processes, which is directly linked to logistics management [2].

A supply network is made up of nodes, which are warehouses, and links that represent transportation routes. This network connects various sources, such as producers and suppliers, to points of demand, which are the recipients of humanitarian assistance. Within this framework, both goods and information move throughout the system. Locating warehouse facilities and logistics centers in humanitarian logistics is not a simple process. Locating near disaster zones increases the risk of losing humanitarian supplies, endangers lives and raises the risk of increasing the number of causalities. For this reason, important factors that could jeopardize the activities of a humanitarian logistics center must be considered when making decision.

This paper begins by outlining the fundamental concepts related to humanitarian logistics centers, followed by a discussion on the challenges involved in determining the optimal location for such centers. From these sections, it is concluded which key factors must be considered when defining location selection criteria. Consideration must be given to the nature of the products, the purpose of the center, and the operations planned for the future facility. In this particular context, which centers on reducing the adverse effects of disasters, the site selection for the center becomes critically important. Given that this is a specific case, where the focus is on mitigating the negative consequences of disasters, the location of the center is of crucial importance. Once these factors are identified in this section, the next step is to define the criteria that will be considered when locating the center. In this case, the center is to be located in Serbia, so it was necessary to examine the characteristics of the territory. After that, alternatives were identified that are not, according to research findings on the characteristics, at risk, while at the same time representing suitable locations for the construction of a humanitarian center. Accordingly, seven cities were identified as alternatives: Novi Sad, Belgrade, Kragujevac, Niš, Zrenjanin, Kruševac, and Subotica. Subsequently, the methods for evaluation are established. Here, the SWARA method is utilized to determine the significance of each criterion, followed by

the application of the ADAM method to prioritize the alternatives based on the specified criteria. Ultimately, it was determined that Belgrade emerges as the most suitable location according to the identified criteria

Author Contributions

Conceptualization, M.K. and S.T.; methodology, M.K.; software, M.K. and S.T.; validation, M.K., and A.S.; formal analysis, M.K., S.T., and A.S.; investigation, M.K. and A.S.; data curation, M.K., and S.T.; writing—original draft preparation, A.S.; writing—review and editing, M.K., and S.T.; visualization, A.S.; supervision, M.K. All authors have read and agreed to the published version of the manuscript.

Data Availability

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

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