



# A-GIS Based Risk Assessment Approach for Evaluating Shelters in Crisis Areas: Case of Idleb/Syria

Jamil Hallak<sup>1</sup>, Melik Koyuncu<sup>2</sup>, Pınar Özkurt<sup>3\*</sup>

<sup>1\*</sup> Dr Industrial Engineer, Gaziantep, Turkey (ORCID: 0000-0001-5975-4075), [jamil.hallak@southwales.ac.uk](mailto:jamil.hallak@southwales.ac.uk)

<sup>2</sup> Çukurova University, Faculty of Engineering, Department of Industrial Engineering, Adana, Turkey (ORCID: 0000-0003-0513-6276), [mkoyuncu@cu.edu.tr](mailto:mkoyuncu@cu.edu.tr)

<sup>3</sup> Tarsus University, Faculty of Economics and Administrative Sciences, Department of Management Information Systems, Tarsus, Turkey (ORCID: 0000-0002-9655-0319), [pinarozkurt@tarsus.edu.tr](mailto:pinarozkurt@tarsus.edu.tr)

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## Abstract

Millions of people escaped the country, and numerous individuals were displaced since the crisis in Syria started on March 15, 2011. Particularly, internally displaced persons confront troubles in the sense of shelter and housing requirements. The aim of this paper is to propose a new approach for risk assessment in selecting shelters at humanitarian context in crisis areas by employing real data from the region. We included conducting risk assessment in crisis areas, identifying the risks/criteria using the Delphi technique, prioritizing risks using Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP), and finally selecting the shelters with lower risk values. For this purpose, we created risk maps for each individual risk/criterion by employing the Geographic Information System (GIS) and merged the risks' maps into a single final risk map by overlaying them utilizing the weights produced from F-AHP to discover the complete risk value for each area in the study region. Lastly, we extracted and ranked the final risk values for the shelters to enable the decision maker to consider the lower-risk value shelters, as it can aid in expediting and facilitating the housing solutions at times of disasters and crisis.

**Keywords:** Syria Crisis, Risk Assessment, Delphi Technique, Shelter, IT2F-AHP (Interval Type-2 Fuzzy Analytic Hierarchy Process), Geographic Information System (GIS).

## Kriz Alanlarında Sığınakları Değerlendirmek için CBS'ye Dayalı Bir Risk Değerlendirme Yaklaşımı: İdlib/Suriye'de Uygulama

### Öz

Suriye'deki kriz 15 Mart 2011'de başladığından beri milyonlarca insan ülkeden kaçmıştır ve çok sayıda birey yerlerini değiştirmiştir. Özellikle, ülke içinde göç etmek zorunda kalmış insanlar sığınak ve barınma açısından zorluklarla karşılaşmaktadır. Bu çalışmanın amacı, bölgeden gerçek veriyi kullanarak, kriz alanlarında insani yardım kapsamında sığınakları seçmenin risk değerlendirmesi için yeni bir yaklaşım önermektir. Çalışmaya; kriz alanlarında risk değerlendirmesi yürütme, Delphi tekniği ile riskleri/kriterleri belirleme, Aralık Tip-2 Bulanık Analitik Hiyerarşi Prosesi (IT2F-AHP) kullanarak riskleri önceliklendirme ve son olarak düşük risk değerlerine sahip sığınakları seçme dâhil edilmiştir. Bu amaçla, Coğrafi Bilgi Sistemi'ni (CBS) kullanarak her risk/kriter için risk haritaları oluşturulmuştur ve çalışma bölgesindeki her alanın son risk değerini bulmak için, Bulanık AHP'den elde edilen ağırlıklardan faydalanarak ve risk haritaları örtüştürülerek tek bir nihai risk haritasına dönüştürülmüştür. Son olarak, afet ve kriz zamanlarındaki barınma çözümlerini kolaylaştırabileceği ve hızlandırabileceğinden dolayı, karar vericinin düşük risk değerli sığınakları göz önünde bulundurmasını sağlamak için, sığınakların nihai risk değerleri bulunmuş ve sığınaklar sıralanmıştır.

**Anahtar Kelimeler:** Suriye Krizi, Risk Değerlendirme, Delphi Tekniği, Sığınak, Aralık Tip-2 Bulanık Analitik Hiyerarşi Prosesi, Coğrafi Bilgi Sistemi (CBS).

\* Corresponding Author: [pinarozkurt@tarsus.edu.tr](mailto:pinarozkurt@tarsus.edu.tr)

## 1. Introduction

An individual or a group of individuals, who have been compelled or obligated to run away or set off their homes/rooted locations, particularly in consequence of or on the purpose of refraining from the harmful impacts of armed conflict, circumstances of generalised brutality, disregards of human rights, natural or artificial disasters, and have not crossed over an internationally recognised border, are termed as “internally displaced people” (IDPs) (Inee Toolkit, 2019). According to United Nations High Commissioner for Refugees (UNHCR), the estimated number of IDPs worldwide is approximately 36 million at present, and approximately 3 million of these individuals are looking for asylums. Of the 36 million IDPs, about 16% belong to Syria only. These numbers are increasing every twenty minutes due to ongoing wars in several countries. The grim reality about IDPs is that it is difficult to reach them, and unfortunately, they are not preserved by a specific status (Bilak et al., 2015). As a result of these circumstances, IDPs are among the most defenseless people in the world today (UNHCR, 2019). Since they lack education in a land with cultural and religious diversities, their living conditions are caustic. Hence, they encounter considerable obstacles to fulfil their needs, just as accession to foodstuffs, water, shelter, and health services. Furthermore, mortality rate in complicated emergencies is estimated to be the highest among IDPs when in comparison with those among the occupants or migrants with refugee status (Heudtlass et al., 2016).

As Syria hosts more than 15% of IDPs worldwide, this subject requires a considerable emphasis. The reason for higher number of IDPs in Syria is the Syrian Crisis, which started out on March 2011 at Daraa city in the southwestern part of the country. It is considered one of the most complicated and dynamical humanitarian crisis in the world. The spread and intensification of conflicts has led to a dire humanitarian crisis with approximately 6.3 million IDPs and approximately 4.5 million people live in hard-to-reach and encircled regions, as pointed out by the UNHCR. Over half of the citizens has been forced to leave their houses, and many individuals have been moved several times. Furthermore, children and young person constitute more than half of the displaced people. Ongoing conflicts; which render the settlements, hospitals, and trade centers dysfunctional, are the fundamental reasons of internal migration. Of the 6.3 million IDPs in all Syrian governorates; 908,929 IDPs belong to the Idleb governorate, which represents approximately 15% of the total number of IDPs and this situation is ranked to be the second after Rural Damascus.

Thus, Idleb governorate plays a significant role in the current situation. Before conducting studies to devise permanent solutions for this humanitarian situation, obtaining real data by analyzing the region’s circumstances is of capital importance.

However, to best of our knowledge, there is no systematic statistics that contains the real data about target areas in crisis regions, such as Idleb/Syria. Therefore, in the

light of all the factors discussed so far, the objective of this study is to handle one of the crisis area’s survival problems using the risk assessment aspect from the humanitarian perspective and bridging the gaps in the related subject by serving as an effective source for similar problems. We focused on determining shelters in Idleb based on the risk factors. For this purpose, we presented a novel method that ranks all the candidate shelters according to their risk value using a Geographic Information System (GIS) - based risk assessment. For the risk evaluation, we utilized the Delphi method to discover the potential risks in an ongoing conflict area and then prioritized the risks by applying a Fuzzy Analytic Hierarchy Process (F-AHP). For identifying the risks, we collected the real data from the specific area using beneficiaries and direct stakeholders. The data obtained are projected in GIS as geographic layers and all the identified risks are merged in the final layer to procure the final risk map. The method constituted the shelter risk ranking, which aided us in determining the shelters based on their final risk values. These points are the motive that makes this study valuable contribution in determining the available shelters for IDPs in the conflict area. To this end, our contributions, compared to existing literature can be summarized as indicated below:

- First of all, the proposed approach provides a beneficial procedure to decision makers for assaying and selecting the shelters based on risk assessment.
- Secondly, the proposed approach is applicable in crisis areas for obtaining the best possible solutions from a humanitarian perspective and providing solutions for IDPs’ housing issues.
- Thirdly, it depicts the possibility of analyzing a multi-criteria decision-making methodology with GIS techniques using real-time data and fuzzy logic.
- Last but not the least, the proposed approach can be used by any institution or authority in conflict contexts.

The remaining of this paper is organised in this way: in the Section 2, we represent a literature review with a short summary of the related studies; in Section 3, we propose the risk assessment approach employed in this study; Section 4 demonstrates the case study results with risk maps generated by the GIS and finally Section 5 summarizes the discussions about this study and presents suggestions for further studies.

## 2. Literature Review

In this study, we handle a risk assessment approach with GIS for shelter location problem. In literature, we encountered various aspects which indicated that none of the studies matched our topic entirely. Several studies suggested risk assessment approaches in conflict areas (Mock et al., 2004; Burnley et al., 2008; Yu and Lee, 2012). While one of the studies proposed a systematic approach to conduct a domestic armed conflict risk assessment in any part of the world by constructing a statistical model (Burnley et al., 2008; another presented a framework for risk assessment with the aim of preventing the human immunodeficiency

virus in conflict-affected surroundings in Africa (Mock et al., 2004). Yu and Lee (2012) concentrated on an urban reformation project and organized a conflict-risk evaluation model based on Fuzzy Failure Mode and Effect Analysis (Fuzzy-FMEA).

However, any study did not address risk assessment via GIS in a conflict area. Particularly in humanitarian areas, it is not sufficient to only optimize the shelter's locations to include as many individuals as possible; it is also important to ensure that the risks in these shelters are relatively low. This enables the process of selecting the available shelters with lower risk levels and alleviating the misery of IDPs within that specific crisis area. At this point, Geographic

Information System (GIS) can handle and analyze large scale spatial data efficiently (Zhang et al., 2017; Çeliker et al., 2019; Karimi et al., 2019).

Therefore, the GIS platform, which is a valuable resource for such studies, is required to project all the risk values and criteria corresponding to the target area on maps, analyze all the risk criteria, and then extract the output values from maps to each of the candidate shelters. It is observed that the GIS is applied widely in literature for humanitarian solutions for risk assessment. The summary of GIS-based Risk Assessment Studies containing utilized approach and problem area are presented by Table 1 below.

Table 1. Summary of GIS-Based Risk Assessment Studies

| Author(s)                  | Approach  | Problem Area  |
|----------------------------|---|---|
| Huabin et al. (2005)       | GIS Based Landslide Hazard Assessment                                       | The state of the art of landslide hazard evaluation focusing GIS-based techniques                           |
| Abdalla et al. (2006)      | GIS, Digital Evaluation Model (DEM), Digital Terrain Model (DTM)            | Evaluating flood risk of the Qu'Appelle River, Southern Saskatchewan, Canada                                |
| Fedeski and Gwiliam (2007) | GIS, Vulnerability Index  | Developing a risk assessment methodology for flood and geological hazards and applying in Lewes, Sussex, UK |
| Wang et al. (2011)         | GIS, Spatial Multi Criteria Decision Analysis (SMCA)                        | Flood Risk Evaluation in the Dongting Lake Region, China  |
| Beni et al. (2012)         | GIS, Spatio-Temporal Analysis   | Assessing food safety risks in Canadian food distribution organizations                                     |
| Uddin et al. (2013)        | GIS, Remote Sensing   | Identifying flood hazard zones and flood shelters in Sindh Province, Pakistan                               |
| Alcorn et al. (2013)       | GIS, Multi-Criteria Evaluation  | Volcanic hazard and risk evaluation of eruptions in Valles Caldera, New Mexico, USA                         |
| Abdalla et al. (2014)      | GIS, Three-Dimensional Fuzzy Risk Assessment, Hydro, Statistical Simulation | Measuring the flood risk evaluation at the Red River in Southern Manitoba, Canada                           |
| Sarkar et al. (2016)       | GIS, Remote Sensing, Fuzzy-based Risk Assessment Model (FRAM)               | Specifying the areas with varying intensity of wetland conversion risk in East Kolkata Wetland Area, India  |
| Aye et al. (2016)          | GIS, Web Based Tool   | Analyzing the impacts and consequences of a certain hazard event in the Fella River basin, Italy            |
| Çankaya et al. (2016)      | GIS, Multi-Criteria Decision Analysis, AHP                                  | Tsunami risk evaluation in Yenikapı, İstanbul, Turkey   |
| Zhao and Liu (2016)        | GIS, Regional Risk Assessment   | Evaluating regional urban major hazards in urban district of northern China                                 |
| Chen et al. (2017)         | GIS, Disaster Risk Analysis   | Urban emergency shelter system for natural disasters in Guangzhou, China                                    |
| Şentürk and Erener (2017)  | GIS, Multi Criteria Analysis, AHP   | Determining temporary shelter areas in natural disasters for Gölçük, Turkey                                 |
| Al-Awadhi et al. (2018)    | GIS, Flood Hazard Maps  | Assessing flooding risk analysis for Muscat, Sultanate of Oman  |
| Isahak et al. (2018)       | GIS, Flood Disaster Risk Map  | Delineating risk zones and evaluating shelter centers for Pahang River, Malaysia                            |
| Rincon et al. (2018)       | GIS, Multi Criteria Analysis (AHP)  | Developing updated and accurate flood risk maps in Greater Toronto Area, Canada                             |
| Chen et al. (2018)         | GIS, Spatial Distribution   | Selecting urban resources and allocating for emergency shelters in Guangzhou, China                         |
| Repetto et al. (2018)      | GIS, Web Based Platform   | Assessing complex structural and infrastructural systems' risk for wind exposure                            |
| Sahoo and Bhaskaran (2018) | GIS, Multi Hazard Risk Assessment   | Risk assessment of coastal vulnerability from typical cyclones in Odisha coast, India                       |

|                          |   |   |
|--------------------------|---|---|
| Lyu et al. (2018)        | GIS, AHP, Interval AHP (I-AHP)                            | Flood risk assessment in the Guangzhou metro system, China  |
| Pence et al. (2019)      | GIS, Level 3 Probabilistic Risk Assessment (PRA)          | Advancing emergency preparedness, planning, and response for severe nuclear power plant accidents in Surry Power Station, USA |
| Cai et al. (2019)        | GIS, Multi-Index Fuzzy Comprehensive Evaluation Model     | Analyzing flood disaster risk in the urban area of Yifeng, Jiangxi Province, China.   |
| Eccles et al. (2019)     | GIS, Spatial Analysis                                     | Evaluating spatial ecological risk in Athabasca Oil Sands Area, Canada  |
| Zhang et al. (2019)      | GIS, Hazards that Create Risk                             | Increasing tsunami shelter accessibility in Nagoya city, Japan  |
| Benguerai et al. (2019)  | GIS, Remote Sensing                                       | Forest fire risk assessment in Northwest Algeria  |
| Shalyari et al. (2019)   | GIS, Monte Carlo Simulation                               | Health risk evaluation of nitrate in groundwater resources of Iranshahr, Iran   |
| Gallego et al. (2019)    | GIS, PROMETHEE, AHP                                       | Risk assessment for livestock production in Valencian Community (VC), Spain   |
| Skilodimou et al. (2019) | GIS, Multi-Criteria Analysis, AHP                         | Multi hazard assessment for natural hazards in Peneus (Pinios) River, Greece  |
| Gao et al. (2019)        | GIS, AHP, Fuzzy Theory, Pollutant Diffusion Model         | Regional water ecosystem risk assessment in Shenzhen eco-industrial park, China   |
| Hawchar et al. (2020)    | GIS, High Level Risk Analysis                             | Assessing climate change risk of critical infrastructure in Ireland   |
| Yariyan et al. (2020)    | GIS, Fuzzy AHP, Artificial Neural Networks                | Evaluating the extent of earthquake vulnerability in Sanandaj, Iran   |
| Hadipour et al. (2020)   | GIS, Spatial Multi-Criteria Decision Analysis (SMCA), AHP | Providing a coastal flood risk assessment approach and implementation in Bandar Abbas City, Iran                              |
| Zhang et al. (2020)      | GIS, Spatial Multi-Index Model                            | Flood risk assessment in the Yangtze River Basin, China   |
| Ak et al. (2020)         | GIS, Spatial Decision Support System (SDSS)               | Analyzing hazardous materials transportation risk in Istanbul, Turkey   |
| Török et al. (2020)      | GIS, Risk Based Quantitative Approach                     | Evaluating territorial compatibility for Seveso-type sites in Oltchim Chemical Plant, Romania                                 |
| Psomiadis et al. (2020)  | GIS Based Multi Criteria Analysis, AHP                    | Landslide susceptibility and risk evaluation in the Basin of the Sperchios River, Greece                                      |

As seen from Table 1, the framework of GIS-based risk assessment studies varies. For example, while some studies focused on climate change risk assessment (Hawchar et al., 2020), ecological risk assessment (Eccles et al., 2019) or food safety risk assessment (Beni et al., 2012); some papers handled the related topic for natural disasters. In this context, some studies concentrated on multiple disasters (Chen et al., 2017; Chen et al., 2018); however, there are risk assessment researches on earthquake (Yariyan et al., 2020), fire (Benguerai et al., 2019), landslide (Huabin et al., 2005; Aye et al., 2016; Psomiadis et al., 2020), tropical cyclone (Sahoo and Bhaskaran, 2018), tsunami (Çankaya et al., 2016) and volcanic hazard (Alcorn et al., 2013). Still, it is observed that majority of existing studies concentrated on utilizing GIS for flood risk assessment (Abdalla et al., 2006; Fedeski and Gwilliam, 2007; Wang et al., 2011; Uddin et al., 2013; Abdalla et al., 2014; Aye et al., 2016; Al-Awadhi et al., 2018; Isahak et al., 2018; Rincón et al., 2018; Lyu et al., 2018; Cai et al., 2019; Hadipour et al., 2020; Zhang et al., 2020).

However, to the best of our knowledge, six of the studies integrated GIS and risk assessment to resolve the shelter issues (Uddin et al., 2013; Chen et al., 2017; Şentürk and Erener, 2017; Isahak et al., 2018; Chen et al., 2018; Zhang et

al., 2019) (Table 1). But, application of these studies was limited to natural disasters.

Therefore, this study is motivated by the fact that it is important to determine shelter locations, particularly in conflict areas, based on the risk factors related to the conflict. As indicated by the literature review, no studies have addressed the shelter locations in crisis areas by integrating the risk assessment process from the humanitarian perspective. Other distinguishing features of this study are the introduction of a novel approach based on GIS and application of the Delphi method and F-AHP for determining the possible risks and prioritizing the related risks, respectively.

### 3. Material and Method

#### 3.1. Risk Assessment Approach

In this section, we present a risk assessment approach starting from collecting the related data to calculating the risk parameters for identifying the final risk for each shelter. Figure 1 presents the approach proposed in this study for assessing the risks in the targeted area and choosing the shelter locations based on it. As shown in Figure 1, the



proposed approach was primarily based on risk assessment in the conflict areas using: Delphi technique to identify the criteria according to the beneficiaries lived in the affected area; Interval Type-2 Fuzzy AHP to handle uncertainty while calculating the weights of each criteria (since we are utilizing opinions and words which mean different evaluations/values to different experts) and GIS to draw the related maps to each criterion and overlapping all maps to find out the final risk map. The proposed approach included six basic stages (Figure 1):

1. *Collecting Data:* A needs assessment was conducted using surveys and interviews to assess the needs and understand the context in the study region with respect to considered factors, criteria, and related risks from the perspectives of direct beneficiaries and local authorities. The data about Idleb were drawn from direct beneficiaries and key informants across all 26 sub-districts in the Idleb governorate. For this case study, relevant data were collected between January 03, 2019 and March 22, 2019.

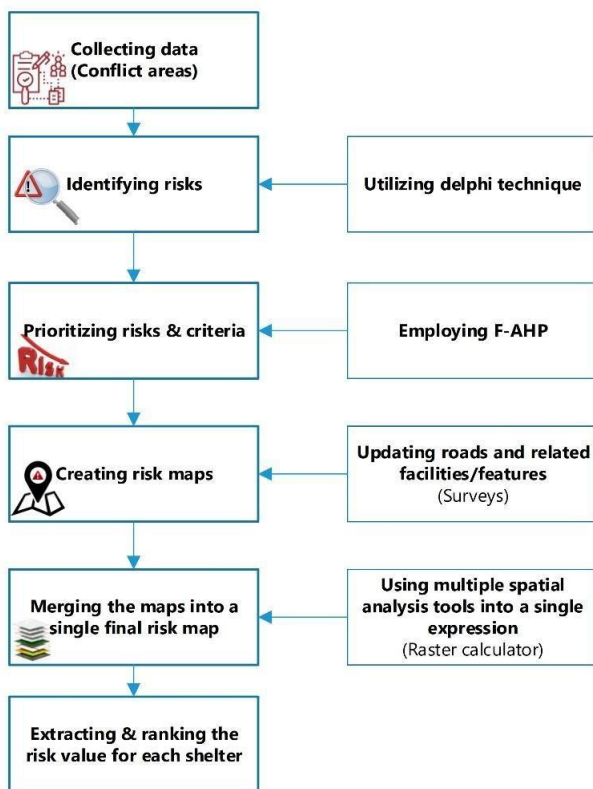


Figure 1. Flowchart of the Proposed Methodology

2. *Identifying Risks Using the Delphi Technique:* All of the decision makers do not live in the same location and therefore, they possess various points of view about the topic. However, it is essential to achieve a consensus on the identification of risks related to determining the shelters. Due to the previous reasons and to allow experts express their views and opinions in an individual and anonymous way and to access other experts' views as the process, the Delphi

technique is utilized. By this tool, we combine 3 dedicated expert's opinions from different areas and contexts to help and influence the identification. It is a collaborative method for building consensus between specialists and includes independent investigation and voting by the specialists. Throughout this tool, every expert can define the risks without the effect of other experts on his/her opinion.

In this paper we have two types of criteria; the first one is crisp/non-spatial criteria which is determined by crisp value and not related to spatial data such as the cost and number of IDPs. The second type is spatial criteria which is related to the spatial data such as the closeness from frontlines or main roads.

We deal with these two types from the risk perspective and we handle the crisp type as a risk for example the higher cost corresponds to the higher risk and the lower cost corresponds to the lower risk. Then we reflect this information on the map to study all criteria from the maps perspective and solve the problem by the GIS tool to facilitate the process of selecting shelters in such a crisis context for the people in the area; instead of utilizing high-advance mathematical software which is not available right now for local authorities in the crisis area.

As a result, criteria/risks are defined in the study and categorized as described in Figure 2.

3. *Prioritizing Risks and Criteria Using Interval Type-2 Fuzzy AHP:* In this stage, the risks/criteria were arranged in a hierarchical structure and evaluated by the 3 dedicated experts from various points of view. The relative importance of each criterion was determined using linguistic variables and the uncertainty was obtained by presenting interval type-2 trapezoidal membership function.

4. *Creating Risk Maps:* After updating/collecting the related spatial data for each risk identified in Stage (2), the maps were generated for each criterion/risk as below:

- Building and updating the roads network using GIS;
- Facility locations, for instance schools and hospitals, to classify the study region according to the real distance from these facilities;
- Features of shelters, such as the capacity and setup costs.

A risk map was created by classifying the areas, which demonstrate the areas from the lower risk throughout the high-risk areas. Each identified risk is classified under one of the six classes according to experts (on a scale of 1–6 with 1 being/having the lowest risk and 6 being/having the highest risk). As shown in Figure 2, the risks are divided under three categories: (i) Criteria that affect the implementation of humanitarian actors as these actors/organizations conduct projects in the crisis area, the risks need to be analyzed from their perspectives. (ii) Criteria affecting the civilian population, as they have been

suffering from the crisis more than eight years and are the direct beneficiaries. (iii) Criteria that affect the both categories (i) and (ii).

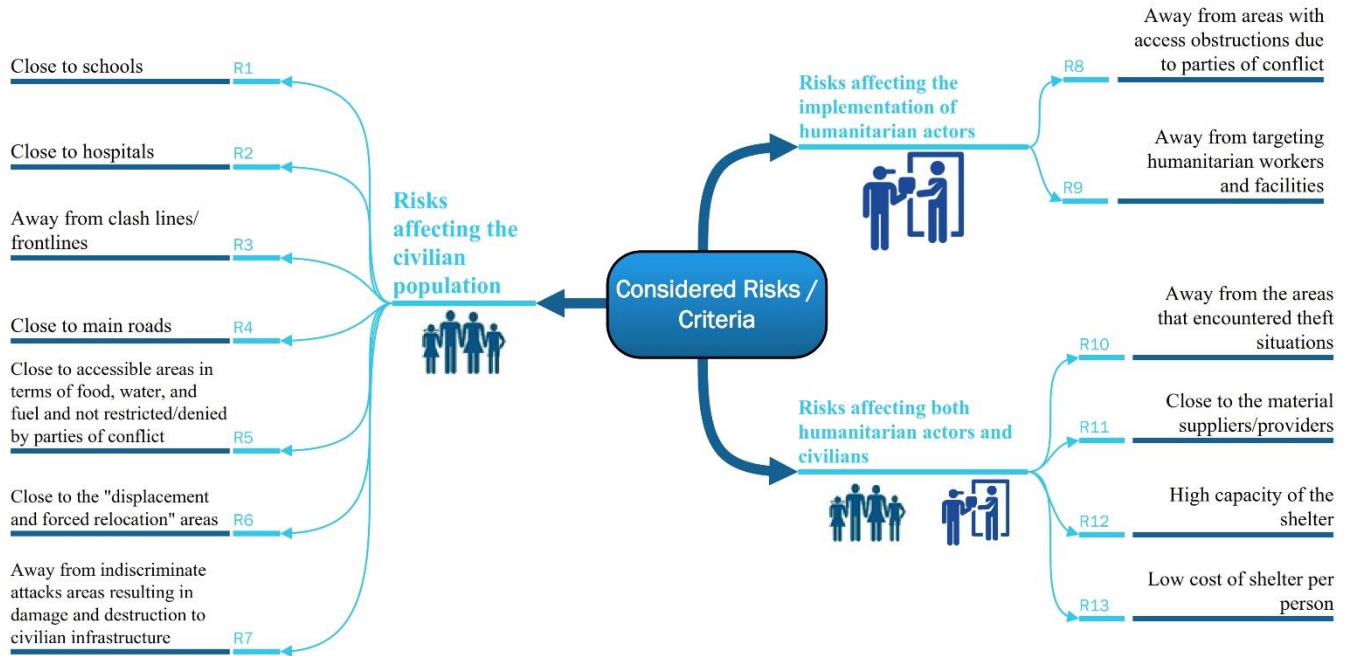


Figure 2. Risks and Categories Utilized in the Study

**5. Merging the Risks Maps into a Single Final Risk Map:** After building different risk maps, a single final risk map was created by overlaying maps using the weights calculated in Stage (3) to find out the complete risk value of each area in the study location. Equation (1) below is used to compute the final risk value by multiplying each risk/criteria weight by the respective risk value and then obtaining the sum of the all of the products calculated. This was performed using the GIS package (ArcMap 10.4.1).

$$FRV = \sum_{n \in N} RW_n RV_n \quad (1)$$

where N is the set of risk map/layer ( $n \in N$ ), FRV is the final risk value, RW is the risk weight calculated using the IT2F-AHP, and RV is the risk value of each criterion in the area.

**6. Extracting and Ranking the Final Risk Value for Shelters:** In this stage, we extracted the final risk value for each shelter in the area according to the shelter's location in the final risk map obtained from Stage (5). Then, we ranked them ascendingly from low to high-risk values to enable the decision makers to consider the shelters with lower-risk values.

**3.2. Prioritizing Risks Using Fuzzy Analytical Hierarchy Process (F-AHP)**

Using Interval Type-2 Fuzzy AHP, the goal and criteria were arranged in a hierarchical structure and evaluated by experts. The comparative importance of each criterion was specified using linguistic variables, which were represented as trapezoidal interval type-2 fuzzy scales as shown in Figure 3 where for linguistic variable there is upper trapezoidal membership function (-U) and Lower trapezoidal membership function (-L). In this study, The Defuzzified Triangular Type-2 Fuzzy Set (DTTrT) method (Kahraman et al., 2014) is utilized to convert the fuzzy evaluations into their corresponding crisp values.

A 5-point scale was utilized to describe the relative significance of criterion with regard to the others as summarized in Table 2 and graphically in Figure 3.

Fuzzy comparison matrix  $\tilde{A}$  representing the fuzzy relative importance of each pair elements is defined by Equations (2) and (3) below (Öztayşi, 2015):

Table 2. Interval Type-2 Fuzzy Scales for Pairwise Comparison (Öztayşi, 2015)

| Linguistic variables   | Trapezoidal Interval Type-2 fuzzy scales |
|------------------------|--|
| Absolutely Strong (AS) | (7,8,9,9;1,1) (7.2,8.2,8.8,9;0.8,0.8)    |
| Very Strong (VS)       | (5,6,8,9;1,1) (5.2,6.2,7.8,8.8;0.8,0.8)  |
| Fairly Strong (FS)     | (3,4,6,7;1,1) (3.2,4.2,5.8,6.8;0.8,0.8)  |
| Slightly Strong (SS)   | (1,2,4,5;1,1) (1.2,2.2,3.8,4.8;0.8,0.8)  |
| Exactly Equal (E)      | (1,1,1,1;1,1) (1,1,1,1;1,1)              |

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \dots & 1 \end{bmatrix} \quad (2)$$

$$1/\tilde{a}_{12} = \left[ \left[ \frac{1}{a_{14}^U}, \frac{1}{a_{13}^U}, \frac{1}{a_{12}^U}, \frac{1}{a_{11}^U} ; H_1(a_{12}^U), H_2(a_{13}^U) \right], \left[ \frac{1}{a_{24}^L}, \frac{1}{a_{23}^L}, \frac{1}{a_{22}^L}, \frac{1}{a_{21}^L} ; H_1(a_{22}^L), H_2(a_{23}^L) \right] \right] \quad (3)$$

The geometric mean method is applied to get the fuzzy geometric mean  $\tilde{r}_i$  with Equation 4 given below (Öztayşi, 2015):

$$\tilde{r}_i = (\tilde{a}_{i2} \times \tilde{a}_{i3} \times \dots \times \tilde{a}_{in})^{\frac{1}{n}} \quad (4)$$

The fuzzy weight  $\tilde{w}_i$  of the  $i$ .th criterion is computed with Equation 5 given below (Öztayşi, 2015):

$$\tilde{w}_i = \tilde{r}_i \times (\tilde{r}_1 + \tilde{r}_2 + \dots + \tilde{r}_n)^{-1} \quad (5)$$

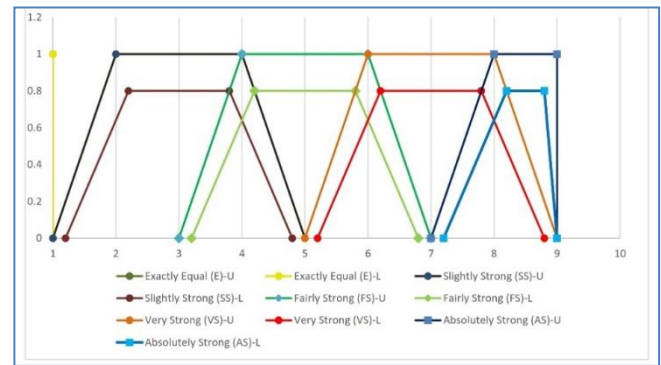


Figure 3. Fuzzified Scale Type 2 for Pairwise Comparison

Table 3 lists the weights obtained using interval type-2 fuzzy AHP in this paper which shows risks criteria are prioritized and ranked from 1 to 13.

Table 3. Weights Obtained from Interval Type-2 Fuzzy AHP

| Risk No. | Fuzzy Weights $\tilde{w}_i$                             | Normalized Weight (NW) | Risk Ranking (From 1 to 13) |
|----------|---|------------------------|-----------------------------|
| R1       | (0.11,0.17,0.32,0.45;1,1) (0.12,0.18,0.3,0.42;0.8,0.8)  | 0.02                   | 10                          |
| R2       | (0.09,0.14,0.27,0.39;1,1) (0.1,0.15,0.25,0.36;0.8,0.8)  | 0.03                   | 9                           |
| R3       | (0.07,0.1,0.21,0.33;1,1) (0.07,0.11,0.2,0.3;0.8,0.8)    | 0.22                   | 1                           |
| R4       | (0.05,0.08,0.16,0.26;1,1) (0.06,0.09,0.15,0.23;0.8,0.8) | 0.01                   | 13                          |
| R5       | (0.04,0.06,0.12,0.2;1,1) (0.04,0.06,0.11,0.18;0.8,0.8)  | 0.09                   | 5                           |
| R6       | (0.03,0.05,0.1,0.16;1,1) (0.04,0.05,0.09,0.14;0.8,0.8)  | 0.07                   | 6                           |
| R7       | (0.02,0.03,0.07,0.11;1,1) (0.02,0.04,0.06,0.1;0.8,0.8)  | 0.05                   | 7                           |
| R8       | (0.02,0.02,0.05,0.08;1,1) (0.02,0.03,0.04,0.07;0.8,0.8) | 0.15                   | 3                           |
| R9       | (0.01,0.02,0.04,0.07;1,1) (0.01,0.02,0.04,0.06;0.8,0.8) | 0.19                   | 2                           |
| R10      | (0.01,0.01,0.03,0.04;1,1) (0.01,0.01,0.03,0.04;0.8,0.8) | 0.03                   | 8                           |
| R11      | (0.01,0.01,0.02,0.03;1,1) (0.01,0.01,0.02,0.03;0.8,0.8) | 0.01                   | 12                          |
| R12      | (0.01,0.01,0.01,0.02;1,1) (0.01,0.01,0.01,0.02;0.8,0.8) | 0.01                   | 11                          |
| R13      | (0,0.01,0.01,0.01;1,1) (0,0.01,0.01,0.01;0.8,0.8)       | 0.12                   | 4                           |

## 4. Case Study and Results

### 4.1. Case Study

We have applied proposed methodology to a crisis area in Idleb, Syria for our case study since this area contains the highest number of IDPs in need to shelter housing solutions. This is carried on by applying the methodology defined in the Material and Method Section.

The Idleb governorate is located in the northwest of Syria and has a border with Turkey. Its total size is 6,097 km<sup>2</sup> and has approximately 1,464,000 person (this number is 2010 prediction, because due to ongoing crisis in the country, there is not any updated population prediction).

In the preparation process of this study, an evaluation is performed in the study region. Within this evaluation, our aim was specifying and assessing the condition of shelters, IDPs, and

related factors in the target area. Figure 4 demonstrates the pattern of IDPs and nominee shelters corresponding to the location-allocation problem addressed in this study.

The data about the study area's characteristics, such as the capacity, costs of setup, and IDPs are collected by conducting surveys and interviews in coordination with the authorities in the area (local councils and civil community organizations). A total of 331 nodes are incorporated in the study. Moreover, 51 nominee shelters with varied capacities, costs, and distances from the frontlines/clashes, hospital, and schools are also taken into consideration for the study.

Authorities in the region are facing so many difficulties in terms of finding the most suitable candidate shelters to allow the most vulnerable IDPs who are living in random cluster of makeshifts, cramped tents to move to those selected shelters which have better circumstances (built by concrete/bricks and contain an operating kitchen, bathroom) to improve their lives, give them privacy and dignity. Before this approach, the selection of shelters and IDPs was utilized by a non-systemically

approach, according to decision of local authorizes and sometimes without any transparency to beneficiaries in the area.

Thus, in this study, each service facility, such as a school, hospital or shelter is determined by its longitude and latitude. Afterwards, a road network dataset is built and definitions of the classes of area according to the distance from this service facility are realized. For instance, Class 1 defined the area within a distance of 1 km from the school, and Class 2 defined the area within a distance of 2 km from the school. This definition is continued until the distance between the area and service facility was higher than 10 km. All the classes corresponding to each criterion are listed in Table 4. These definitions were obtained based on the interviews/surveys with experts and key stakeholders in each field. This approach provided the desired values to be used in the classification of each risk/criterion. In this process, the experts and key stakeholder agreed on making 6 categories to classifying the risks in humanitarian context. We employed the Natural Break (Jenks) classification method for this purpose.

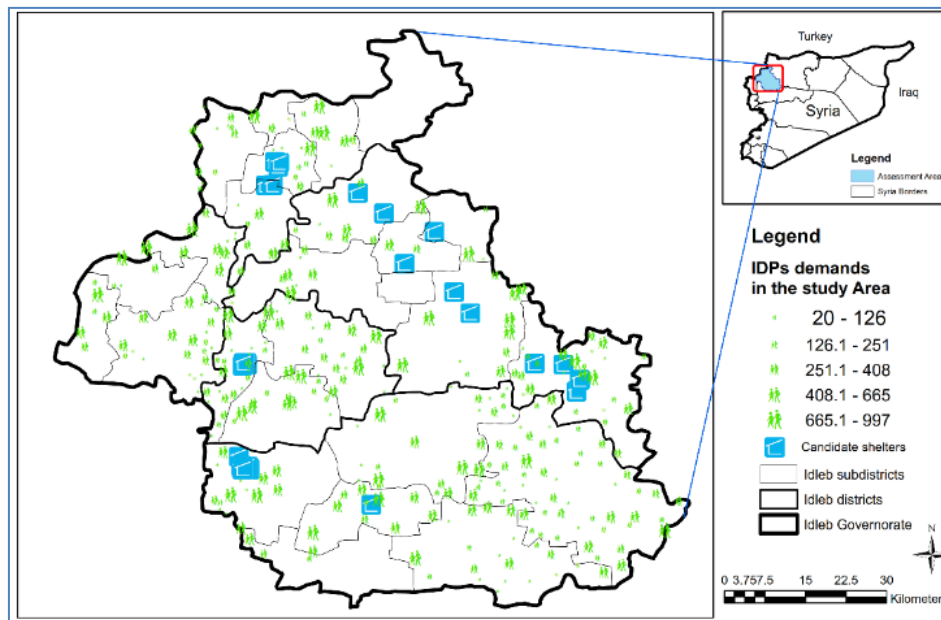


Figure 4. Overview About Displacement and Candidate Shelters in Idlib, Syria

Table 4. Risk Classifications for Each Identified Risk in the Study

| Risk No. | Risk classification   |
|----------|---|
|          | <b>6 classes: from class 1 (low risk) through class 6 (high risk)</b>   |
| R1       | 1 - low risk: Located within a region of 5 km from schools<br>6 - high risk: Located in a region 10 km away from schools  |
| R2       | 1 - low risk: Located within a region of 5 km from hospitals<br>6 - high risk: Located in a region 50 km away hospitals   |
| R3       | 1 - low risk: Located within a region of 5 km from frontlines<br>6 - high risk: Located in a region 10 km away from frontlines  |
| R4       | 1 - low risk: Located within a region of 5 km from main roads<br>6 - high risk: Located in a region 10 km away from main roads  |
| R5       | 1 - low risk: fully accessible<br>6 - high risk: fully besieged   |
| R6       | 1 - low risk: number of IDPs is more than 7824/km <sup>2</sup> in the area surveyed<br>6 - high risk: number of IDPs is less than 1505/km <sup>2</sup> in the area surveyed |



|     |   |
|-----|---|
| R7  | 1 - low risk: no incident reports were issued about indiscriminate attacks during the last year in the area surveyed<br>6 - high risk: more than 10 incident reports were issued about indiscriminate attacks during the last year in the area surveyed   |
| R8  | 1 - low risk: no incident reports were issued about access obstructions during the last year in the area surveyed<br>6 - high risk: more than 10 incident reports were issued about access obstructions during the last year in the area surveyed   |
| R9  | 1 - low risk: no incident reports were issued about targeting humanitarian workers and facilities during the last year in the area surveyed<br>6 - high risk: more than 10 incident reports were issued about targeting humanitarian workers and facilities during the last year in the area surveyed |
| R10 | 1 - low risk: no incident reports were issued about areas encountered theft situations during the last year in the area surveyed<br>6 - high risk: more than 10 incident reports were issued about areas encountered theft situations during the last year in the area surveyed                       |
| R11 | 1 - low risk: Located within a region of 5 km from vendors' locations<br>6 - high risk: Located in a region 50 km away from vendors' locations  |
| R12 | 1 - low risk: shelter capacity is within 679–989 individuals<br>6 - high risk: shelter capacity is within 40–90 individuals   |
| R13 | 1 - low risk: setup costs of 22–34 \$/person in the candidate shelter<br>6 - high risk: setup costs 94.1–135 \$/person in the candidate shelter   |

Figure 5, 6, 7, 8 below show the top four prioritized risks according to IT2F-AHP results obtained from Table 3. These risk maps can be described respectively as follows: away from

clash lines; away from the area that targets humanitarian workers; away from access obstructions by parties of conflict and shelters' setup costs [\$/person].

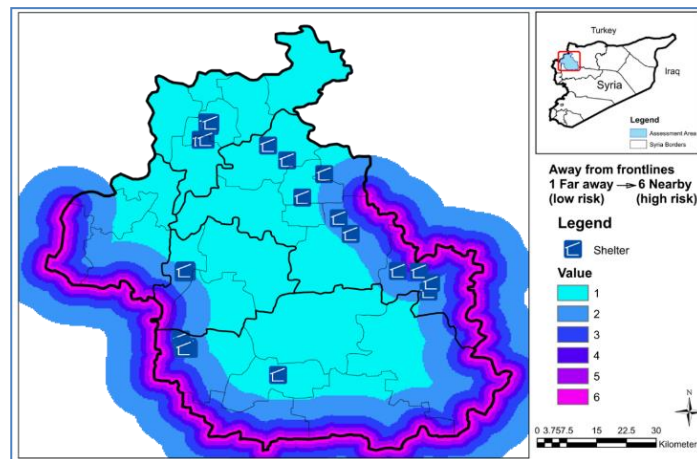


Figure 5. Risk Map: Away from Clash Lines/Frontlines in Idleb, Syria

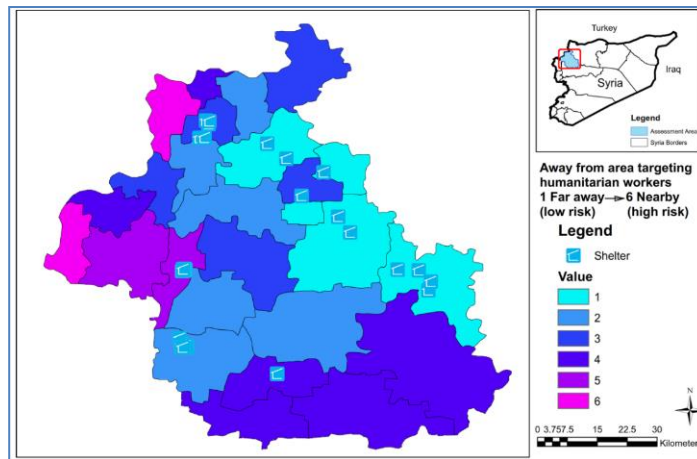


Figure 6. Risk Map: Away from the Area Targeting Humanitarian Workers

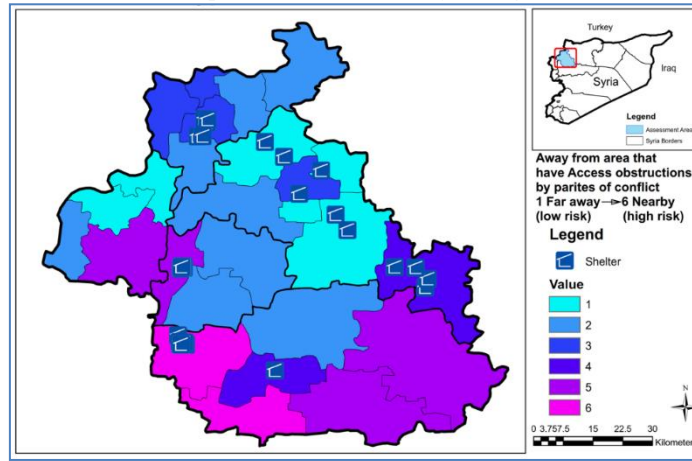


Figure 7. Risk Map: Obstructions by Parties of Conflict

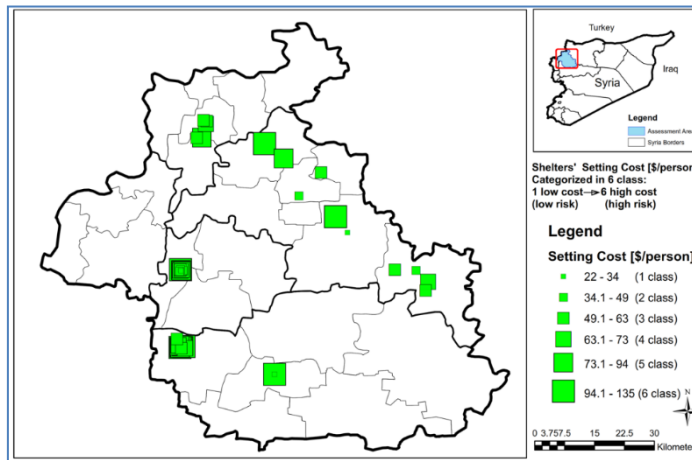


Figure 8. Risk Map: Shelters' Setup Costs

The other risks according to their risk rankings are included in Appendix1: accessibility to food, water, and fuel; proximity to displacement and forced relocation areas; indiscriminate attacks resulting in damage and destruction; away from the areas of theft; proximity to hospitals, proximity to schools, shelters' capacity [persons], proximity to venders/suppliers; and proximity to main roads that serves the area.

## 4.2. Results

In this section we considered the risk weight in each criterion utilizing the IT2F-AHP as calculated in Table 3. As well, the risk value in each region in the target study area is evaluated and then we utilized the Equation 1 to obtain the final risk value/map in each region. In the final map, all the risk maps are merged and overlapped into a final risk map, as demonstrated in Figure 9.

This map is described as follows:

- Each region is colored according to its risk value from 1.260 (lower risk regions) to 4.654 (higher risk regions)
- As the shelters are located in the final risk map, we projected the shelter coordinates on the final map to acquire the risk value for each shelter which vary from 1.662 (lower risk) to 3.594 (higher risk).
- While there are six risk category areas ranging approximately from 1.1260– 4.6540, the risk value for

each shelter varies from 1.126–3.594. We can observe that there is no shelter located in the highest risk area (darkest red one) and therefore, there are no shelters within the highest risk value.

- Some of the shelters are so adjacent to each other as shown in Figure 9 in groups A, B, and C (distances between them are less than 1 km). We

can observe that the risk values within those located in the same group are approximately similar, because most risk criteria are based on the region features perspective.

- The more criteria we involve the more varied values we obtain. This results in higher variance between the shelters, which facilitates the selection process for the decision makers.

Table 5 defines the risk values of different shelters and the related ranking to facilitate the decision makers. The lower risk value shelters are more favor for the crisis areas since it takes into account the factor considered by affected people such as to be closer to the services like hospitals, schools, main roads and etc. and avoid the dangers of being closer to frontlines, thief areas, being in besieged areas and etc. as well facilitating the works of humanitarian actors implementing such as projects in the conflict areas.

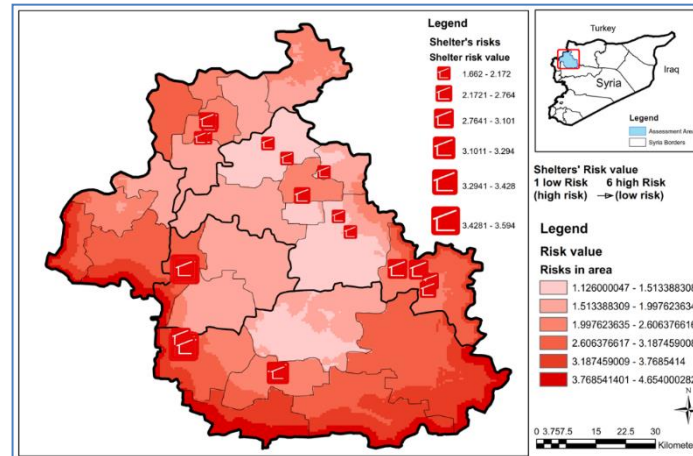


Figure 9. Risk Map: Shelters' Final Risk Value

Table 5. Risk Values and Rankings of Shelters

| Shelter No. | Shelter risk value | Shelter ranking | Shelter No. | Shelter risk value | Shelter ranking | Shelter No. | Shelter risk value | Shelter ranking |
|-------------|--------------------|-----------------|-------------|--------------------|-----------------|-------------|--------------------|-----------------|
| SH1         | 3.04               | 19              | SH18        | 3.38               | 38              | SH35        | 3.09               | 21              |
| SH2         | 3.14               | 25              | SH19        | 3.22               | 30              | SH36        | 3.26               | 33              |
| SH3         | 3.14               | 26              | SH20        | 3.18               | 28              | SH37        | 2.66               | 12              |
| SH4         | 2.94               | 16              | SH21        | 2.74               | 13              | SH38        | 2.76               | 14              |
| SH5         | 3.38               | 37              | SH22        | 3.29               | 35              | SH39        | 3.00               | 17              |
| SH6         | 3.42               | 42              | SH23        | 3.50               | 48              | SH40        | 2.83               | 15              |
| SH7         | 3.26               | 31              | SH24        | 3.28               | 34              | SH41        | 1.66               | 1               |
| SH8         | 3.14               | 27              | SH25        | 3.51               | 49              | SH42        | 1.70               | 2               |
| SH9         | 3.01               | 18              | SH26        | 3.49               | 47              | SH43        | 2.01               | 6               |
| SH10        | 3.12               | 24              | SH27        | 3.59               | 51              | SH44        | 2.42               | 10              |
| SH11        | 3.36               | 36              | SH28        | 3.39               | 40              | SH45        | 1.98               | 5               |
| SH12        | 3.53               | 50              | SH29        | 3.09               | 20              | SH46        | 1.70               | 3               |
| SH13        | 3.42               | 43              | SH30        | 3.40               | 41              | SH47        | 2.54               | 11              |
| SH14        | 3.49               | 46              | SH31        | 3.10               | 22              | SH48        | 2.36               | 8               |
| SH15        | 3.43               | 44              | SH32        | 3.19               | 29              | SH49        | 2.38               | 9               |
| SH16        | 3.43               | 45              | SH33        | 3.38               | 39              | SH50        | 1.97               | 4               |
| SH17        | 3.26               | 32              | SH34        | 3.10               | 23              | SH51        | 2.17               | 7               |

## 5. Conclusions

In this study, we introduced a new approach that can aid the decision makers in the crisis areas to identify optimal shelter locations by performing the risk scoring of each candidate shelter in terms of the most important factor to the affected people in the target area.

This study mainly included the definition of the most important criteria according to beneficiaries and their representative, experts, and the donors utilizing the Delphi

technique. Then the agreed criteria are prioritized using the F-AHP followed by assessing the risks in all areas according to each agreed criterion and merging all the risk maps into a final

risk map using the weights derived from F-AHP. The final risk value is then obtained for each shelter by extracting the risk value of shelters from the final risk map.

As a result, we ranked all the 51 shelters according to their final risk scores considering the predetermined criteria from the humanitarian perspective in crisis regions. This can enable the decision maker in selecting the shelters effectively.

However, the study demonstrates a number of restrictions. Firstly, the study region is restricted to north of Syria, and locations are assessed with 13 risk criteria from crisis and humanitarian perspectives. Furthermore, the study is restricted in dealing with static/stable situation in the studied area. To address these drawbacks, future studies can incorporate the recommendations below:

- Exclusive of the 13 noted risk criteria, different criterion (such as electricity, water, parks, and social services) could be considered.
- Collecting data on smaller areas (at community level rather than at sub-district level) may provide finer details and produce more accurate values.
- Instead of a static approach, a dynamic one can be proposed to deal with the high-level uncertainty of these kind of questions in crisis regions.
- The study region can be widened to extend the investigation for more extensive results.
- Different risk techniques can be utilized to obtain varied results.

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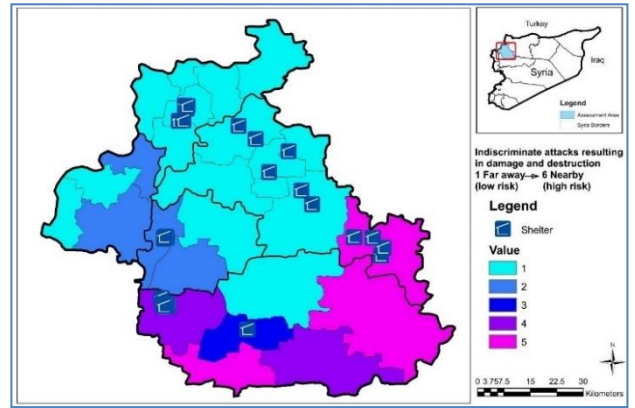
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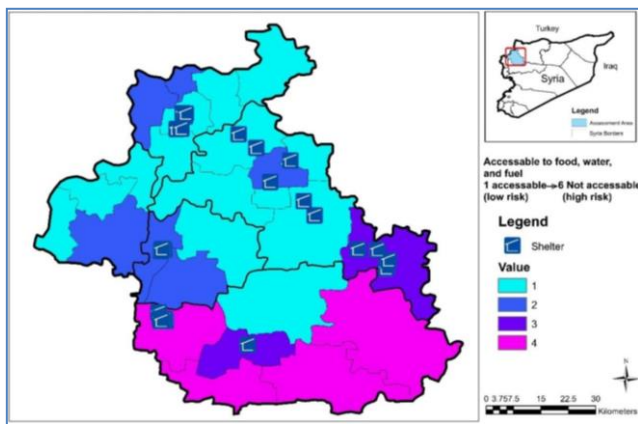
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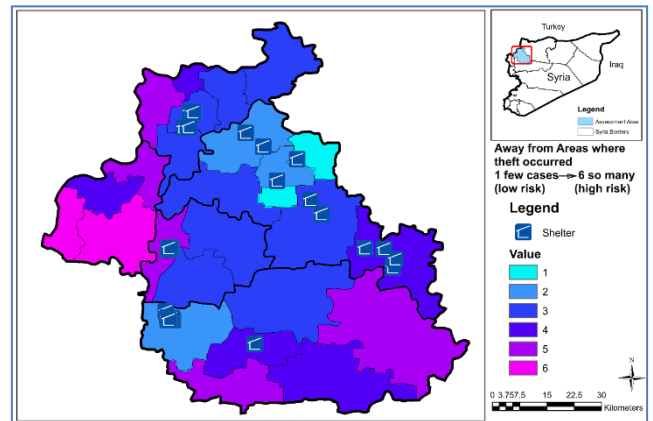


Risk map – indiscriminate attacks resulting in damage and destruction

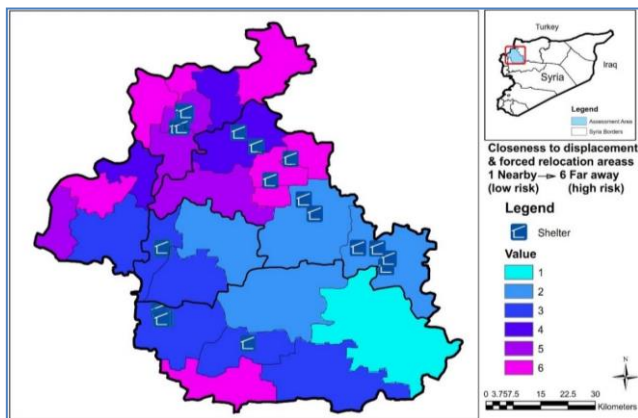
**Appendix: Lower Prioritized Risk Maps**



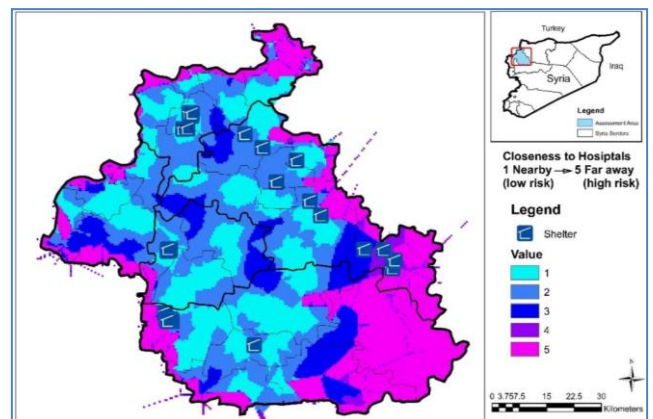
Risk map – accessibility to food, water, and fuel



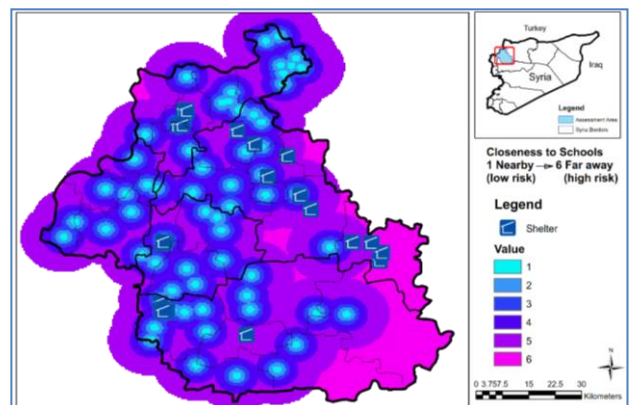
Risk map – away from areas of theft



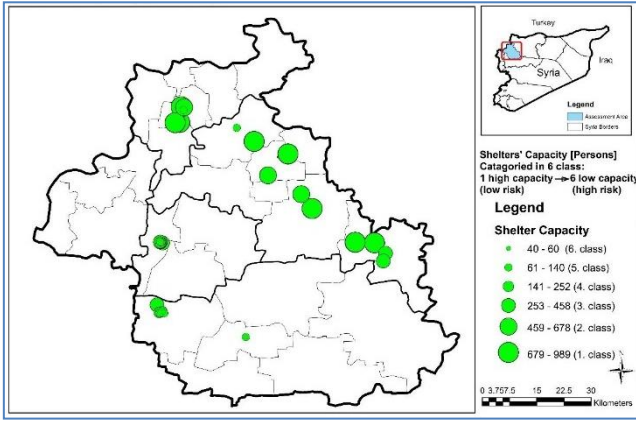
Risk map – proximity to displacement and forced relocation areas



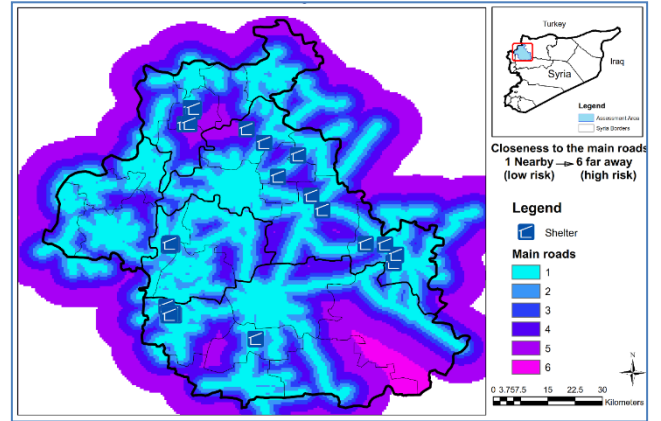
Risk map – proximity to hospitals



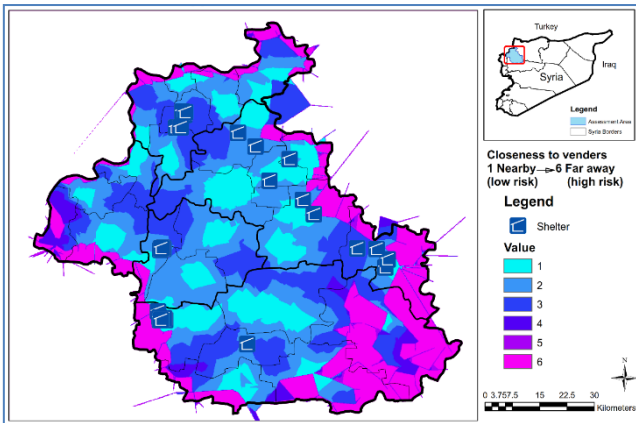
Risk map – proximity to schools



Risk map – shelters' capacity [persons]



Risk map – proximity to main roads



Risk map – proximity to vendors/suppliers