A Decision Support Tool Proposal for Public Emergency Scenarios

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Every day the world is facing a possible emergency or disaster scenario that affects the basis of ordinary life as we know such as natural disasters such as earthquakes or floods, or a vast viral epidemic that alters the way we live. Public emergency scenarios shift the way of living, and ramifications of ongoing or post-emergency issues related to extraordinary circumstances affect many aspects such as sustaining everyday life, welfare, health, economy, and more that require strategic planning and management. The impacts of such emergencies are so massive and extended in almost every aspect of human lives that it is impossible to overlook. Even with the wide range of possible emergency scenarios, there is a common challenge for all: accessibility. Extraordinary circumstances cause potential difficulties for access to facilities in any case and supplying facilities in a considerably short distance. An adequate number can be a matter of life and death. Tackling the issues caused by emergencies might be challenging because each entails unique contingency plans and managing operations. However, for all the emergency scenarios, one of the most crucial common matters is the accessibility to facilities. Coming up with a good comprehensive strategy that functions as a decision support system is crucial to eliminating human factors that may affect and delay response solutions for emergencies due to workload, complexity, and time management. The study aims to overcome the inadequate number of facilities during the time of crisis in the response phase to emergencies that may occur due to the accessibility of facilities. Through identifying critical considerations for sustainable life in emergency scenarios, this paper proposes an approach to assure welfare and a sustainable daily life even in extraordinary circumstances through proposing a decision support tool. This support tool can be used for any emergency scenario to strategically allocate indispensable temporary facility structures that can be accessible for all people at a minimum possible distance according to relevant emergency conditions' necessities. It generates to provide and allocate temporary facilities for unmet demand by considering population density in the response phase of emergency management. By providing fast and specific to case results, the proposed decision support tool has the potential to eliminate human errors via proposing suitable zones that are finalized according to the population density of the district. The proposed tool can be used by disaster and emergency management presidencies, NGO's, municipalities and governmental organizations. A case of a flood is issued to demonstrate a possible scenario. The final section discusses the proposed tool's contingency plan possibilities, constraints, and feasibility.

Keywords: Decision Support Tool, Emergency Planning, Temporary Complementary Unit Allocation.

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Kamusal Acil Durum Senaryoları için Karar Destek Aracı Önerisi

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Çeşitli acil durum veya doğal afet koşulları gündelik yaşamın sürdürülmesi, refah, sağlık, ekonomi ve stratejik planlama ve yönetim gibi hayatın birden çok yönünü etkileyen göz ardı edilemez sonuçlar doğurmaktadır. Bu gibi olağandışı durumların neden olduğu sorunlarla mücadele etmek, her birinin kendine özgü acil durum plan ve operasyonları gerektirmesi sebebiyle zorlu olabilmektedir. Öte yandan çok çeşitli olası acil durum senaryolarında bile, herkes için ortak bir zorluk vardır: erişilebilirlik. Çalışmanın amacı iş yükü, karmaşıklık ve zaman yönetimi nedeniyle acil durumlarda müdahale çözümlerini etkileyebilecek ve geciktirebilecek insani faktörleri olabildiğince ortadan kaldırmayı hedeflemenin yanı sıra, müdahale aşamasında tesislerin erişilebilirliği ve tesis sayısının yetersiz olma hali sebebiyle meydana gelebilecek sorunların kriz anında üstesinden gelmektir. Bu çalışma, acil durum senaryolarında sürdürülebilir yaşam için temel hususları belirleyerek, öncelikli olarak vazgeçilemez geçici tesisleri stratejik olarak tahsis etmek için herhangi bir acil durum senaryosu için kullanılabilecek bir karar destek aracı önererek, olağanüstü durumlarda bile refahı ve sürdürülebilir bir günlük yaşamı güvence altına alacak bir yöntem önermektedir. Olağandışı durumlar her koşulda tesislere erişim için zorluklara sebep olur ve bu gibi durumlarda tesislerin erişilebilir mesafelerde ve yeterli sayıda temin edilebilmesi hayati önem taşımaktadır. Önerilen araç, acil durum yönetimlerinin müdahale aşamasında nüfus yoğunluğunu dikkate alarak karşılanamayan talepler için mümkün olan en az mesafede geçici tesisler sağlamayı hedeflemektedir. Önerilen araç, afet ve acil durum yönetimi başkanlıkları, STK'lar, belediyeler ve devlet kurumları tarafından kullanılabilirken hızlı ve vakaya özgü sonuçlar sunarak, ilçenin nüfus yoğunluğuna göre kesinleşmiş uygun bölgeler önererek insani hataları ortadan kaldırma potansiyeline sahiptir. Olası bir senaryoyu ortaya koymak için bir sel vakası üzerinden olay örneği yapılmıştır. Son bölüm önerilen aracın acil durum plan olasılıklarını, kısıtlamalarını ve fizibilitesini ortaya koymaktadır.

Anahtar Kelimeler: Acil Durum Planlaması, Geçici-Tamamlayıcı Ünite Ataması, Karar Destek Aracı.

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1. INTRODUCTION

An emergency can be defined as an extraordinary circumstance that transforms and affects our daily life at different scales. Furthermore, such situations are the ones that neither expected nor informed us in advance: as in its nature, it emerges on impulse. Making predictions for some cases might be possible, yet there is no schedule for the exact incident moment. According to Van de Walle and Turoff (2008), emergencies are strange incidents, or according to CCS (2004), an emergency can be defined as a situation that endangers human welfare, environment, or security. Emergencies can threaten life, health, or the environment. Emergencies can occur in relatively minor situations such as a car crash or road maintenance work. Also, natural disasters such as earthquakes, floods, blizzards, wildfires, tsunamis, hurricanes, or viral epidemics are examples of emergencies on a bigger scale.

All in all, disasters affect and threaten welfare whether they occur unexpectedly via natural causes or premeditatedly via humans. Any emergency needs awareness, attention, and remediation of related situations to avoid unfavorable results (Fuents et al. 2017). On the other hand, emergency management is a critical process for reducing the impact of emergencies that may cause damage to humans, economics, and the environment. Since every emergency scenario is one of a kind, each one of the possible situations will require planning. However, to cope with unusual scenarios, a series of steps can be followed. Van de Walle and Turoff (2008) suggest that emergency management can be specified in primary and secondary phases as analysis, planning, and evaluation of the situation in terms of analyzing threats, errors, mitigation, detection, intelligence, response, and recovery or normalization. For the mitigation phase of emergency operation that focuses on preventing or reducing the impacts caused by disasters, criteria such as controlling the land use to prevent occupation in high-risk areas, stabilizing the built environment structures to the ground, controlling and redirecting the water to prevent flood, constructing barriers to block disaster forces, controlling rebuilt processes after events, and analyzing risk to foresee potential for hazards are deployed (Altay and Green, 2006; FEMA, 2013). The second step of an emergency operation preparedness phase which takes a proactive turn by focusing strategic planning, involves assigning personnel and volunteer groups for emergency services, planning, educating the public about threats, maintaining emergency supplies, and supplying a list of needs in case of a disaster, and practicing drills through various mediums (Altay and Green, 2006; FEMA, 2013; Savaş, Cenani, and Çağdaş, 2019). In the third phase of operation, as a response stage that focuses on the repercussions of the disaster period in which the fastness and adaptability on short-term operations are the core issues, activities such as activating emergency response operations plan and operations center, initiating the rescue and search operations, evacuating under-risk populations, providing shelters and medical care, and recovering lifeline services are considered (Altay and Green, 2006; FEMA, 2013; Savaş, Cenani, and Çağdaş, 2019). For the final phase, recovery, cleaning debris areas, assisting individuals and governments financially and psychologically to reduce or prevent the overall effects by caring for mental and rural health, reconstructing roads and key facilities, restoring lifeline services entirely, and taking precautions to reduce vulnerability to possible new disaster situations (Altay and Green, 2006; FEMA, 2013). For emergency decision-making, there are uncertain issues such as form, nature, scale, and incident time, out-of-control changes in the environment. The decision will be made in a short time, perhaps with information that is not complete or exact, eliminating goals according to their priorities, and evaluating of decision scenario in terms of effectiveness and feasibility (Jianshe, Shuning, and Xiaoyin, 1994). In the design process, many stakeholders such as agencies, individuals, and governments need to be involved in the decision-making process by also considering ethical and moral responsibilities. Stakeholders include disaster relief organizations, national and local governments in different roles in different sectors, citizens and members of communities, volunteers and civil society organizations, private sector members as business and industrial groups, professionals such as academicians and training organizations, media as newspapers, radio and television networks (Abulnour, 2014).

According to Van de Walle and Turoff (2008), a possible emergency circumstance should be addressed by a proper crisis response team since making sense of the situation with limited information in a limited time may lead to inefficient decisions that can make the situation more critical. The inefficiency of allocating required sources within the necessary duration is an issue that mainly arises, intensifying the effects of disaster scenarios (Rolland, Patterson, Ward et al. 2010).

This study proposes a decision support tool for emergency scenarios to ensure accessibility to vital resources by enabling specific case services and regions by taking the population into account. Today, with the help of computational design tools, it is possible to develop both generic yet specific-to-case tools that can be comprehensive for most emergencies. The proposed tool generates in three stages: selecting the region, selecting the necessary services according to the relevant emergency case, and defining a diameter for each service. After the user provides the inputs, the tool generates possible locations to allocate missing requested services on the intersection points of available requested services by considering the population density. A case of a flood is selected to illustrate how the tool will generate in a possible emergency scenario. With fast, easy to operate, and suitability for any disaster case features, this study has an importance within the emergency management studies.

2. A DECISION SUPPORT TOOL PROPOSAL

The proposed tool will address the emergency operation preparedness and response phase by providing an alternative to emergency planning and active emergency operation for disaster and emergency management presidencies, NGO's, municipalities, and governmental organizations. According to regions that are enounced as emergency or disaster areas, identifying essential requirements specific to a relevant emergency case is the primary phase. This process may be managed in advance to eliminate the time management issues under pressure conditions by first categorizing possible emergency scenarios and their primary necessities in terms of vital facilities to maintain good daily life. The main motive for developing such a tool is to ensure self-sufficient response zones at walking distance in case of an emergency or disaster scenario.

2.1 Literature Review

This section reveals related studies within the literature on humanitarian logistics and operations. With the insights of planning and operational strategies of humanitarian relief, related studies are subcategorized into two decision support systems for disaster scenarios and facility location-allocation problems. For the second subcategory, studies are examined within two subsections: facility location and facility allocation to clarify the scope of the reviewed studies. Selected studies are found by specific keywords such as humanitarian logistics, facility location-allocation, and decision support systems. There are 27 articles found and reduced to 10 articles as shown in **Table 1** by their relevancy to the conducted study.

Humanitarian Logistics and Operations	Author	Year	Method	Scope
Decision Support Systems	Thompson et al.	2006	Decision support systems for structured, unstructured, short-term semi-structured and long-term semi-structured problems	Information technologies for disaster response
	Tuğba Turğut et al.	2011	Fuzzy AHP based decision support	Disaster center location selection
	Brown and Vassiliou	1993	Real-time operational and tactical decision support	Optimization model for operation and tactics
	Hobeika, Kim, and Beckwith	1994	Knowledge-based microcomputer software	Evacuation planning and operations
	Efendioğlu and Cenani	2021	DDS with Digital Elevation Model	Evacuation in case of earthquake-induced tsunamis
	Savaş, Cenani, and Çağdaş	2019	Mixed-method model with Geographic Information System and The Analytic Hierarchy Process	Emergency assembly points
Facility Location-Allocation Problems				
Facility Location	Oksuz and Satoglu	2020	Two-stage stochastic programming	Temporary medical center location planning
	Balcik and Beamon	2008	Maximal covering location model	Facility location and inventory
Facility Allocation	Zhu et al.	2008	Resource allocation model with multi-modal stochastic programming	Resource allocation for local reserve depots
	Sebatlı-Sağlam and Köse-Küçük	2020	Spreadsheet-based decision support	Temporary disaster response facility

Table 1: Characteristics of reviewed studies

Literature reviews on humanitarian logistics show that the primary focus on the subject is more on the preparedness phase of the disasters rather than the recovery or response phase, in which there is a lack of research and applied methods (Leiras et al., 2014; Kovács and Spens, 2007). Thompson et al. (2006) presented possibilities on how to utilize information technologies and related processes to enhance decision-making in case of emergencies through exploring decision theory and its efficacy in the response phase of disasters within its limits. The importance of the study is that through the introduced decision support technology and theories, it is possible to cope with the uncertainties and limitations of decision making. Furthermore, Tuğba Turğut et al. (2011) introduce a support system for the selection of logistics of a disaster center's location through fuzzy analytic hierarchy process procedures, which reduce the decision-making duration and eliminate its subjectivity. The most salient contributions of the carried study are; first, it presents a support system that corresponds to the needs of a disaster scenario, and second, it involves the assignment of location which can be deployed for various disaster cases. On the other hand, Brown and Vassiliou (1993) present a decision support system that depends on operations as simulation and optimization processes for the operational and task-related necessities of disaster situations in terms of tactics. The operations in which the provided tool assesses each task and optimizes them to achieve maximum efficiency to repair or address any required response (Brown and Vassiliou, 1993). The study offers insight for real-time utilization of the decision support systems while giving room for the decision maker to maneuver manually. Studies focused on the evacuation phase of potential incidents, such as earthquake-induced tsunamis and nuclear power station emergencies, has been held with different insights (Efendioğlu and Cenani, 2021; Hobeika, Kim, and Beckwith, 1994). For the earthquake-induced tsunamis, a decision support tool with digital elevation model is designed to evacuate evacuees from defined risky areas to safe zones such as hospitals and designated meeting areas, as stated by Efendioğlu and Cenani (2021). For nuclear power station emergencies, a decision support system for the transportation evacuation consists of the operation time, optimal route, and traffic for various cases to transport evacuees to the shelters is developed with a simulation model (Hobeika, Kim, and Beckwith, 1994). Flexibility for more than one scenario can be named the most prominent feature of these studies. In contrast to designating evacuation routes, Savaş, Cenani, and Çağdaş (2019) presents an approach for the selection of emergency assembly points by the criteria such as capacity, position and accessibility, size, connection, function, infrastructure, support units, and ownership in which geographic information system and analytic hierarchy process are used. The study does not include population density for the proposed assembly points.

Oksuz and Satoglu (2020) proposed a two-staged stochastic model which operates to assign temporary healthcare centers for any disaster situation in terms of location and quantity by taking into account available healthcare centers' location and capacity. The importance of the study resides in the fact that it considers the possible disaster scenario thoroughly as within three significant issues of any disaster case: location, capacity, and accessibility with possible demand. Balcik and Beamon (2008) proposed a tool to meet the possible demands in case of before or after the disaster situations in terms of facility location and inventory stock. However, the pre-assigned stock volumes may not correspond to the demand, which may cause facilities to function less than expected. In case of a disaster, to meet the demand of the districts that are lower than a specific level, a study is conducted to determine local reserve resources and compensate for the shortage of the supplies by the central resources (Zhu et al., 2008). The study includes two sets of disaster impact scenarios, slight and serious, in which randomness stands out as the most operative input. On the other hand, for the response phase of disaster cases, a decision support tool to allocate temporary facilities to correspond wide range of emergency scenarios is developed by utilizing a spreadsheet-based method. For the settlement and the distribution of required needs, a case study is presented in which, after the determination phase, allocation of the temporary facilities is addressed again (Sebatli-Saglam, and Kose-Kucuk, 2020). However, it is possible to suggest that with the pre-settled facility types, there is a limitation on the generic utilization of the proposed tool. The common interest and significance of all of the issued studies above is the focus on the allocation problem from crucial points of after-disaster scenarios. As uncertainty, accessibility, and flexibility can be game changers in any case, and aside from the salience of key considerations, addressing not only the allocation problem but the determination is also essential.

2.2 Preliminary Decisions and Model Structure

The first subsequent variable after selecting the region that needs emergency response operations is the number of necessary facilities in respect to the emergency scenario. Since the primary objective is accessibility and the tool will operate with the possible intersection points of the selected facilities, there is no upper limit on the selection of requested facilities. However, with the same rationale, at least two facilities must be selected to provide possible interaction points and suitable zones.

There are two sub-criteria to set limits on population density. After the first step, which involves specifying requirements in the relevant context, the second step inquiries whether the requested service(s) are available or not in the emergency area. Furthermore, identifying the missing ones is the following phase if some of the requested services are available and some are not. The sequent phase encompasses determining suitable zones to allocate missing facilities as a temporary complementary unit by considering available facilities distances. At this phase, secondary criteria must be considered as population density. Since the suitable zones will accommodate and serve a specific district hence people, the population ratio per square meter needs to be appropriate to avoid accumulation.

The first one involves a temporary complementary unit's capacity. The unit that will be utilized for missing requested services is considered a container. The decision on selecting containers is the fact that allocated units are going to be temporary ones to compensate for missing facilities in a possible emergency scenario; it is considered that units need to be easy to provide, transport, and low-cost. Selected container unit dimensions are 2.35x5.90x2.37 meters. Because each container will be utilized for a different service type, the person/m² ratio must be suitable for general usage. Furthermore, since the requested and missing facilities are public spaces such as retail, health, and governmental areas, the area per person must be bigger than a temporary shelter. According to Çınar, Akgün, and Maral (2018) The Disaster and Emergency Management Authority (AFAD) suggests a standard of 3.5-4.5 m² for either container units or tents. On the other hand, semi-closed working spaces with 0-2 visitors require 7 to 7.5 m² workspace, and client-focused workspaces and an enclosed space can be up to 9.3-15.5 m² (EPA, 2004; IPD Occupiers, 2007). Therefore, to correspond to various facility types and public spaces, for the optimal facility area per person, a 7 m² usage area is settled. With these inputs and accepting daily working hours as 8 and estimating 15 minutes' duration per person, with one employee and one customer, every 13.8 m² container can serve 4 people in one hour and 32 people daily. For this case, the tool does not aim to finish service time in a specific duration. Therefore, it is considered adequate to allocate one container unit for each missing facility in suitable zones. However, if the service time supposed to finish is in limited duration, to meet the demand, container quantity can be increased due to the required total service time.

The second sub-criteria involve the arithmetic average of population densities of districts. According to **Table2**, **Equation 1** demonstrates the following steps of the calculation of the population density of the districts as km²/per person.

Table 2: Parameters of population density

Parameters
j: forest land of the city (%)
a: agricultural land of the city (%)
k: total area of the city (km²)
p: population of the city
d: population density (km²/per person)

$$d = \frac{p}{k - [\frac{j+a}{100} xk]} \quad (1)$$

The number of districts with a population density above the acquired population density (*d*) person/km² is included in calculating the districts' arithmetic average. According to **Table 2** and **Table 3**, **Equation 2** shows the estimated population density coefficient as person/km².

Parameters
d_k: *the* total amount of population of the districts above
d d_n: the number of districts above d
Variables
d_c: estimated population density coefficient (person/km²)

Table 3: Parameters and variables of population density and coefficient

$$d_c = \frac{d_k}{d_n} \quad (2)$$

For further calculations, it is essential to underline that one of the inputs that need to be specified by the user is the diameter for the requested service. According to Gerçek and Güven (2016), access distances are suggested with three thresholds as high accessibility distance as 100 m with 1-2 minutes of walking duration in which the service zones have 0-100 meters of diameter, medium accessibility distance as 400 m with 5 minutes of walking duration in which the service zones have 100-400 meters of diameter, and low accessibility distance as 800 m with 10 minutes of walking duration in which the service zones have 400-800 meters of diameter. Since accessibility is the primary objective, high and medium accessibility considered suitable and the walking distance limits for the proposed decision support tool are settled as 150-300 meters. According to **Table 4** and **Equation 3**, with the specified diameter for the requested service, the calculation of the capacity of the one suitable zone is shown.

Table 4: Parameters and variables of capacity of the suitable zone

Parameters
r: specified radius of the suitable zone for the allocation of the missing facility (m)

Variables
d_c: estimated population density coefficient (person/km²)
r_n: capacity of the suitable zone

$$r_n = \pi r^2 \times \frac{d_c}{1000} \quad (3)$$

Since every district has its population density in the suitable zones, the next step is to calculate the specific district's related population density. By doing so, if the population is dense in the selected district, the suitable zone's diameter will increase or decrease to correspond to demand in terms of accessibility. An example of the possible scenario is shown in **Table 5** and **Equation 4**.

Table 5: Parameters and variables of the finalized radius for suitable zone.

Parameters
d_d: population density of the district
r: specified radius of the suitable zone for the allocation of the missing facility (m)

Variables
d_c: estimated population density coefficient (person/km²)
r_f: finalized radius for suitable zone according to population density

$$r_f = \frac{\frac{d_d}{d_c}}{r^{-1}} \quad (4)$$

As shown below in **Equation 5**, the relation between district population density and the estimated population density coefficient determines the finalized radius for suitable zones. Suppose the district's population density is higher than the estimated population density coefficient. In that case, the finalized radius will be reduced to capacity. Suppose the district's population density is lower than the estimated population density coefficient. In that case, the finalized radius will enlarge to minimize the total traveled distance due to residential area distribution in a wider field.

If $d_d > d_c$ then $r_f < r$(5)
If $d_d < d_c$ then $r_f > r$

In the first possible scenario, temporary complementary unit(s) should be allocated more compactly, whereas in the second possible scenario, unit(s) should be allocated in a scattered configuration.

2.3 Methodology

This section intends to reveal the optimization of preliminary decisions and constraints by identifying the method and the operations of the proposed decision support tool.

2.3.1 Database

As shown in Figure 1 below, there will be three databases containing necessary data that will be used in the operations of the proposed tool. For the regions, definitions are region name, region type, address, boundary, coordinate, population density, and its last updated year will be included. Google Geolocation API will provide the database. For places or place types, there are constraints on the database of Google Places API. The returned results are not precise to put into use; therefore, the necessary database with name, address, coordinate, type, icon, and region name has to be obtained through different place type API service providers. For the intersection zones in which the pre-determined diameter data by the user will be utilized, through the database provided by Google JavaScript Maps, API name, address, region name, and coordinate of the intersection points will be used. It is important to note that since for the facility type, the database of Google Places API is used, users can only select the facility types that are available within the database.

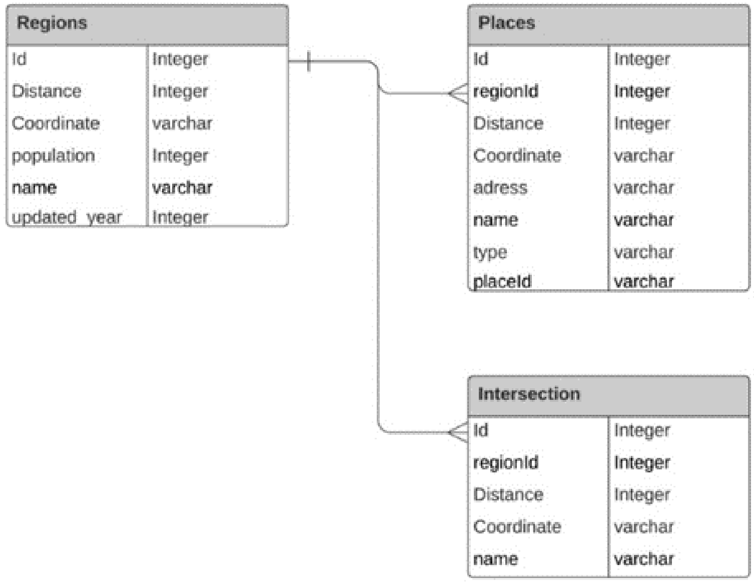

Figure 1: Database of the proposed decision support tool

2.3.2 Workflow Chart

In this section, according to **Figure 2** stages of the workflow chart of the proposed decision support tool and the optimization strategies are probed. According to the possible emergency scenario, the user must provide three inputs: region name, place type, and diameter for place types. Furthermore, the user selects a region such as Maltepe (located in İstanbul). According to the relevant emergency, scenario user selects a minimum of two place types: hospital, pharmacy, supermarket, shipping agency, bank, government office, police station and fire station. Lastly, the user defines a standard diameter for the selected place types between 150-300 meters. With these inputs, the tool searches the first requested region at Google Geolocation API. If any results are found, the address, name, coordinate, boundary, and type of the region information will return. Followingly selected place types within the region will be searched in the database of Place type API, which might be obtained from different service providers. This search will return outputs such as an address, name, coordinate, type, icon, and opening hours. Depending on whether the requested place type(s) is found at the previous step, the next step marks the pre-defined diameter by the user at found place types in the selected region through Google JavaScript Maps API. The sequent step creates a new diameter by taking the intersection points of the marked diameters of place types at a pre-defined diameter. This intersection zone is the one called a suitable zone to allocate missing services. The next step finalizes the intersection zone diameter according to the district's population density depending on the relation (**Equation 4**). If the population is dense, intersection diameter will reduce, and low diameter will enlarge due to reduction or growth ratio (**Equation 4, Equation 5**). There are two options for dense populations; proposing more than one missing complementary unit or displaying more intersection zones to allocate units in different suitable zones for each facility. For the optimization of finalized diameter due to estimated population density, in denser populated districts, it is decided to reduce the diameter of the population and display more intersection zones to allocate units in different suitable zones. The purpose was to create self-sufficient zones within walking distance by decreasing distances to reach preferred or vital facilities that ensure the maintenance of daily life. Furthermore, the finalized diameter according to the population density also determines the allocation pattern, as shown in **Figure 4**. Suitable zones will be marked on the map with the finalized intersection diameter. As the final step, the proposed tool will display suitable zones as the intersection zones marked on the map, showing the available and missing place types according to the initially made search request.

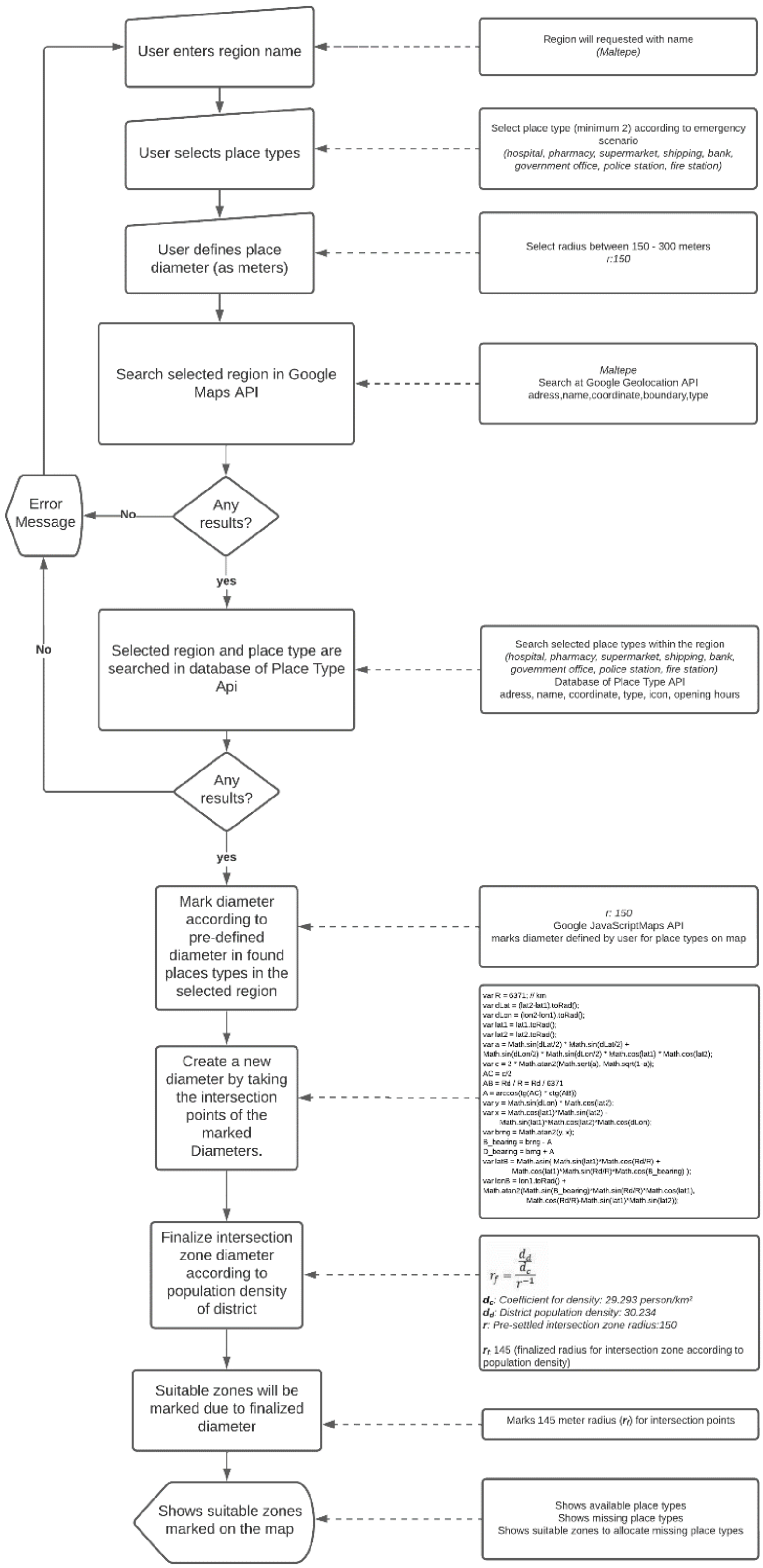

Figure 2: Workflow chart with case demonstration

3. EMERGENCY RESPONSE PROJECTION: A CASE OF FLOOD

Natural disasters cause difficulties with sufficient access to the facilities at a minimum level of daily requirements. With the ongoing climate crisis, the impacts of climate change have become more critical and threatening. Therefore, a case of a flood is selected because accessibility to facilities has become critical for a sustainable and habitable daily life. Moreover, by minimizing the total traveled distance in flood, the proposed decision support tool might be beneficial in decreasing the casualties while increasing the level of welfare. Facilities such as healthcare services, pharmacies, food supply facilities, banking facilities, shipping services, governmental services, and security units can be suggested as the primarily necessary utilities to maintain daily life sufficiently in case of a flood. Healthcare services, such as a hospital or community clinic, can be on different scales. Food supply services can be a supermarket, grocery stores, and so on. Banking facilities include both ATMs and banks. As for the security units, it can be police or fire station that people could rely on for their safety.

3.1 User Interface

A demonstration of the user interface of the proposed decision support tool for a case of a flood is shown below in **Figure 3**. For this case, the Maltepe region is selected randomly with no selection criteria. Place types requested as healthcare, pharmacy, supermarket, shipping, bank, governmental office, police station, or fire station with 300 m diameters. Intersections A, B, C, and D are displayed according to the available requested place type's intersections. At intersection A, pharmacy, shipping agency, governmental office, and police or fire station are missing; hence should be implemented as a temporary complementary unit. At intersection B, a supermarket, pharmacy, governmental office, healthcare, police or fire station, and bank are the missing facilities. At intersection C, supermarket, bank, healthcare, police or fire station, and governmental office are missing. At intersection D, shipping agency, governmental office, and police or fire station are missing and should be implemented. For each suitable zone to allocate missing facilities as intersection zones listed A, B, C, D, available and missing requested services are displayed. The diameter of each shown intersection varies due to the population density of the related district. For all suitable zones as intersections, a radius of the intersection zones is finalized according to the equation mentioned earlier, **Equation 4** and **Equation 5**.

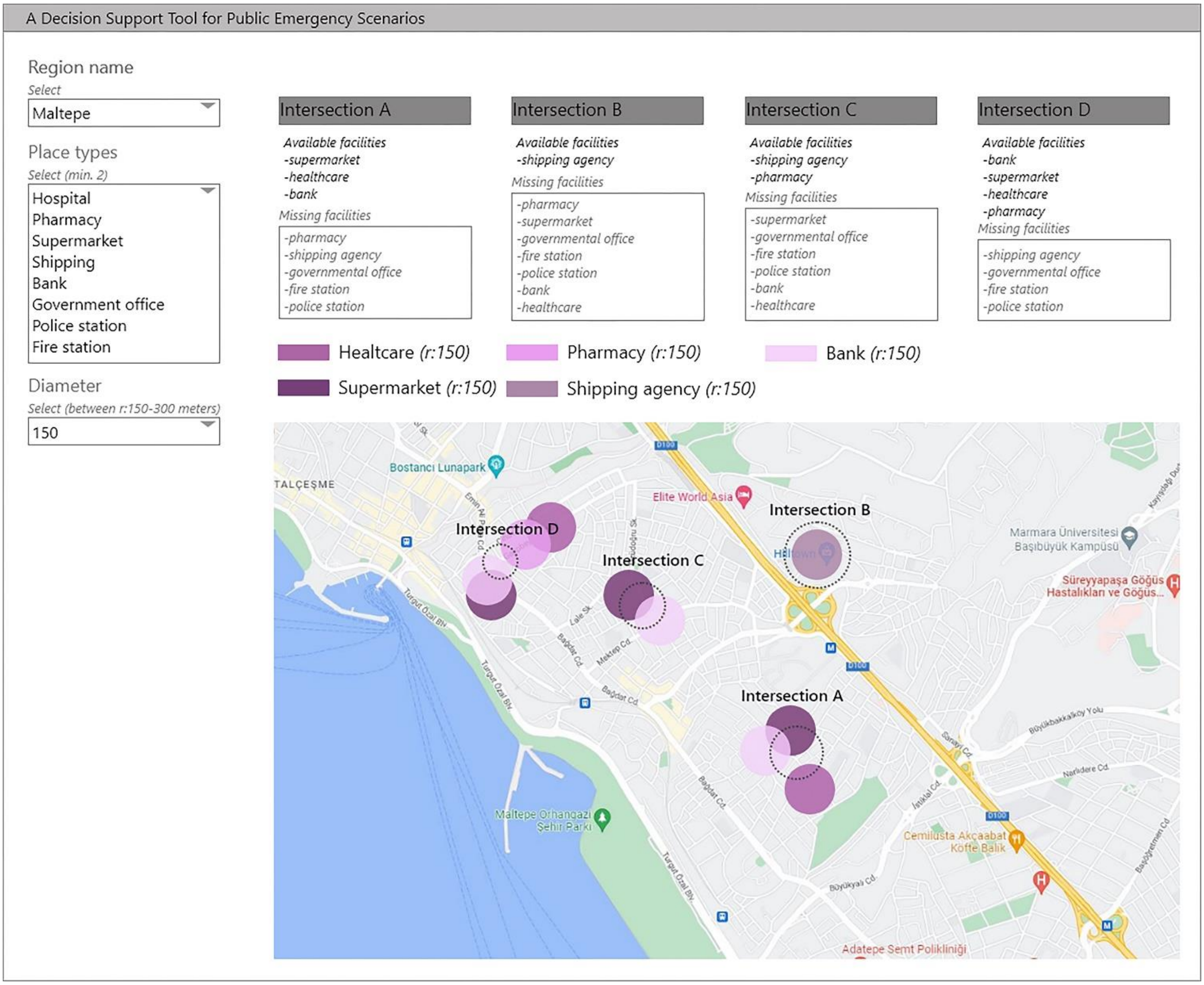

Figure 3: Demonstration of the user interface of the proposed decision support tool for a case of flood

3.2 Guidelines for the Strategic Decision on Temporary Complementary Unit Allocation

The proposed decision support tool provides strategic zones for allocating complementary units. Although the type of the complementary unit might differ according to the logistics and security needs, the container unit is selected as one of the common temporary units to demonstrate a possible allocation. A strategic decision should be made according to suitably displayed zones to locate missing facilities in temporary units as containers. The following descriptions can be considered as guidelines for the allocation. Since the suitable zones are in the residential areas, to locate unit(s) user needs to decide on a convenient empty or available area. These areas can be parks, parking lots, town squares, and such like plots. The quantity of the complementary unit depends on the requested service time. If there is not a limitation on the service time, the user can provide one unit for each missing facility. In case of a limitation on service time, the user should increase the number of complementary units per one facility type as needed according to the time schedule. On the other hand, the specific location of the complementary units depends on the manual evaluation from the user within the proposed suitable zones since simultaneous data flow with the disaster zones is not included to the proposed decision support tool. If the proposed suitable zone is not available to allocate temporary complementary units, the user can select the next closest suitable zone to allocate missing facilities in which the amount of temporary complementary units might be increased to meet the demand and capacity of the district. The other issue on allocation is the relation between diameter and population density. If the suitable zone has a wider diameter (**Equation 5**), that means population density is low; hence, missing units should be located in a more scattered way which can ensure accessibility in the minimum traveled distance for all residents. As shown in **Figure 3**, intersection B has a wider diameter than intersection D. Therefore, the temporary complementary units in intersection B must be scattered, whereas in intersection D it should be denser. **Figure 4** below represents the accessibility of the temporary complementary units in two different situations where the total traveled distance in both cases does not exceed the walking distance.

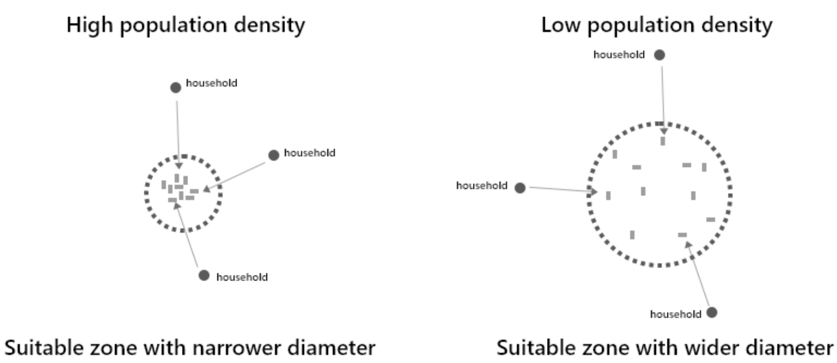

Figure 4: Demonstration of a possible allocation to ensure accessibility within walking distances

4. CONCLUSION

It is possible to say that coping with emergency scenarios might be challenging for both individuals and operation managing parties in terms of physical and psychological aspects. Perhaps avoiding possible emergency scenarios is not likely; however, being prepared in advance to minimize the impacts of any case is very critical to avoid unwanted effects and ramifications. Poorly managed operations can result in disruption and worsen the situation. Also, decisions made under pressure may lead to undesirable consequences with incorrect judgment. In this aspect, developing a decision support tool for emergencies might ease the weight on the decision-maker's shoulders. However, with a better operation management system, hence more accurate decisions that can decrease or prevent the damage caused by the disaster, can be employed. Using computational systems for decision-making in emergencies can eliminate possible human error and enables rapid response. Moreover, utilizing computational design tools for extraordinary conditions may offer an inclusive template to tackle unpredictable scenarios by providing various possibilities and demonstrations of any case.

With the proposed decision support tool for public emergencies, this paper seeks to provide a reliable decision-making mechanism by eliminating human factors and reducing the amount of time spent on feasibility for each disaster case. To perform such task, proposed decision support tool followed the steps as:

- Determining the preliminary decisions for accessibility to vital facilities in minimum walking distance

- Followingly, setting limits on population density to perform the initial goal as accessibility in terms of distance and capacity

- Identifying the indispensable facilities for each emergency scenario and searching them within the selected disaster zone

- Proposing suitable zones to allocate missing facilities as temporary complementary unit

The proposed decision support tool addresses an emergency's preparedness or response phase that involves designating strategic locations by considering population density. Calculations for each step of population density are explained and added, enabling alterations to guide future studies. It is important to note that the proposed tool uses the estimated population density of İstanbul as a coefficient to generate districts' population density; thus, suitable zones diameter are finalized due to population density of issued city. Furthermore, since the tool is not yet developed, demonstrating a case of a flood is just a projection. Key considerations and strategic decisions on allocating temporary complementary units are eligible; however, user interface and intersection areas as suitable zones can vary after the tool is finalized. Regardless, future studies can benefit from this study as a template for preliminary decisions. Proposed tool aims to provide a user friendly and simplified set of rules and decisions to rapidly utilize in case of an emergency situation. In future studies, database and selection criteria can be enhanced and organized. Additional features such as allocation operation for missing facilities, documentation, costs, and specification for each disaster case in further level can be considered.

A decision support tool developed with computational technologies may alter traditional approaches due to it being generic yet specific simultaneously. It enables specification according to relevant emergency scenarios, whereas common key consideration as accessibility remains the same, which is, in most cases, the main challenge. In addition, it can utilize low-cost planning and execution because it does not depend on a large group of people at the planning phase of the operation and considers containers for implementing missing facilities. By decreasing the number of people that the tool depends on operating, it is also beneficial in terms of reaching a satisfactory solution in a short amount of time which is also a significant issue in any emergency case. Thus, the importance of the study resides in the fact that it makes a complex situation easier to handle by outlining common key inputs for any emergency scenario. Overall, the decision support tool can increase the chance of success in public emergency scenarios by ensuring to reach every district in need rapidly and cost-efficiently.

References

Abulnour, A., H. (2014). The post-disaster temporary dwelling: Fundamentals of provision, design and construction. *Housing and Building National Research Center. 10*(1), 10-24. https://doi.org/10.1016/j.hbrcj.2013.06.001

Altay, N. and Green, G., W. (2006). OR/MS Research in disaster operations management. *European Journal of Operational Research, 175*(1), 475-493. https://doi.org/10.1016/j.ejor.2005.05.016

Balcik, B., & Beamon, B. M. (2008). Facility location in humanitarian relief. *International Journal of Logistics: Research and Applications*, *11*(2), 101-121. http://dx.doi.org/10.1080/13675560701561789

Brown, G.G., & Vassiliou, A.L. (1993). Optimizing disaster relief: real-time operational and tactical decision support. *Naval Research Logistics*, *40*, 1-23. https://doi.org/10.1002/1520-6750(199302)40:1%3C1::AID-NAV3220400102%3E3.0.CO;2-S

Cavdur, F., Sebatli-Saglam, A., Kose-Kucuk, M. (2020). A spreadsheet-based decision support tool for temporary-disaster-response facilities allocation. *Safety Science*, *124*(2020), 104581. https://doi.org/10.1016/j.ssci.2019.104581

Civil Contingencies Secretariat (2004). Civil Contingencies Act 2004: a short guide (revised). Cabinet Office. https://www.merseysideprepared.org.uk/media/1053/15mayshortguide.pdf

Çınar, A.K., Akgün, Y., and Maral, H. (2018). Afet sonrasi acil toplanma ve geçici barinma alanlarinin planlanmasindaki faktörlerin incelenmesi: Izmir-Karşıyaka örnegi [Analyzing the Ppanning criteria for emergency assembly points and temporary shelter areas: Case of İzmir-Karşıyaka]. *Planlama 28*(2):179–200. https://doi.org/10.14744/planlama.2018.07088

Efendioğlu, G., and Cenani, Ş. (2021). Deprem kaynaklı tsunami durumunda tahliye için karar destek sistemi önerisi: Kadıköy Caferağa ve Osmanağa Mahallelerinde vaka analizi. G. Çağdaş, M. Özkar, L. F. Gül, S. Alaçam, E. Gürer, S. Yazıcı, B. Delikanlı, Ö. Çavuş, S. Altun, & G. Kırdar (Editörler), *Mimarlıkta Sayısal Tasarım XV. Ulusal Sempozyumu* (sf.268-279). https://mstas2021.itu.edu.tr/sempozyum/bildiri-kitabi

Federal Emergency Management Agency. FEMA (2013). Livestock in Disasters. *Emergency Management in United States*. https://training.fema.gov/emiweb/downloads/is111_unit%204.pdf

Gerçek, D. & Güven, İ. T. (2016). Kentsel dirençliliğin Coğrafi Bilgi Sistemleri ile analizi: Deprem ve İzmit kenti [Analysis of urban resilience through Geographic Information Systems: Earthquake and izmit city]. *Harita Teknolojileri Elektronik Dergisi*, *8*(1), 51-64. https://doi.org/10.15659/hartek.16.04.298

Hobeika, A. G., Kim, S., and Beckwith, R. E. (1994). A decision support system for developing evacuation plans around nuclear power stations. Interfaces, 24(5), 22-35. https://doi.org/10.1287/inte.24.5.22

IPD Occupiers (2007). Efficiency Standards for Offices: A report to Office of Government Commerce, Investment Propoerty Databank Ltd. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjAsvyr3Jb6AhVlXvEDHaS6CMcQFnoECAMQAQ&url=http%3A%2F%2Ffiles.engineering.com%2Fdownload.aspx%3Ffolder%3Daed05c0a-827f-4d67-8b1a-7e8eb369487a%26file%3DEfficiency_Standards_for_Office_Space.pdf&usg=AOvVaw2f5pzRKhwWjMPogfeUMR2j

Jianshe, D., Shuning, W., and Xiaoyin, Y. (1994). Computerized support systems for emergency decision making. *Annals of Operations Research*. 51, 313–325. https://doi.org/10.1007/BF02048553

Kovács, G. and Spens, K.M. (2007). Humanitarian logistics in disaster relief operations. *International Journal of Physical Distribution & Logistics Management*, 37(2), 99-114. https://doi.org/10.1108/09600030710734820

Leiras, A., Brito, I.D., Peres, E.Q., Bertazzo, T.R., & Yoshizaki, H.T. (2014). Literature review of humanitarian logistics research: trends and challenges. *Journal of Humanitarian Logistics and Supply Chain Management*, 4(1), 95-130. https://doi.org/10.1108/JHLSCM-04-2012-0008.

Lopez-Fuentes, L., van de Weijer, J., González-Hidalgo, M. et al. (2018). Review on computer vision techniques in emergency situations. *Multimed Tools Appl*, 77, 17107. https://doi.org/10.1007/s11042-017-5276-7

Oksuz, M.K., & Satoglu, S.I. (2020). A two-stage stochastic model for location planning of temporary medical centers for disaster response. *International Journal of Disaster Risk Reduction*, 44, 101426. https://doi.org/10.1016/j.ijdrr.2019.101426

Rolland, E., Patterson, R.A., Ward, K. et al. (2010). Decision support for disaster management. *Operations Management Research*. 3, 68–79. https://doi.org/10.1007/s12063-010-0028-0

Thompson, S.A., Altay, N., Green, W.G., & Lapetina, J.E. (2006). Improving disaster response efforts with decision support systems. *International*

Journal of Emergency Management, 3(4), 250-263. https://doi.org/10.1504/IJEM.2006.011295

Tuğba Turğut, B., Taş, G., Herekoğlu, A., Tozan, H. and Vayvay, O. (2011). A fuzzy AHP based decision support system for disaster center location selection and a case study for Istanbul. *Disaster Prevention and Management*, 20(5), 499-520. https://doi.org/10.1108/09653561111178943

Savaş, S., Cenani, Ş., & Çağdaş, G. (2019). Selection of emergency assembly points: A case study for the expected Istanbul earthquake. In Y.I Topçu, Ö. Özaydın, Ö. Kabak, Ş, Önsel Ekici (eds), Multiple Criteria Decision Making (MCDM 2019). Contributions to Management Science Book Series (pp. 37–67). Springer. https://doi.org/10.1007/978-3-030-52406-7_2

United States Environmental Protection Agency (EPA). 2004. Space acquisition and planning guides. EPA Facilities Manual Vol. 1. https://www.epa.gov/sites/default/files/201509/documents/space_planning_508.pdf

Van de Walle, B., Turoff, M. (2008). Decision support for emergency situations. *Inf Syst E-Bus Manage* 6, 295–316. https://doi.org/10.1007/s10257-008-0087-z

Zhu, J., Huang, J., Liu, D., & Han, J. (2008). Resources Allocation Problem for Local Reserve Depots in Disaster Management Based on Scenario Analysis. https://www.semanticscholar.org/paper/Resources-Allocation-Problem-for-Local-Reserve-in-Zhu-Huang/1079a0a4a9896d8d2e68b779ceb09171c19c7898