ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

PhD THESIS

Jamıl HALLAK

MULTI OBJECTIVE SHELTER LOCATION-ALLOCATION IN CONFLICT AREAS: A CASE STUDY IN NORTH OF SYRIA

DEPARTMENT OF INDUSTRIAL ENGINEERING

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We certify that the thesis titled above was reviewed and approved for the award of degree of the PhD of Science by the board of jury on 23/07/2019.

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ABSTRACT

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The Syrian crisis broke out in March 2011. Millions of affected people have left their homes, and many of them were displaced as well. Individually, internally displaced persons (IDPs) are encountering difficulties in terms of shelters, health, food, and other urgent needs. In this way, we concentrated on determining shelter locations within a region of Idleb-Syria in this study. For this aim, we employed real data from the region which were collected from the direct beneficiaries and produced a mixed integer model utilizing weighted goal programming model based on humanitarian context which is determined by Focus Group Discussions (FGDs). The aims of the suggested model included maximizing mainly covered demand, cash for work, shelters with scalable up, portable water, sanitation and hygiene (WASH) facilities and covered people with vulnerable humanitarian criteria such as; people with disabilities, children attending school, pregnant/lactating women and people with chronic diseases and concurrently minimizing cost while taking into account shelter capabilities and restrictions of located shelters. Furthermore, GIS (Geographic Information System) was employed. The proposed model was solved via an optimization software and we reached a global optimum solution. Moreover, sensitivity analyses were conducted to strengthen the study. As a result, decision makers can be availed from the model's outputs and sensitivity analyses to obtain a compromised solution in such a disaster in nearby countries.

Keywords: Conflict, (IDPs) internally displaced persons, shelter, weighted goal programming, location-allocation.

ÖZ

DOKTORA TEZİ

ÇATIŞMA ALANLARINDA ÇOK AMAÇLI SIĞINAK YERLEŞTİRME-ATMA: SURİYE'NİN KUZEYİNDE BİR ÖRNEK OLAY ÇALIŞMASI

Jamıl HALLAK

ÇUKUROVA ÜNİVERSİTESİ
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Suriye krizi 15 Mart 2011'de patlak vermiştir Milyonlarca insan ülkeden ayrılmış ve çoğu da yerlerinden edilmiştir. Bireysel olarak, ülke içinde yerinden olmuş kişiler (YOK) barınaklar, sağlık, yiyecek ve diğer acil ihtiyaçlar açısından zorluklarla karşılaşmaktadır. böylece, bu çalışmada, İdleb/Suriye bölgesinde barınma yerlerinin belirlenmesine odaklanılmıştır. Bu amaçla, doğrudan faydalanıcılardan toplanan bölgeden gerçek veriler kullanılmış ve Odak Grupları Tartışmaları tarafından belirlenen insani şartlara dayanan ağırlıklı hedef programlama modelini kullanarak karma bir tamsayı modeli üretilmiştir. Önerilen modelin amacı; esas olarak kapsanan talebin, çalışma için ücretlerin, ölçeklendirilebilir barınakların, taşınabilir su, sıhhi tesisat ve hijyen olanaklarının en üst düzeye çıkarılması ve savunmasız insani kriterleri olan kapsanan insanları; engelli insanlar, okula devam eden çocuklar, hamile /emziren kadınlar ve kronik hastalıkları olan insanlar ve barınak yeteneklerini ve bulunduğu yerdeki barınak kısıtlamalarını dikkate alarak aynı anda maliyeti en aza indirmektir. Ayrıca, Coğrafi Bilgi Sistemi (CBS) işe alınmıştır. Önerilen model, bir optimizasyon yazılımı paketi ile çözülmüş ve soruna küresel bir çözüm bulunmuştur. Ayrıca çalışmayı güçlendirmek için duyarlılık analizleri yapılmıştır. Sonuç olarak, karar vericiler, yakındaki ülkelerde böyle bir felakette uzlaşılmış bir çözüm elde etmek için modelin çıktılarından ve duyarlılık analizlerinden faydalanabilir.

Anahtar Kelimeler: Çatışma, (IDP'ler) ülke içinde yerinden edilmiş kişiler, barınak, ağırlıklı hedef programlama, yer tahsisi.

EXTENDED SUMMARY

The Syrian crisis started out on 15 March 2011. Millions of people have left their home, many of them were displaced, a lot of them passed away as well. Individually, displaced people are encountering difficulties in terms of housing and sheltering solutions, providing health services, food and nutrition, and other urgent needs in such disaster. In this way, we concentrated on determining optimized shelter locations within a region of Idleb-Syria and allocated the most vulnerable people to these selected shelters.

For this aim, we employed real data from the region which were collected from the direct beneficiaries throughout face-to-face meetings, telephone interviews and focus group discussions since there is no official authority who can provide such a data about the following demography, IDP’s and shelter assessment in Idleb Governorate: Findings of demographics and IDPs amounts; Vulnerability rates; Displacement preparing time; Information about displacement; Displacement's reasons; Shelter type and occupation arrangement; Tracking of IDPs from first origin to recent destination; Sector severity in Idleb sub-districts; Shelter Type, Occupancy Arrangement and capacity.

The methodology is proposed mainly in four stages: The first step of the process is handling a needs assessment using FGDs, surveys, etc. to evaluate the needs and most critical factors according to all relevant direct beneficiaries in absences of authorized organizations. Information and data about the governorate of Idleb are extracted from a sample of 425 families and representatives across all the 26 sub-districts within the targeted area by direct beneficiaries and key informant discussions with representatives who are aware and understand what is going on in the affected community on the ground. Data was collected between December 2017 and February 2018.

The next stage is the objectives' and constraints' identification in addition to prioritizing them according to experts and beneficiaries where they've given each object weight throughout FGDs/Surveys for all objectives.

Then, by using GIS, the roads network database is built in the affected targeted region, and it is revised according to risk roads to determine the origin-destination (OD) cost matrix throughout the spent distance between the nodes of IDPs and locations of shelters (Stage three).

Building mathematical model is the last step where multi-objective based mixed integer model was proposed utilizing weighted goal programming model and considered mainly humanitarian context which is determined by Focus Groups Discussions (FGDs) defining the most important criteria and their weights. Then the proposed model was solved by optimization computerized tool to select shelters and allocate IDPs, as well as operating sensitivity analysis was conducted and the results are presented and discussed.

The aims of the suggested model included mainly the objectives of: maximizing covered people demand by the selected shelters; minimizing the total cost including the fixed and operating costs; maximizing cash for work to support the vulnerable affected people finding job; maximizing the amount of selected shelters with the ability to be scalable up in the future; maximizing the amount of chosen shelters with portable water, sanitation and hygiene (WASH) facilities; maximizing the covered people with vulnerable humanitarian criteria such as: affected people who have disabilities, affected people who have children attending school, displaced people who are pregnant/lactating women, displaced people who have chronic diseases.

We tried to reach the objectives declared above while taking into account these constraints are in the proposed model: shelter capabilities; each demand to be allocated at most once; binary variables. Furthermore, GIS (Geographic Information System) was employed to calculate the real distance between demands and shelters according to the updated origin-destination roads network.

The suggested model was validated by considering two databases. First one was synthetically created through three numerical examples after detailed discussions with dedicated stockholders. Second one was assessed as a part of the case study in Idleb/Syria. The outputs confirmed the effectiveness and validation of the model.

Then the model was solved via an optimization software tool and we reached a global optimum solution. Then the results were summarized to show the correlation between the aimed and achieved amounts in each goal as summarized below:

We intended to select 12,000 displaced people within the developed model, and we allocated 11,907 out of 12,000 which corresponds to the achievement of 99%. Since the capacity of 51 candidate shelters was 14,410; the full capacity of chosen 40 shelters was 12,259.

The other outputs reached in each goal in terms of percentage format against the full achievement (100%) showed that many objectives have arrived at the aspired amount; starting from values which are greater than the aspired amount "100%" as in cash for work which is favoured including that the model is attempting to increase this goal as much as it possible. While, the model resulted in exceeding the desired amounts in the total cost objectives by 111%. The 104% obtained amount at chronic diseases corresponds that the allocated amount of internally displaced people with chronic diseases to an opened shelter is greater than the aimed value. Moreover, we realized that a few objectives such as number of disabilities (71.93%), pregnant/lactating women (54.70%) and number of kids (63.37%) have not achieve the desired level.

Furthermore, sensitivity analyses were conducted to strengthen the study. Where 9 cases have taken into account to study the model impact on changing the inputs; in the case1 Changing in number of allowed opened shelter or totally eliminate the related constraint; while in the case 2 population growth rate (PGR) was involved into the model; in the case 3 we made changes in RHS_n amounts (aspired levels) to study the effects on the outputs; in the case 4 changes in p_1^- were tested on the model (penalty related to covered goal); changes in RHS_1 (the target amount in covered affected people) were evaluated; in the case 6 we applied the cases 4 and 5 together to study the impact on the model; while in the case 7 we changed the penalty of deviation related to the total cost goal p_2^+; we made changes on the desired amount of total cost goal in case 8; lastly the case 7 and 8 applied together in the case 9.

All the 9 cases were applied on the model and the results have discussed about the main variables judged by stockholders' perspective as follows; (i) the quantity of displaced people covered and (ii) the total cost, respectively

As a result, Within the proposed research, a multi-objective decision-making approach has been proposed and applied. It will assist decision makers to define the optimum shelter location for affected displaced persons in the northern region of Syria, then allocate the most in shortage displaced people to the chosen shelters which will lead to promote and facilitate the recovery process.

The major contribution of proposed thesis can be divided into four trends: First, the introduced methodology will present a helpful tool to decision-makers to interact with analysing multi-objective problems, find out all potential solutions and the extent of its inputs' variations on results. While the second contribution shows the applicability in such crisis regions to get the best feasible solution from the humanitarian prospect. Third, it depicts the feasibility of merging the multi-objective mathematical model with GIS employing real information. Last but not least, the main objective of this paper was that; any country, community, state or organization can gather related data and can access this methodology. it is beneficial for every similar context. Certainly, the inputs, information, and weights may differ according to the studied circumstances of the associated problem state; but the suggested model could be adopted for alike situations in another country.

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LIST OF SYMBOLS

IDPs : Internally Displaced Persons

MODM : Multi Objective Decision Making

MOFLP : Multi Objective Facility Layout Problem

DR : Disaster Relief

DM : Decision Maker

I : Set of demand/requested nodes; $i \epsilon I$

J : Set of candidate shelter locations; $j \epsilon J$

N : Set of targeted/desired goals; $n \epsilon N$

d_{ij} : Distance between node i and location j (retrieved through building a GIS roads network dataset)

h_i : The Demand at each node i

Vd_i : Number of IDPs people who have disabilities at each node i (vulnerability criteria)

Vc_i : Number of children who are going to school at each demand node i (vulnerability criteria)

Vp_i : Number of lactating /pregnant women at each demand node I (vulnerability criteria)

Vcd_i : Number of people with prolonged/ chronic diseases at each demand node$i$ (vulnerability criteria)

cd_i : Coverage satisfactory distance for each node i (acceptable/pleasant distance for each node i to be moved)

f_j : Fixed charge/cost of locating a shelter at candidate site j

R_j : Running cost of each person at site j

K_j : Full capacity of each candidate shelter location at j

$C4w_j$: Amount in Dollar of cash for work in each candidate location

p_n^- : Penalty of not reaching the objective related to deviation d_n^-

p_n^+ : Penalty of not reachingg the objective related to deviation d_n^+

TG_n : Target goals of desired goal *n* in accordance to goal programming/ aspired levels/ aspired amounts

a_{ij} : Covering matrix

fw_j : $site\ j\ has/has\ not\ portable\ wash\ facilities$

fs_j :$site\ j\ has/has\ not\ flexiblitiy\ in\ scaling\ up\ in\ the\ future$

X_j :$if\ we\ locate\ a\ shelter\ at\ candidate\ location\ j$ or not

Z_{ij} :$if\ demand\ at\ node\ i\ is\ served\ by\ a\ shelter\ at\ location\ j$ or not

d_n^+ : Positive deviational variable – the amount of an over-achieved desired goal *n*

$\mathrm{d_n^-}$: Negative deviational variable – the amount of an under-achieved desired goal *n*

1. INTRODUCTION

In this section, an introduction to the subjects related to the handled problem have introduced starting from covering facility location, classifications, discrete models facility location and shelters types in disaster context. Then Syrian humanitarian crisis is described briefly to make the reader understanding the context there properly. Since the thesis related to determining the shelters locations, the basics and methodology of geographical information system (GIS) demonstrated as well.

1.1. Importance of Facility Location

About all public and private sector business that we can consider have been confronted with the problem of locating facilities/office/plant at one time or another in its history. For example, manufacturing companies must define locations for fabrication and assembling plants as well as depots. Retail outlets must place stocks and stores. State agencies must place departments/offices and other public services including institutions, health care center, fire stations, ambulance stations, vehicle examination stations, exhibitions, fuel stations, and landfills (Daskin 2011).

The firm's ability to design and sell its products effectively in every situation or of a business to deliver high-quality services is dependent in part on the location of the firm's or agency's facilities in relation to other offices and to its shoppers (Daskin 2011).

In a diversity of state and individual/private sector problems, location decisions also rise. For instance, public governments need to define places for bases for emergency roadway patrol transportations. Likewise, regional governments must place health centers and fire stations. In all of these cases, weak locations can raise the likelihood of property waste and/or injury of life (Dean 2004).

The industry must place services, production and assembling factories, distribution centers, and retail outlets in the private divisions. Poor location decisions in these conditions may lead to raised costs and declined competitiveness (Dean 2004).

In brief, failure and success of both private and state division facilities depend in part on the locations determined for those facilities.

We should highlight from the beginning that the word "optimal" is used in a mathematical sense. That is, we will define quantifiable goals that depend on the positions of the facilities. We will then classify algorithms for obtaining optimal or at least suitable facility locations (Daskin 2011).

The position of facilities is crucial in both industries and service companies. With regard to industry, inadequately placed facilities or the usage of too many or too less facilities will end in raised costs and/or degraded consumer service. If too many facilities are deployed, capital costs and inventory carrying costs are likely to surpass the desirable amount. If too less facilities are utilized, consumer service can be severely degraded. Even if the correct number of facilities is employed, inadequately sited plants/ offices will result in undesirably poor client service (Dean 2004).

1.2. Main Questions Addressed by Facility Location-Allocation

The models of location are mainly outlined to discuss a number of inquiries including:

A. The number of facilities that should be placed?
B. Where must/should each building be determined?
C. How capacity/large should each building be?
D. Which demand node should be allocated to the selected building? (Daskin 2011)

The responses to these inquiries depend closely on the context in which the location problem is being answered and, on the goals underlying the location problem. In some circumstances, such as ambulance vehicle siting problems, we will need to settle the facilities as close as possible to the demand node sites. In locating dangerous waste repositories, we will aspire to be in a geologically stable region and would like to be as far away as possible from main population stations.

The size and number of facilities to be placed is often a function of the service /cost tradeoffs. In many situations, the quality of service improves as the number of facilities located raises, but the expense of providing the service increases as well. For instance, having more ambulances vehicles is usually favored to having less ambulances since the probability of having an accessible ambulance near a request for service increases with the number of vehicles used. Moreover, there are no meaningful economies of scale in ambulance operations; that is, having a single site with various ambulances is not much cheaper than having the same number of ambulances at multiple locations. Therefore, owning a large number of single vehicle ambulance bases is reasonable to be preferable to having a small number of multivehicle bases. At some point, nevertheless, the quality of medical care provided by the paramedics degrades as further ambulances are joined to the system. The reason behind this is that there are not enough demands asking a variety of medical skills to maintain the paramedics' training. In many production contexts, there are significant savings of scale, which drive the position decisions to having a less number of large facilities (Daskin 2011).

Facility location models have also treated with the allocation of demands nodes to the chosen facilities. In some situations, it is necessary that demands node at a site not be split between facilities. For example, in some retailing operations, a retail shop must be provided by a single warehouse. For some administrative reasons, the store’s quantity cannot be split between various warehouses. In other circumstances, such as ambulance services, demands can be served by any accessible facility. Facility location models must consider these different demand allocation methods and must then allocate demands (or fractions of the total demand in an area) to various facilities. In several situations, demand nodes will be allocated to the nearest (available) facility; in other situations, doing so may not be optimal (Daskin 2011).

1.3. Taxonomy of Location Problems and Models

Location models and problems may be listed in a number of styles. The classification may be based on the topography that is utilized (e.g., discrete location problems vs planar problems, problems on general graphs versus those on trees, and problems utilizing various distance metrics), or the quantity of facilities to be placed. Problems may also be classified based on the type of the inputs (e.g., whether they are dynamic or static, known with certainty or only known in an uncertainty sense). Models may moreover be classified based on whether single or multiple products or demand nodes must be served by the facilities being located, whether there is one goal or multiple goals, whether the beneficiaries/ receiver and investors are the same or various actors, whether the facilities are of endless capacity or are capacitated, as well as a variety of other classification criteria. This part explains a classification scheme for location models and uses that scheme to help identify those problems that will be the main focus of this study (Daskin 2008).

While there are various ways of dividing the broad spectrum of location models, Figure 1.1 shows a breakdown based on the space in which the problems are formed.

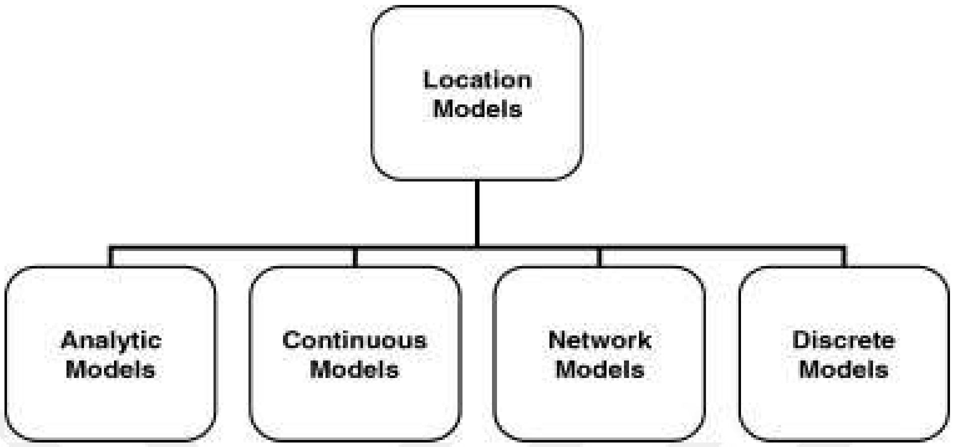


Figure 1.1. Location Models (Daskin 2011).

Analytic models are simplistic location models. Such models typically pretend that demand is spread in some way (e.g., consistently) over a service region and that facilities can be placed anywhere within the region. Analytic models are typically solved utilizing calculus or other simple methods. While the strong assumptions required to develop such models limit their applicability in particular situations, the insights obtained from such models tend to be applicable in a variety of contexts (Daskin 2011).

While analytical models pretend that demands are spread continuously across a service area and that facilities can be placed anywhere within the area, *continuous models* typically assume that demands occur only at discrete spots, demands happen at each of n discrete points (Daskin 2011).

Network models assume that demands appear, and facilities can be placed, only on a network formed of nodes and links. Usually demands occur only on the nodes, while facilities can be placed anyplace on the network (Daskin 2008).

The fourth and final category of the location model classification hand out with *discrete models*. In such models, there may or may not be an underlying distance metric. Distances or expenses between any pair of demand nodes may be arbitrary, although they usually do grasp some rule (e.g., Manhattan, Euclidean, network, or large circle distances). Demand nodes commonly arise on the demand nodes and the facilities are restricted to be a set of candidate places (Daskin 2008).

Since we are dealing with discrete problem, we will give more descriptions and details about the features and types of this model.

1.3.1. Discrete model

The discrete location models are classified in Figure 1.2 by dividing the class into three broad sections. Covering based models demonstrate that there is some crucial coverage time or distance within which demand nodes require to be served if they are to be considered as "covered" or "served adequately". Such models are typically utilized in planning emergency services as there are both practical and, in many jurisdictions, legislative guidelines for coverage. Note that service and coverage are not same. For example, in locating stations, a node may not be served (e.g., it may be more than 20 minutes from the neighboring station), but demands at that location would be served if they were inside the service zone. Increasingly, covering models are also being utilized in the private division as coverage can be employed as a proxy for high quality service (e.g., "when it positively definitely has to be there by...."). Within the category of covering models, three prototypical models are the set covering model, the maximal covering model, and the p-center model (Daskin 2011).

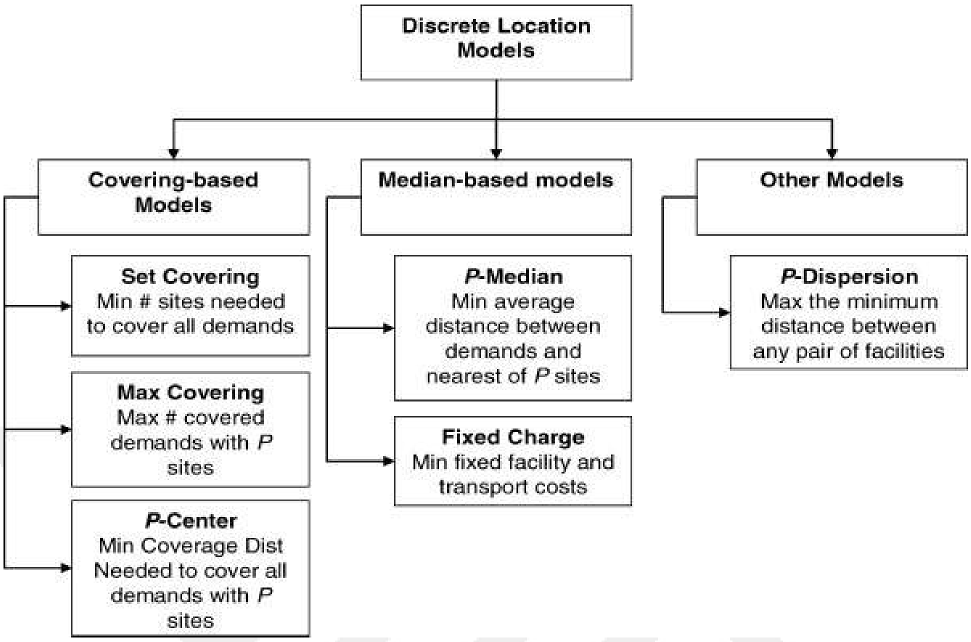


Figure 1.2. Discrete Location Models (Daskin 2011).

Median-based models are working on minimizing the demand-weighted average distance between a demand node and the plant to which it is allocated. Such models are typically employed in distribution planning contexts in which minimizing the total outbound or inbound transport cost is crucial. In this regard two models are shown in Figure 1.2 as the uncapacitated fixed charge and the p-median model location problem.

Eventually, there are models which do not come into either of these classes. For instance, the p-dispersion model maximizes the minimum distance between any pair of facilities. This model is helpful in placing franchise outlets, where minimizing the cannibalization of one outlet’s market by another franchisee is useful. The model can also be adopted in locating weapon supplies (e.g., nuclear weapons) where minimizing the probability that the destruction of anyone cache would impact other supplies is beneficial. Within the class of “other models”, there are a large various number of formulations proposed at locating undesirable facilities (Daskin, 2008).

1.4. Humanitarian Crisis in Syria

A multifarious humanitarian crisis is a community, society or country, where there is a complete or notable destruction of government arising from international or external battle needs a multi-sectoral, intercontinental feedback; and this situation is called "humanitarian emergency" (Office for the Coordination of Humanitarian Affairs 2003). Forced migrations can result in these humanitarian emergencies and this type of migrations can originate from many causes: population growth, natural disasters, social conflicts, political or structural crises, etc. (Perruchoud and Redpath-Cross 2011).

These migrations existed at all times, but still societies and policy makers are astonished by the arriving of refugees (Kleist 2017). Since the 1940s, forced migration has evolved into a phenomenon troubling millions of people and it proceeds to influence increasing number of countries in the world. Every day, thousands of people are escaping their places in search of protection in Myanmar, The Democratic Republic of the Congo, Central African Republic, The Syrian Arab Republic (Syria) and in other places. Estimated number of forcibly displaced people worldwide is 66 million at present and of these about 22.5 million are refugees. More than half of these 22.5 million refugees are under the age of eighteen. Refugees are crossing borderlines, moving to isolated rural communities or to the growing cities affected by municipal impoverishment through the wars within their country's own borders or with each other. Hence, displaced people barely carry their properties while moving from one region to another with same country or from one country to another, with the hope of starting over again (International Bank for Reconstruction and Development 2017).

With the aim of solving these critical problems and supplying general necessities of refugees; at 14 December 1950, the Office of the United Nations High Commissioner for Refugees (UNHCR) is stipulated to guide and systematize an international response to preserve refugees and overcome their problems worldwide. The fundamental aim of the UNHCR is to defend the rights and welfare of refugees.

It struggles to guarantee that each and every person have the rights to search for an asylum and to obtain a safe protection in another state, including an option to go back to their homes voluntarily or to resettle in a third country (UNHCR 2010).

People or group of people who have been compelled or obligated to run away or to set off their houses /rooted places, particularly in consequence of or on the purpose of refraining from the harmful effects of armed crisis, circumstances of generalized brutality, disregards of human rights, natural or artifactitious disasters and who have not crossed over an internationally recognized border are termed as "internally displaced people" according to the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA 2018). UNHCR give noticed that the estimated number of internally displaced people (IDPs) is 36 million in our day and about 3 million of these are looking for asylums. Of these 36 million IDPs, approximately %16 is just in Syria. These numbers are increasing every twenty minute by virtue of continuing wars in many countries or various continents. The harsh reality about IDPs is that they are hard to reach and unfortunately they are not preserved by a specific status (Ward and Consortium 2002). IDPs are among the most defenseless people in the world today as a result of these circumstances as the Office for the Coordination of Humanitarian Affairs mentioned (Ocha. 2017). Since they are deficient in education in a land with cultural and religious diversities, living conditions are caustic. Hence, they encounter considerable obstacles to fulfil their needs such as access to food, water, shelter and health services (Heudtlass, Speybroeck, and Guha-Sapir 2016; Toole and Waldman 2002). Furthermore, in comparison to occupants or migrants with refugee status, excess mortality rate in complex emergencies seems to be the highest in IDPs (Heudtlass, Speybroeck, and Guha-Sapir 2016).

As Syrian crisis contain more than %15 of IDPs worldwide, this subject requires a considerable emphasis. The reason behind that is this crisis has started out in March 2011 and still until the current time without any feasible solution, it began with a tiny sparkle in the Daraa city at the south of country. It is considered as one of the most complicated and dynamic humanitarian crises in the world nowadays. The intensification and spread of conflicts has led to a dire humanitarian crisis, with 6.3 million internally displaced people and 4.5 million people in hard-to-reach and besieged areas, according to the UNHCR (UNOCHA 2018). Over half of the population has been forced to leave their homes, and too many people have been displaced more than once. Furthermore, children and youth cover more than half of the displaced people. The fundamental reasons of internal migration are ongoing conflicts and therefore the settlements, hospitals and trade center's becoming dysfunctionality. According to UNHCR (7 December 2017); over 5.4 million people have fled Syria since 2011, seeking safety in neighbor countries and beyond 13.1 million people are still in need in Syria. Of the 6.3 million internally displaced persons in all Syrian governorates; 908,929 IDPs are just in Idleb governorate which represents approximately 15% of the whole number on IDPs. This situation is ranked to be second after Rural Damascus and ranked first as IDPs displaced to Idlib from the other governorates (UNOCHA 2018).

Under these circumstances, Idlib governorate plays a significant role in the current situation. Before carrying out studies to work out permanent solutions to this humanitarian situation, obtaining real data by analyzing the region's circumstances is of capital importance. However, to best of our knowledge, still, there are no systematic statistics including real data and any previous study has not researched this region in general or governorate (Idleb) in particular and this specific population. In this direction and in the light of all the factors concurring to the situation previously depicted; the circumstances of shelters and IDPs in the northern Syria/Idleb governorate are analyzed by real data in this study. Some of the factors discussed in the study are demographics, sectors severities and vulnerability.

1.4.1. Disaster Relief (DR) Shelters

Sufficient shelter has a vital impact on human survival in the beginning stages of a disaster (Sphere Project 2011). A shelter needs more than just a tent or a roof for a place to be inhabitable. People living in a shelter must have enough urgent needs such as blankets, clothing, mattresses, stoves, fuel, as well access to health services ,water and sanitation (Ashmore 2004). Shelters are usually secured, roofed, hygienic, and livable places for people to utilize during periods of disaster until they are able to return to their permanent houses. Several shelters are designed and planned so that they can be built, disassembled, and stored for future use (Arslan 2007). These kinds of shelters are lightweight formations that can be employed for various purposes (The Institute of Structural Engineers 2017). Shelters include tents, plastic sheets, prefabricated house, and state community buildings such as schools, leisure centers, university halls of residence, mosques, sports venues, and sometimes private rentals. A shelter and a dwelling have various purposes. While shelters offer a safe and secure space to stay within immediately after a disaster, dwellings include regular household duties and work systems (Johnson, 2007; Danial, Branco and Feio, 2013). According to UNOCHA (UN 2006) and Hadafi and Fallahi (Hadafi and Fallahi 2010), adequate shelter is defined as an "immediate environment for all aspects of family life, providing protection from the elements, secure tenure, personal safety, and access to clean water and sanitation, proximity to places of employment and educational and health care facilities." On the other side, housing is defined as, "lodging, shelter for human habitation”. The immediate physical environment is both within and outside buildings, in which families and households live and which serve as shelter. Housing also includes “government project(s) to provide shelter to low-income groups" as it was indicated in both resources (UN, 2006; Hadafi and Fallahi, 2010).

1.4.2. Categories of Shelter/Housing

People tend to transfer between various DR shelter settings before they either return to their past permanent houses, enhance shelters to permanent dwelling, or build new homes. Shelters can be subdivided into four divisions: emergency/contingency shelters, temporary shelters, temporary housing, and permanent home (Quarantelli, 1995; Wu and Lindell, 2004; Johnson, 2007; Danial, Branco and Feio, 2013). Nevertheless, the International Federation of the Red Cross and Red Crescent Societies (2011) have added extra divisions to these, such as progressive shelters, transitional shelters, and core shelters /one-room shelters (International Federation of Red Cross and Red Crescent Societies 2011).

1.4.1.1. Emergency Shelter

The first type of shelter is utilized for short periods of time to deliver lifesaving aid and is the most essential kind of shelter assistance apart from staying in different permanent building (to be utilized for a temporary period) for a single day to a few days during an a crisis or emergency (Quarantelli, 1995; Wu and Lindell, 2004; Johnson, 2007; Danial, Branco and Feio, 2013). This sort of shelter usually does not support the comprehensive preparation of food or prolonged health services.

1.4.1.2. Temporary Shelters

The second type of shelter is indicated for short-term usage. A single tent or a public shelter utilized for a some weeks following a disaster compounds a temporary shelter (Quarantelli, 1995; Wu and Lindell, 2004; Johnson, 2007; Danial, Branco and Feio, 2013). According to the Red cross, the duration of staying in such places may be restricted, and accordingly, prioritizing speed and restricting costs should be taken into consideration while constructing this sort of shelter.

1.4.1.3. Temporary Housing

This kind of shelter is usually given for long-term periods starting from six months through three years. Temporary housing such as rental homes and prefabricated block allow disaster-affected people to return to their ordinary daily activities (Quarantelli, 1995; Wu and Lindell, 2004; Johnson, 2007; Danial, Branco and Feio, 2013). In many situations, temporary houses are established on temporary land.

1.4.1.4. Transitional Shelters

The transitional shelter is normally improved by displaced people themselves after a disaster, and such resourcefulness and self-management should be maintained c. Transitional shelters are usually replaced from a temporary site to a permanent location, promoted into part of a permanent home, activities to produce income to assist with recovery, recovered for reconstruction, and reused for other aims (IOM 2012). Such transitional shelters are presumed to serve for several months or years (Engstrom et al. 2018).

1.4.1.5. Progressive Shelters

The progressive shelter is planned and established to be more durable and upgradeable in the future through alterable constructional elements (International Federation of Red Cross and Red Crescent Societies 2011).

1.4.1.6. One-Room/Core Shelters

This type of shelter is planned and established with the purpose of being a more permanent residence in the future, including a providing all or many of the key services, such as plumbing electricity and various utilities (IOM 2012). The aim with this type is to produce at least one room to meet permanent home standards and facilitate recovery. Nonetheless, these shelters are not assigned to be a full permanent house (IOM 2012).

1.4.1.7. Permanent Housing

Upgrading from of transitional shelter, progressive shelter, a core shelter, or even a new house can be as permanent housing (Quarantelli, 1995; Wu and Lindell, 2004; Johnson, 2007). Such homes should be safer, secured, resilient and resistant to any likely hazards and emergencies.

Of this range of shelter classes, as an authority should understand which type of shelter is most suitable for a group of survivors' demands and circumstances to be implemented in the area. It is also thought that aspects of sheltering and houses are unlikely to work in a neat linear mode (Quarantelli, 1995; Nigg, Barnshaw and Torres, 2006). For example, in certain disaster situations, it is recommended to utilize contingency shelters if damages can be repaired instantly (some weeks) before going back to one's house, or if one cannot return to his or her own home due to it being too broken. Nonetheless, in such a case it would be useful to build transitional shelters on one's own area. The quicker the repair process begins, the lower the social and economic expenses of a disaster.

1.5. Introduction to Geographic Information System (GIS)

Geographic Information System (GIS) was basically developed for scientific area management goals in Canada throughout the 1960s where the Canadian Geographic Information System was founded for the collection and analysis of data regarding the land use and the generation of statistics for land use management layout (R. Johnson 2000). Following, GIS has been typically utilized as a technologically high-level tool to provide potentially high importance of the progress in display, flexibility and preparation to microplanning to prove the benefits (Shah and Nerurkar 2012).

GIS term is difficult to be determined. It represents a mixture of several subject areas. Consequently, there is no absolutely agreed upon determination of a GIS (Wise 2000). A broadly admitted definition of GIS is the one given by the National Centre of Geographic Information and Analysis: "a GIS is a system of software, hardware, and styles to facilitate the administration, guidance, analysis, modelling, representation and pretension of georeferenced data to answer complicated problems regarding planning and management of sources" (Goodchild and Kemp 1990). Geographic information systems have developed in the last decade as a fundamental tool for urban and resource planning and administration. Their capability to store, recover, analyse, model and map large regions with huge volumes of spatial data has led to an extraordinary proliferation of applications. Geographic information systems are presently utilized for land use utility administration, planning, ecosystems modelling, landscape planning and assessment, shipping and infrastructure planning, visual impact analysis, facilities administration, tax assessment, real estate examination and so many other purposes.

Functions of GIS include data record, data presentation, data administration, information retrieval, and investigation. A more comprehensive and simple method to define GIS is the one that looks at the disposition, in layers of its presented data sets. Wise described it as group of maps of the same division of the region, where a given place has the same coordinates in all the maps involved in the system (Wise 2000). This way, it is possible to analyse its spatial and thematic characteristics to gain a better understanding of this region.

In shelter planning, a GIS can be used for many different purposes, four of which are particularly important. Firstly, it helps to make the presentation of data more effective, realistic and attractive, since reading information on maps is very clear and easy to understand. Secondly, translating data into maps helps in recognizing ‘unexpected’ situations, which need closer examination. The third use of a GIS is that, through considering geographical factors, the analysis becomes finer, more precise and the ensuing strategies probably more pertinent. Fourth possible use is assisting in prospective planning (Attfield et al. 2002).

1.6. Working Structure of GIS

GIS spatial (geographical) information in a single system to provide a uniform structure for data analysis is defined as the spatial and integrated. GIS geographic proximity performs the relationship between activities. Digital data structure that affords a common record-keeping "floating electronic maps" can be displayed. Following (in detail) the map of the masses in the "expression" is utilized.

The spatial relationship executes the relationship between the activities based on GIS geographic proximity. Spatial relationships can be summed as shown in Figure 1.3 which shows map feature, GIS vector format, and GIS format in raster way.

Figure 1.3. Map property dot plot (vector format raster format) (Esri 2011)

Every Cell in GIS circumstance is segmented into pixels and ingredients. Then the cells are combined arrays. Column and line numbers are utilized to distinguish the position of cells in the array. Line tabulated data points are linked with the line or the area within the limits of points coordinates and Figure 1.4 displays map property areal (vector format and raster format). Vectors of the connection lines (line sections as described by the vector direction and magnitude that the length of the initial coordinates) has been characterized by a number. (Ay 2012).

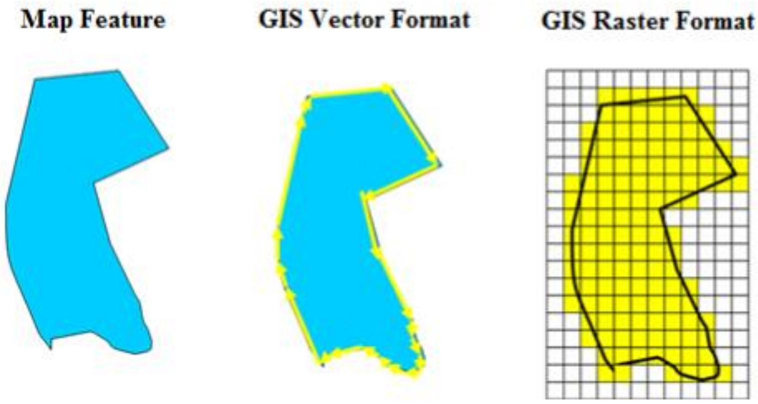


Figure 1.4. Map property areal (vector format raster format) (Esri 2011)

Raster or vectors constituting the polygon area is described by a number. Information comparing orders between raster formats with the same size is effective. Each "Geographic Information Systems"; location-based acquired by remark charts and graphs of non-information collection, storage, processing and is an information system that operates in unity function to be shown to the user.

A GIS is not only a computer software for creating maps. Indeed, a map is commonly the most popular way of summarizing information from a GIS data sets. A GIS is an “information system”. These systems are not only the hardware and software but additionally, the gathering of information (the database) about where geographic characteristics (buildings, roads, fire hydrants, hospitals, schools, shelters, pipes, crime incidents, streams, ponds, etc.) are placed in your society. Making this database involves organizing the information from maps and card files, aerial photos, people’s personal practice, or existing processor databases. A GIS database combines all this information so that it can be employed together and is accessible through a single layer as described in Figure 1.5 (Esri 2011).

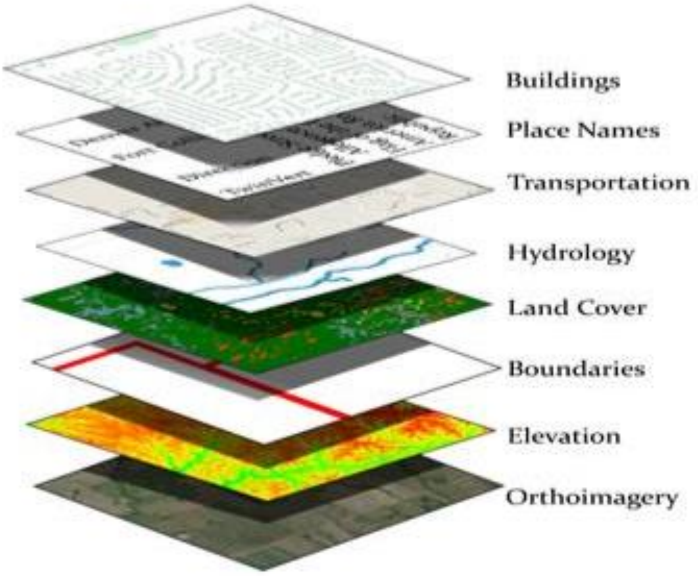


Figure 1.5. GIS Model (Raju 2003)

Utilization of GIS range from indigenous people, associations, research organizations, environmental scientists, health associations, land use planners, companies, businesses, and government agencies at all levels. In a more general sense, GIS gives the opportunity to examine and is a system that helps to make the best decisions based on this investigation (Raju 2003).

1.7. Definition of the problem

The Syrian humanitarian conflict started out on 15 March 2011. Millions of civilians have left their home, many of them were displaced, a lot of them passed away as well. Individually, displaced people are encountering difficulties in terms of housing and sheltering solutions, providing health services, food and nutrition, and other urgent needs in such disaster. In this way, we concentrated on determining optimized solution of housing problems throughout defining the shelter locations within a region of northern Syria/Idleb taking into account all related objectives and constraints from the beneficiaries' perspective; as allocating the most vulnerable affective civilians to those selected shelters.

Unfortunately, authorized data from the region were not available due to there is no authority can provide such a data. As well the decision makers have various knowledge background, different countries and opinions.

1.8. Purpose of the Study

This thesis aims to choose limited shelters within candidate ones and allocate the most in need demand nodes to those chosen shelters in the conflict areas in accordance with the humanitarian context. Consequently, by the help of this thesis, the chosen shelters are determined. Demands are allocated to the selected shelters utilizing multi-objective criteria from the humanitarian perspective.

This study considers for each demand nodes; the number of IDPs at each, crucial vulnerability criteria. While for each shelter; capacity of shelters, fixed costs, running cost, cash for work are considered.

Utilizing the techniques of GIS, the distances between nodes and shelters are determined using origin-destination (OD) cost matrix, throughout a real roads network that has been collected within the targeted area.

There are nine objective functions: maximizing covering, minimizing cost, maximizing cash for work, maximizing the four vulnerability criteria, maximizing the number of facilities that have portable Water and Sanitation hygiene (WASH) facilities and maximizing the number of facilities with future scale-up flexibility.

Simultaneously, there are two constraints: shelters' capacities and a distance to allow nodes to be allocated by a shelter. The study uses field observations and interviews to provide the principal data sources. In this research, a new four-stage approach for shelter planning is developed and implemented to obtain the optimal results. Moreover, sensitivity analysis has been employed to check the system impact on changes in the inputs.

1.9. Scope of the Study

The scope of this study includes the following activities:

1- Collecting data from the targeted region in terms of distribution of affected people and features of candidate shelters to understand the context there since there were not official authority can provide such a data.
2- Updating the situation of roads network to be utilized in the find out the distances between demands nodes and shelters' locations and avoid the risky streets.
3- Holding focus group discussions with the beneficiaries' representatives and decision makers to defining the objectives and constraints.
4- Prioritizing the goals from the beneficiaries' perspective.
5- Building the model utilizing the weighted goal program.
6- Validation the model using numerical and real case studies.
7- Solving the model and study the impact of changing the inputs utilizing sensitivity analysis.

1.10. Original Contribution of the Study

This study aimed to develop a multi-objective decision-making methodology that could help decision-makers identify optimal shelter locations for affected people in the conflict areas, and place the most-in-need displaced people to the selected shelters to expedite and facilitate their recovery. This study also aimed to mitigate the negative impact of such crisis and alleviate the suffering of affected people in conflict areas. The main contributions of this study can be divided into four categories:

1- The proposed methodology will provide a useful mechanism to decision-makers for analysing multi-objective problems, finding all possible alternative solutions, and seeing the extent of input changes on outputs.
2- The model has applicability to conflict areas in terms of getting the best possible solutions from a humanitarian perspective.
3- It depicts the possibility of merging a multi-objective mathematical model with GIS techniques utilizing real information.
4- Lastly, any country, authority, or institution could collect the relevant data and utilize this model; it is not just a special case study for Syria but is useful for all humanitarian contexts. While the inputs and weights may vary according to the specific context, but the proposed model could be used for similar situations in other countries.

Nevertheless, despite these papers, the level of attention of scientific studies and academic in the sector of shelter location-allocation in conflict regions is still not satisfactory. This study proposes to fill this gap and to be a useful source in such crisis regions.

1.11. Stages and Organization of the Study

This section is described under the following two headings

1.11.1. Stages of the Study

The steps to be followed in the study are as follows:

1- *Identification of Problem:* Defining the problem throughout its variables, parameters, goals and constraints.
2- *Evaluation of Previous Studies:* The previous studies were exanimated and reviewed, the gap between the previous studies and our problem were defined and contribution of the proposed study was described.

3- *Model Developing:* the steps in the proposed methodology were followed and weighted goal programming was employed.

4- *Case Study:* The developed model was employed to solve a real data through a case study in a crisis area Idleb – Syria

5- *Results and Discussion:* The results obtained from solving the problem were discussed and concluded.

6- *Sensitivity analysis and recommendations:* Sensitivity analysis was conducted to study the impact of changing one parameter or more on the proposed model.

1.11.2. Organization of the Study

The rest of thesis has been organized into four sections; in the second section "literature review" the previous related studies and articles are described, abstracted and reviewed to get benefited from them and striving to handle the problem in the most possible appropriate way; in the third "Material and Method" the way of how data in the targeted area are collected and described, then the multi-objective based methodology has been developed and validated by two data sets; last section, the "Results and discussions" where outputs are discussed, analysed and conclusion built based on these results.

2. LITERATURE REVIEW

The problem handled in this study is bilateral as it is both a facility location problem and a disaster management problem. In this section, we summarize the papers and studies in literature from these perspectives.

2.1. Facility Location Literature

After reviewing the related literature, we detected many studies about the topic. Some of the recent ones can be summed up in this way: Aiello et al. (2006) specified the Pareto-optimal solutions by adopting multi-objective constrained genetic algorithm to facility layout problem and then implemented the next selection of the optimal solution by way of the multi-criteria decision-making procedure. By this procedure, the decision maker is allowable to state his preferences based on the knowledge of the suggested solution. Quantitative objectives such as handling expenses and qualitative objectives such as adjacency and distance needs between offices are considered to be as structure-based layout model. Realistic restrictions have been taken into consideration such as the aspect ratio of departments and the outputs obtained confirm the effectiveness of the suggested method as a practical tool for the decision maker.

Ye and Zhou (2007) built a modern local genetic algorithm utilizing hybridized tabu search algorithm to systematically location planning including the objectives of material moving expenses and non-material relations necessities, according to the idea of systematic layout planning. They employed both numerical experiments as well as comparative tests which show the effectiveness of the suggested method in addressing such problems.

Singh S.P. and Singh V. K. (2011) increased the awareness of taking into account many conflicting objectives that reflect the realistic of our life, they dealt with multi-objective facility layout problem where it was formulated as q quadratic assignment problem. They introduced a new three-level AHP-based heuristic algorithm to the solution of this type of problems as well a new normalization steps and a novel heuristic technique for the constitution of objective weights were presented. The suggested approach included three levels: the first one paired comparison matrices, the consistency of matrix is obtained by AHP approach; the second level normalising matrices of qualitative and quantitative objectives and the last level calculating the objective weight for qualitative and quantitative goals.

Xu and Li (2012) tried to deal with dynamic, conflicting multi-objective and uncertainty of construction site layout planning issues. They suggested a Fuzzy random multi-objective model taking into consideration the goals of minimizing the total expenses of facility and maximizing the measure paths amongst the high-risk buildings and the high-protection buildings, in order to reduce the likelihood of safety or environmental accidents; by utilizing a fuzzy stochastic multi objective decision-making approach based on swarm optimization algorithm. They implemented the approach to the Longtan hydropower construction project to demonstrate the effectiveness of the suggested model.

Hathhorn et al. (2013) addressed a multi floor plant layout problem by adjusting a linear approximation system to present the size of each section. In that study, the number and the location of lifts, the number of levels in the facility, overall length, and width of the building, the capacity, and position of each department were all modelled as decision variables. They considered two objective functions in the model; minimizing material handling expenses and set up costs of facility building, A lexicographic ordering technique was employed and numerical experiments were utilized to deal with multi goals.

Emami and Nookabadi (2013) emphasized on considering the layout problem as a dynamic problem with the goals: minimizing the sum of the re-arrangement and material moving expenses but to be used as distinct goals functions and permitting the decision makers utilizing their own views in the model as well they aimed at maximizing adjacency scores between the facilities in the layout. Therefore they introduced a multi-objective model as a complex combinatorial optimization problem for the dynamic facility layout problem. As a result, the tests showed that the population based metaheuristic approaches were beneficial tools in getting responses the handled model.

Matai (2015) presented a modified simulated annealing approach to multi-objective facility layout problem with various objective weights constructed by decision maker. The proposed approach made the process of designing the facility independent of the decision-maker, it handled both the qualitative and quantitative objectives. Computational outputs showed the effectiveness of suggested heuristic approach compared with others available before while the comparisons have conducted in terms of quality of obtained solutions and time required for computation as well, it showed the efficiency and effectiveness of suggested revised simulated annealing approach.

Xu et al. (2016) adopted a new fuzzy multi-objective decision-making model to make a positively contribution to the dynamic construction site layout planning area, where it was complex due to the unique issues related to enhancement of safety and productivity. They built a hybrid optimization model which employed fuzzy numbers and fuzzy logic to describe the proximity relationship between temporary facilities. Two major phases were presented to represent knowledge throughout: 1) an optimization model that took into account both dynamic and uncertainty elements; 2) application of that to a case study. A simulated annealing-based genetic algorithm was proposed to solve the multi-objective model as well the case study. The computational process was conducted to showed the practicality effectiveness of the suggested method.

Li et al. (2017) purposed to specify the optimum locations for China's strategic petroleum reserve storage sites in their study. Sometimes policy makers are not able to select the most appropriate locations strategically due to the complexity in the sites' choosing; and in line with this, they proposed a multi-objective programming model which took into consideration both the minimum response time and minimum transportation cost based on reasonable assumptions and related restrictions. The criteria influencing sites' selecting are defined and potential demand points and candidate sites were determined. Estimation and suggestions were conducted for the selection of China's future storage sites based on the outputs of this model, to be used as a reference for decision makers.

2.2. Shelters in Disaster Management

Another aspect of this study is disaster management which contains either natural or human related disasters. In literature, there are various papers in this area; however, we will present a brief summary here about the literature review in topics related to shelters locations in disaster management.

Turner et al. (2009) aimed to categorize and analyse the links among shelter circumstances and reported frequency of certain signs in seven temporal camps and five permanent shelter projects in the southwest of Sri Lanka. Analysis within the study demonstrated that living circumstances were importantly poorer than in temporal camps than permanent housing projects for every criterion researched; excluding 'having a leaking ceiling'.

Subasinghe (2013) obtained a connection between total and partial desertion of transitional houses following the 2004 Indian Ocean tsunami in Sri Lanka, by investigating different types of place-based discussions. Discussions which caused verbal and physical violence among evacuees were taken into consideration in the study and these were reported during the foundation of temporal shelters.

Kranz et al. (2014) investigated four regions in the Darfur region, Sudan which contained the main and most dynamic IDPs' camps in the region. The study purposed to find out the effect of camps for IDPs on their neighbouring environment by performing time series analyses of medium-resolution satellite data over a long period.

Curry et al. (2015) specified the lessons discovered throughout the first 2,5 years of performing the evolving promoting to family planning which assisted government health systems to present family preparation aids in 5 crisis-affected contexts (Chad, Democratic Republic of the Congo, Djibouti, Mali and Pakistan).

Abdelmoneium (2015) investigated the difficulties and challenges that IDPs in Khartoum-Sudan faced in meeting their basic needs of shelter and health, finding out the results which the basic needs of displaced families were not met. The factors that interrupted families in reaching to shelter and health supplies were discussed by using empirical data within the study.

Humayun et al. (2016) evaluated the mental health needs in monthly camps for a period of six months in Bannu, Pakistan. Within the study, mental health care was offered to 680 people who participated to camps by a multi-disciplinary team and as a consequence common mental health estimates were acquired.

Kisindja et al. (2017) researched the family designing consciousness and shortages between internally displaced women staying in the Mugunga camps in North Kivu, eastern Democratic Republic of Congo. For this purpose, a cross-sectional questionnaire of 14-15 aged women in Mugunga camps was applied through March 2014, with acquiring descriptive statistics.

Lagos-Gallego et al. (2017) evaluated the prevalence and differences of Post-Traumatic Stress Disorder (PTSD) in population and IDPs in Colombia, which had the biggest number of IDPs worldly, throughout 2009-2012. By collecting data from the National Health Records System (RIPS) in both communities, PTSD incidence rates and incidence rates proportions were calculated for both communities.

2.3. Disaster Management and Facility Location

In addition to those literatures above, within this study, we examined the literature combining two perspectives together: facility location and disasters. In this section, we particularly summarize the papers with shelter locations in disaster situations, as it is the focus of this study.

Sherali et al. (1991) developed both a planning and an operational computer-based tool through a real location-allocation model. This model choosed a set of candidate shelters from among a candidate set of admissible alternatives in a manner feasible to available resources, and prescribed an evacuation plan which minimized the total congestion-related evacuation time. An extraneous flow was also superimposed on the network in order to represent the traffic of evacuees not using the designated shelters as destinations. The formulated model was a nonlinear mixed-integer programming problem, for which they developed a heuristic and an exact implicit enumeration algorithm based on the generalized Benders' decomposition method.

Kongsmsaksakul and Yang (2005) studied optimal shelter locations for the flood evacuation planning. They assumed that the authority could control the traffic in certain part of the network while the evacuees choose which shelter to go and by which route. The shelter location problem was posed as a Stackelberg game, consisting of the leader defining the shelter locations to minimize the total evacuation time and the follower selecting the destination and route to evacuate. Then the issue was formulated as a bi-level programming. The upper level problem was a location problem that modelled the authority’s decision. They presented a combined distribution and assignment (CDA) model to evacuees’ decision as the lower level problem. As a result, the issue was solved utilizing genetic algorithm. Numerical example with a real-world network was given to show the application of the suggested model.

Horner and Downs (2010) focused a major aspect of handling hurricane disasters by managing the flow of goods delivery to people in need by a various capacitated warehouse location model which is utilized to manage the flow of shipments' goods to persons in need. The results depicted that the criteria defining people's reachability to relief goods were affected by both the distribution infrastructure and conjectures associated with the population assumed to be in need of assistance. The model is employed with policies set in Florida's Comprehensive contingency plan and tested in a smaller region in northern of Florida. Scenarios explored the effects of alternate distribution strategies on the provision of relief.

Wei et al. (2012) made a comparison between the maximum covering and set covering location problems' advantages and disadvantages to make a decision for urban shelter location in small/medium-sized cities. They presented a qualitative and quantitative method to the urban shelter decision problem to define uncovering requirement places and unmet service need. Later they developed an alternative plan for the decision and the most suitable scheme was determined to adapt to the different strategies in considering the equity and efficiency of emergency rescue facility. The model incorporated the location set covering issue and maximum covering problem with numerical examples. The study discussed the solution approach of the model and some solution strategies. Along with the proposed method, cost and benefit factors were taken into account.

Chen et al. (2013) developed a three-level hierarchical location model for optimization the arrangement of earthquake shelters, considering temporal variance of people's needs. The article implemented the model in region with real-world details based on the optimization outputs derived from context of GIS. They have found that the procedure quality of the earthquake response was not only related on the placement strategy of shelters, but more crucial on the expenses restrictions imposed on the planning and construction of these shelters. A trade-off balance between budget and evacuation efficiency was conducted to help policy makers consider both the geographical and financial aspects of the arrangement of shelters in emergencies.

Abounacer et al. (2013) intended identifying the number, position and task of needful Humanitarian Aid Distribution Centers (HADC) within the scope of the disaster area. Hence, they introduced a multi-objective location-transportation model for the purposes of minimizing total transportation length from the delivery centres to the demand sites, minimizing the number of agents (first-aiders) required to open and to manage the chosen distribution centres, and minimizing the non-covered demand for all demand sites inside the affected area.

Bozorgi et al. (2013) presented a multi-objective robust stochastic programming approach for disaster relief logistics under uncertainty. In this approach, not only demands were taken as the uncertain variables but also expenses, supplies and transportation. Furthermore, the model considered uncertainty for the locations where those demands might need and the possibility that some of the pre-positioned goods in the relief distribution centre. The multi-objective model tried to minimize the sum of the expected value and the variance of the total cost of the relief chain while penalizing the solution's infeasibility due to parameter uncertainty. Simultaneously, the model aimed to maximize the affected areas' satisfaction through minimizing the sum of the maximum shortages in the affected areas. Considering the global evaluation of two objectives, a compromise programming model was formulated and solved to obtain a non-dominating compromise solution. Finally, a case study was presented utilizing robust stochastic optimization approach for disaster planning scenarios in an earthquake area of Iran.

Barzinpour and Esmaeili (2014a) proposed a new multi-objective mixed-integer linear programming model for preparation planning phase of disaster management. The devoloped model was inspired from a real case study of an urban district in Iran, which considered both humanitarian- and cost-based objectives in a goal-programming approach. Proactive damage estimation result of Risk

Assessment tool for Diagnosis of Urban regions against Seismic Disaster software was used as an input in order to allocate affected people to local emergency management facilities that should be established. The location allocation model was solved and mathematical results showed that the efficiency of the decisions improved.

Lauras et al. (2014) defined the problem statement of the research work as the capability to design a consistent network that would be able to manage adequately the disaster response despite of potential failures of resources and infrastructures. The research work consisted in proposing a location-allocation model in order to enhancing the humanitarian response efficiency such as cost minimization and effectiveness such as non-served beneficiaries minimization. A stochastic mixed integer program was proposed to reach this goal. A numerical application regarding the management of the Peruvian earthquakes relief network was proposed to illustrate the benefits of our proposition.

Barzinpour and Esmaeili (2014b) prepared a proper response program to be considered early activities of disaster management. Then they stimulated a practical case study of an urban region in Iran to help the local authorities which are responsible for disaster-related operations such as providing emergency shelters, equipment, and relief supplies in order to reduce sufferings of affected people. They proposed a new multi-objective mixed-integer linear programming model for the preparation planning stage of disaster management. The proposed model took into consideration both humanitarian and cost-based objectives using virtual zones.

Xu et al. (2016) developed a multi-criteria constraint location model to solve the location problem which contained seven policies for placing earthquake evacuation shelters utilizing an iterative method. The model was based on GIS and comprised of three phases: choosing candidate shelters, analysing the spatial coverage of applicant shelters and specifying the shelter locations. Eventually, a case study was employed to show the applicability of this multi-criteria model and the related solution method for its effectiveness in earthquake evacuation shelters planning.

After the Syrian refugee's mitigation to Turkey and together with the need for additional refugee camps, Çetinkaya et al. (2016) proposed a three-step solution approach: specifying different culture, infrastructure and risk associated rules for 10 south-eastern cities in Turkey (which are quite near to border of Syria). They inputted these criteria data to GIS application to allocate a refugee camp positioning availableness score; prioritised criteria by Fuzzy Analytic Hierarchy Process (FAHP) and organized possible refugee camp sites by Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).

Boonme et al. (2017) integrated a heuristic algorithm and an exact algorithm in order to deal with crisis humanitarian logistical obstacles based on data modelling types and problem types employing a questionnaire. The paper purposed to research the pre- and post-disaster conditions associated with facility location like the location of distribution centres, warehouses, shelters, etc. where the survey tested four main highlighted problems: deterministic facility location problems, dynamic facility location problems, stochastic facility location problems, and robust facility location problems. Taking into consideration the type of facility location, type of data modelling, type of crisis, restrictions; goals and methods utilized to solve the proposed problem as well as the presented case studies.

Vaz et al. (2017) aimed to interpret optimum micro-spatial for refugees to begin their lives in Toronto, by employing a spatially-explicit approach and interlacing key variables such as accessibility to employment; closeness to food, clothing, healthcare and English language classes. A combinatory criterion was designed to assess the most adequate liveability within the Toronto region. The micro-spatial models proposed an integrative vision of weighted to assess the spatial perspective brought by GIS. It is summarized that suburban areas around major cities hold a significant potential for refugee habitats, suggesting the integration of regional intelligence paradigms in the spatial planning and regional decision support systems of governmental and policy interaction.

Zhao et al. (2017) implemented risk mitigation and disaster operation management to improve the responses to disasters throughout transforming existing open spaces into emergency shelters to provide essential life support and an agent of recovery in the wake of disasters. They considered both the buildings' post-disaster condition and the human choice factor that affect evacuees' decision, and suggested a forecasting method to estimate the time-varying shelter demand. Later they formulated an integrated location-allocation model that is implemented sequentially; firstly, they used an emergency shelter location model to satisfy the time-varying required demand in a given region with a goal of minimizing the total setup cost of locating the shelters, secondly an allocation model that allocates the evacuees to shelters with a goal of minimizing their total evacuation distance was utilized. They also enhanced an effective algorithm to solve this model. Eventually, they employed a case study of Shanghai, China.

Li et al. (2017) matched the time-varying demand with the shelter planning by projecting the hierarchical shelters that provide different level services. First, the varying number of the victims in shelters during the post-earthquake period was estimated, and then locations model for emergency shelters with a nested hierarchy and also model the allocation of victims among shelters was built. Furthermore, an efficient hybrid cross-entropy method was employed to solve the location model and develop a better victim allocation scheme with a swap move to overcome the drawbacks of other allocation schemes. The empirical results from application to the District in Shanghai-China showed that emergency shelter planning based on a time-varying demand could reduce the construction cost of shelters and the averaged evacuation distance travelled by the victims, compared to the current policy based on the unvarying demand.

X. Zhao et al. (2017) utilized mathematical models, allied with suitable optimization algorithms, to define the locations at which to construct disaster shelters and allocate the population to them. This paper compared the use of two optimization algorithms, namely a genetic algorithm and a modified particle swarm optimization. Both have advantages and disadvantages when solving the disaster shelter location-allocation problem.

Bayram and Yaman (2018) suggested a scenario-based two-stage stochastic evacuation planning model that optimally placed shelter positions and assigned evacuees to nearest shelters and to shortest paths within a tolerance to minimize the expected total evacuation time. The model considered the uncertainty in the evacuation required and the situation of street network to shelter positions. Eventually, a case study for a potential earthquake in Istanbul was employed and comparison of the performance of the stochastic programming solutions to solutions based on single scenarios and mean values were presented.

Mollah et al. (2018) concerned about the humanitarian logistics and relief distributions during disaster, keeping in mind the cost and time aspects. The first priority was to attend the most affected regions for reducing casualties. Then, the humanitarian operations needed to be carried out efficiently and effectively. People of some regions also might require temporary shelters. Unlike other disasters, flood related disasters also gave rise to water-borne and vector-borne diseases where relief materials must be quickly distributed along with the reallocation operation. Here, they have tried to address the issues of evacuation of people, their reallocation to comparatively safe location and distribution of relief goods by developing a cost optimization model. They proposed two methodologies for the problem based on mixed-integer programming technique and genetic algorithm. The solutions have been showed using a case study and the results of the two methods have been subsequently compared. The result showed that, performances of both the techniques were good in the situation.

Song et al. (2019) showed that the prevailing Multi Criteria Decision Making (MCDM) methods utilized in related sheltering have poor mechanism dealing with inconsistent data, meanwhile, they are commonly lack of flexibility. In view of the above-mentioned facts, an innovative integrated method was developed in this study. The proposed approach combined the strength of the qualitative flexible multiple criteria method in manipulating multiple evaluation criteria with heterogeneity and the advantages of interval rough number in fuzzy information environment. Moreover, social and environmental criteria which are of great significance whereas rarely mentioned were taken into consideration when shelter sites were evaluated. The competence and feasibility of the proposed method was showed in a case study in the settings of Wenchuan County to verify the validity of the proposed method and provided a comparative analysis with other related approaches.

Shavarani (2019) aimed to find the best topology for both relief places and recharge centres to cover a large-scale region with minimum and feasible incurred costs and waiting times. In this regard, a multi-level facility location problem (FLP) was used to find the optimum number and position of relief places and refuel centres. A hybrid genetic algorithm was presented to solve the model. The effectiveness of the algorithm was tested throughout a case study. The suggested method delivered high efficiency and responsiveness of the humanitarian relief management. The coverage area of the drones was widened by refuel centres where the total costs of the system were reduced and the time as well, which is a crucial factor in survival rate in the humanitarian situations.

Kınay et al. (2019) aimed investigating multi-criteria modelling frameworks for discrete stochastic facility location problems with single sourcing assuming that demand was stochastic and also that a service level was showed. This situation was modelled using a set of probabilistic constraints, considering a minimum throughput at the facilities to justify choosing them. They investigated two paradigms: vectoral optimization and goal programming. Additionally, they discussed the joint use of goals that were related in the context of some humanitarian criteria. Then they applied the general modelling frameworks proposed to the so-called stochastic shelter location problem, emerging in the context of preventive disaster management. Two real benchmark data sets were employed. The results showed that considering uncertainty and multiple objectives in the type of facility location problems leads to solutions that may better support decision-making.

Ozbay et al. (2019) targeted locating shelter sites and allocated the affected people to the established set of shelters in cases of secondary disaster following the main earthquake by three-phase stochastic mixed-integer programming model. In each phases, before the uncertainty in that stage (that was the number of victims needing a shelter) was resolved, shelters were established, and after the uncertainty was resolved, affected people were selected to the established set of shelters. The assumption on nearest allocation of victims to the shelter sites implied that the allocation decisions were finalized immediately after the location decisions, hence both location and allocation decisions could be considered at the same time. And, when people were selected to the nearest established shelter sites, the site capacities might be exceeded. To handle the risk, inherit to the demand uncertainty and capacities, conditional value-at-risk was utilized in modelling the risk involved in allocating people to the established shelter sites. As a case study, dataset on Istanbul/ Turkey were presented to emphasize the necessity of considering secondary disaster.

Table 2.1 shows a comparison between the previous studies and the proposed study in terms of approach utilized, objective, facility type, disaster type and case study.

Table 2.1. Comparison between the previous studies and the proposed study

Authors	Model/ Approach Used	Objectives	Facility Type	Disaster Type	Case Study
Bozorgi et al. (2013)	A multi-objective robust stochastic programming approach for disaster relief logistics under uncertainty	Maximize the affected areas' satisfaction	Relief Distribution Centre	Earthquakes	Iran
Barzinpour and Esmaeili (2014a)	Multi-objective mixed-integer linear programming model	Humanitarian Objective Cost-based objectives	Distribution Centres	Earthquakes	Tehran
Lauras et al. (2014)	Stochastic mixed integer program	Cost minimization Non-served beneficiaries minimization	Relief Network	Earthquakes	Numerical Application
Xu et al. (2016)	GIS based multi-criteria constraint location model with 7 policies	Coverage	Evacuation Shelters	Earthquake	Numerical Application
Çetinkaya et al. (2016)	Three-step solution approach Gis, fahp, topsis	Infrastructure Culture Risk	Refugee Camps	General	South-Eastern Turkey
Vaz et al. (2017)	Spatially-explicit approach	As accessibility to employment; closeness to food, clothing, healthcare and English language classes	General (Housing - Sheltering)	General	Toronto
Zhao et al. (2017)	Integrated location-allocation model that is implemented sequentially	Minimizing the total setup cost Minimizing their total evacuation distance	Emergency Shelters	Earthquake	Shanghai, China

Li et al. (2017)	Nested hierarchy and also model Hybrid cross-entropy method Time-varying demand	Cost of shelters Evacuation distance	Shelter	Earthquake	Shanghai-China
Bayram and Yaman (2018)	A scenario-based two-stage stochastic evacuation planning model	Minimize the expected total evacuation time.	Emergency Shelters	Earthquake	Istanbul
Mollah et al. (2018)	Mixed-integer programming technique and genetic algorithm	Cost and time aspects	Humanitarian Logistics And Relief Distributions During Disaster	Flood	Numerical Application
Shavarani (2019)	Hybrid genetic algorithm	Number and position of relief places and refuel centres Incurred costs and waiting times	Relief Places And Recharge Centres	Earthquake	Numerical Application
Kınay et al. (2019)	Multi-criteria modelling frameworks With single sourcing assuming that demand was stochastic Vectoral optimization and goal programming	Humanitarian criteria	Facility Location Problems	General	Numerical Application
Ozbay et al. (2019)	Three-phase stochastic mixed-integer programming model	Cost and time aspects	Shelters	Earthquake	Numerical Dataset

Hallak et al. (2019)	**Mixed integer model utilizing weighted goal programming**	**Humanitarian criteria (vulnerability criteria) Cost Flexibility of building Maximal covering**	**Shelters**	**Conflict**	**North of Syria**

3. MATERIAL AND METHOD

3.1 Collecting Data from the Targeted Area

Within the proposed study, the data is collected through these sources:

1. Direct beneficiaries through focus groups discussions (FGDs), field visits and surveys,
2. The discussions with people on the ground who know well what is really going on in the targeted area. The purpose of these discussions and meeting is to gather information and data from various groups of affected populations like residents, professionals, and community leaders. These groups of people with their dedicated knowledge and understanding the situation on the ground, can give an insight into the matter of the issues/problems and suggest proper solutions.

The followings are three common methods employed to conduct and gather information and data from the ground:

- Talking with beneficiaries and representatives within telephone,
- Conducting a meeting with them “Face-to-Face”,
- HNO-2018 “Humanitarian Needs Overview”: The Strategic Steering Group (SSG) and humanitarian implementing organizations, that’s coordinating under the framework of Whole of Syria (WoS), provides this document. The document gives the SSG's common and general information about the situation in Syrian crisis, in addition to the estimated number of people in need and the most pressing humanitarian needs (Ocha 2017).

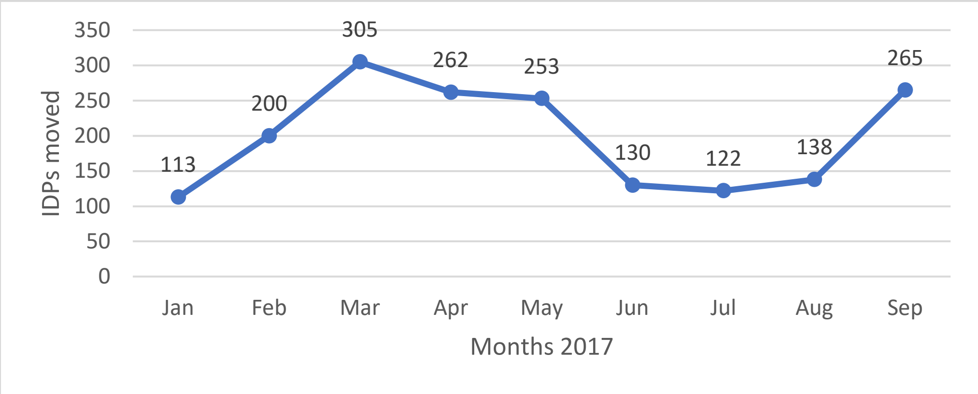


Figure 3.1. IDPs movements per month (in thousands)

Figure 3.1 demonstrates the movements of IDPs per month in thousands in 2017 According to HNO, where approximately 6,550 persons were displaced daily, the average of displacement between January and September 2017.

3.2. Demography, IDP's and Shelter Assessment in Idleb Governorate

By reaching the eighth year of the Civil War, affected people continue to suffer from negative effects of crisis and destructions that affected their area. While this situation ignores civilians' life, as well IDPs amount in need rises every day.

Before studying for permanent solutions about this subject, analyzing the situation in region and acquiring real data are considered as a capital importance. In this direction, this paper examines the shelters and IDPs circumstances in Northern Syria, Idleb governorate. The demographics, sector severities, vulnerability ratios, humanitarian factors, reasons behind displacement, tracking of IDPs and other statistics about the subject are addressed in the study throughout a needs assessment.

In this assessment we demonstrated the situation of shelters and IDPs in north of Syria-Idleb governorate. 425 families and key informant are included in the statistical sample that the findings are collected from, these data were collected from

26 sub-districts in the governate which was collected between December 2017 and February 2018.

Findings are representative of assessed communities in each sub-district at a 95% confidence level and 5% margin of error.

In this section of study, we represent the following findings respectively:

1. Findings of demographics and IDPs amounts,
2. Vulnerability rates,
3. Displacement preparing time,
4. Information about displacement,
5. Displacement's reasons,
6. Shelter type and occupation arrangement
7. Tracking of IDPs from first origin to recent destination,
8. Sector severity in Idleb sub-districts.

3.2.1. Demographics and IDPs Amounts

The estimated total population across the Idleb governorate is 1,925,226 people; estimated total population of assessed sub-districts is 1,835,742 people (NPM 2018) and estimated total IDPs in sub-districts is 908,929 people (Ocha. 2017). Figure 3.2 shows the demographic distribution of IDPs in terms of age groups and sex.

Figure 3.3 presents that approximately 104,000 of IDPs living in Idleb governorate in 331 different communities; 63,000 of them (60%) have vulnerability criteria.

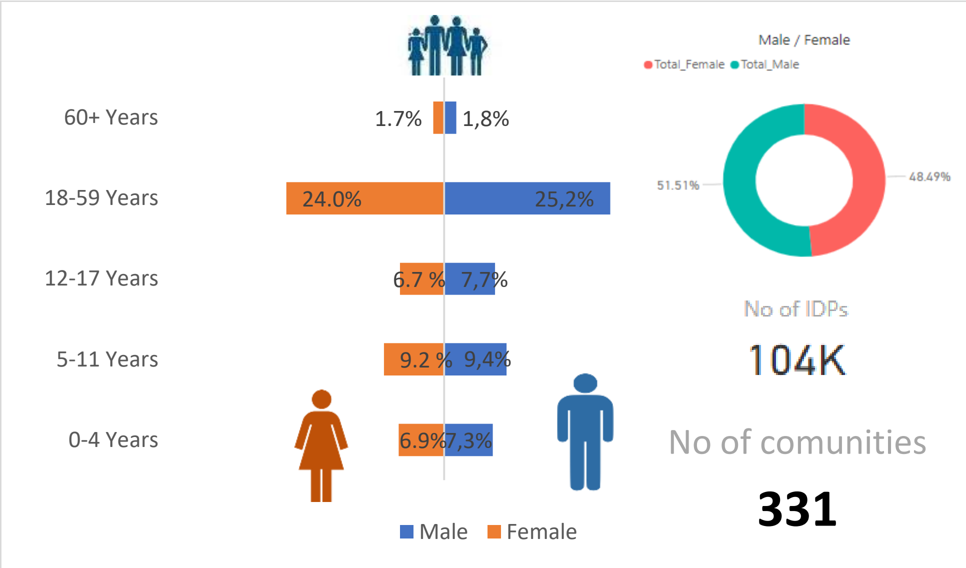


Figure 3.2. IDPs amounts in the assessed communities

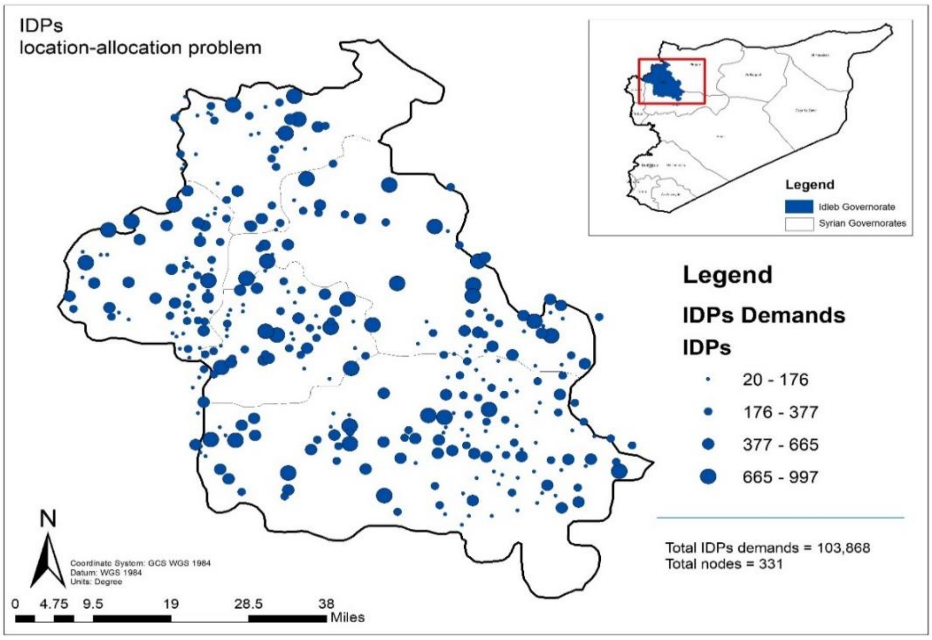


Figure 3.3. IDPs amounts in the assessed communities

3.2.2. Vulnerability Ratio

Four types of vulnerability have been collected within the assessments as following:

1. Disability,
2. Chronic Diseases,
3. Pregnant/Lactating Women,
4. Children Attending School.

Figure 3.4 shows vulnerable IDPs in the Idleb. Throughout these findings approximately 60% of the whole IDPs in Idleb are vulnerable, therefore, projects should be designed and implemented to address their problems, alleviate their sufferings and remove any obstacles that may be faced during the integration into society and protect them from any kind of abuse.

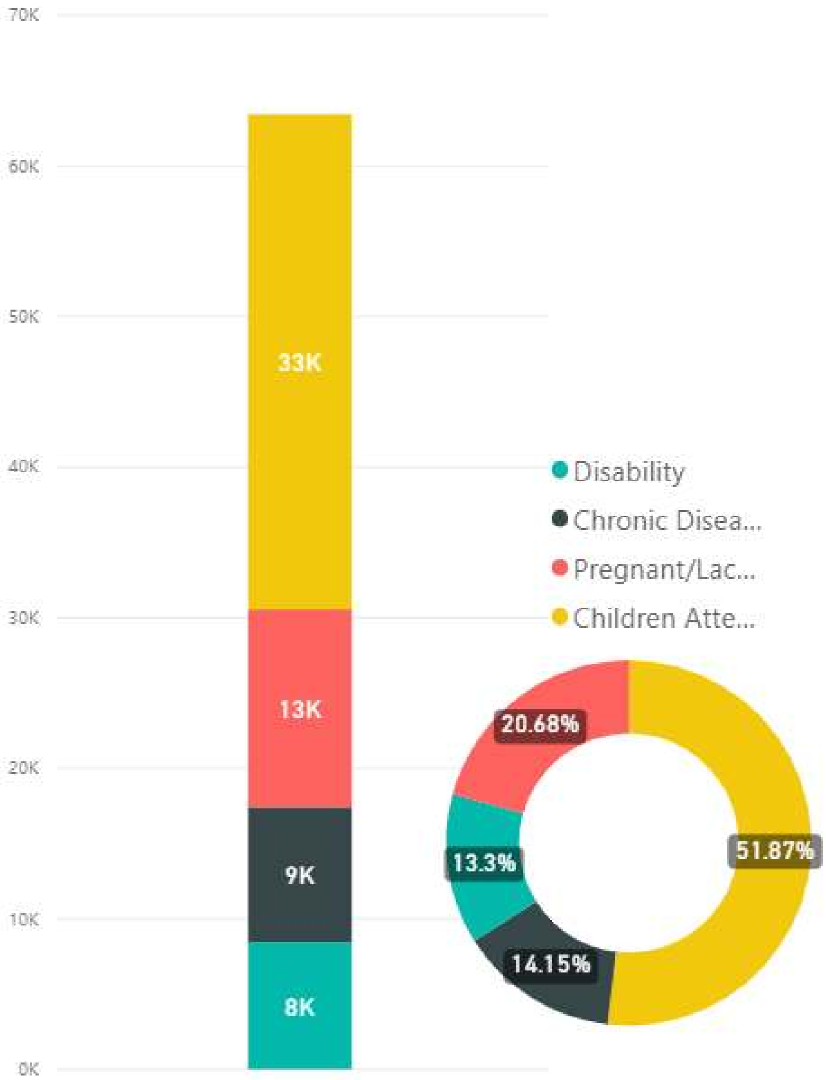


Figure 3.4. Vulnerable IDPs in Idleb (in thousands)

3.2.3. Time to Prepare before Displacement

Figure 3.5 represents the preparing time before displacement and for those IDPs, the amount of time to prepare before most recent displacement has measured in 4 categories:

a) Preparation within a day,
b) Preparation between (> day and less than week),
c) Preparation between (> week and less than month),
d) Preparation more than a month.

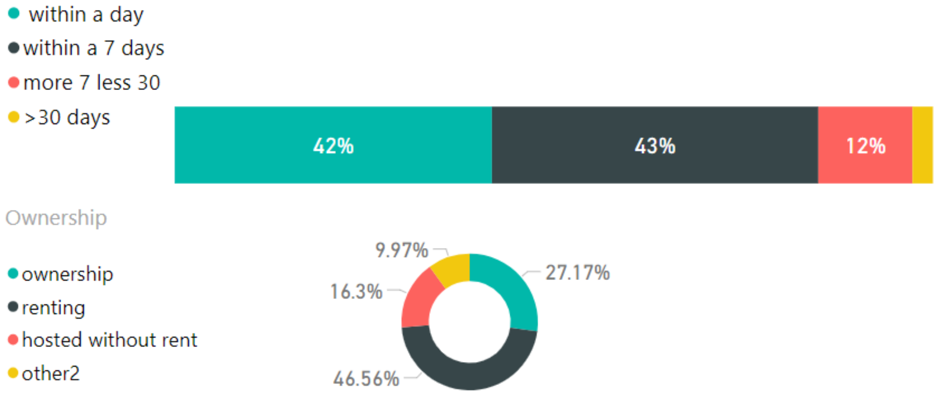


Figure 3.5. Preparing time before displacement

Approximately 85% of IDPs have prepared within a week before displacement across assessed areas and most of them are paying rent to places where they are moving to.

3.2.4. Displacement Information

The findings about displacement information are summarized as; times displaced, average time in the current location (years) and average time since the first displaced to the current location (years) which are demonstrated with Figure 3.6, 3.7 and 3.8 respectively.

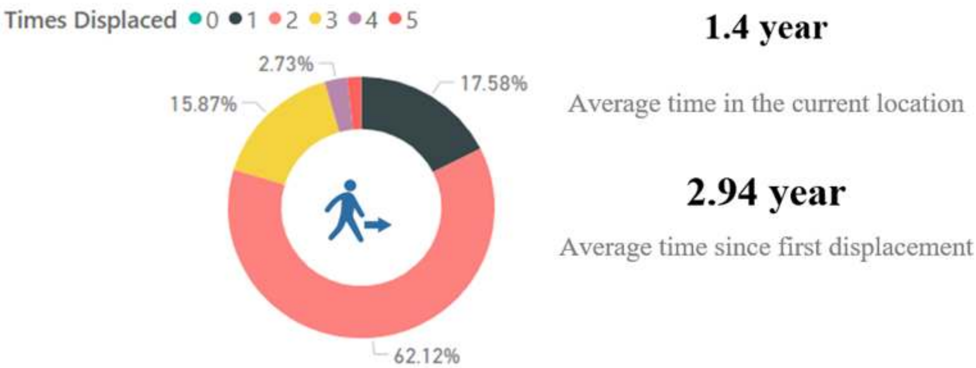


Figure 3.6. IDPs times displaced

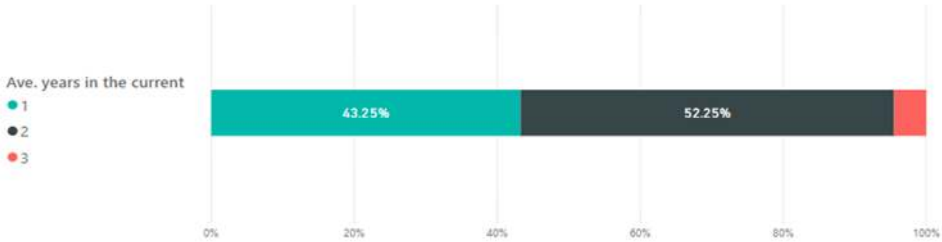


Figure 3.7.Average time in the current location (years)

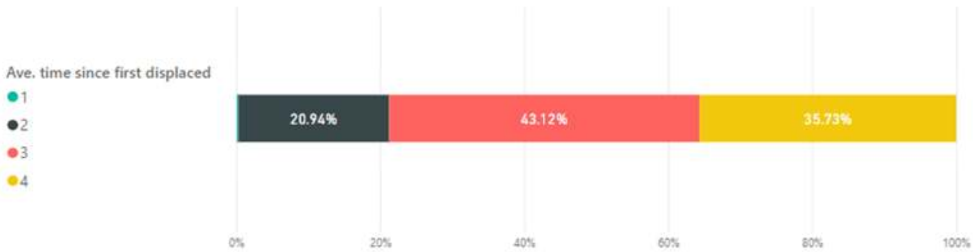


Figure 3.8. Average time since the first displaced to the current location (years)

The data showed that most of the IDPs in Idleb governorate had displaced 2 times or more since the conflict commenced, while the average time that they stayed in the current location is approximately 1.4 years and average time since first displacement from the origin place to the current place is approximately 2.94 years.

3.2.5. Reasons Behind Displacement

Reasons that lead people to be displaced had divided into four categories:

1. Frequent bombing (which is coming from different sources as aerial bombardment, shelling, car bomb/explosion or flyover),
2. Direct conflict (such like clashes or gunshots between armed groups),
3. Improve income (since most of the people had lost their living income),
4. Safe & security (arson/fire, intimidation of people, kidnapping or looting/theft).

The findings are shown at Figure 3.9. The assessment showed that reasons behind the most recent displacement are frequent bombing, airstrikes then the direct conflict between the armed groups.

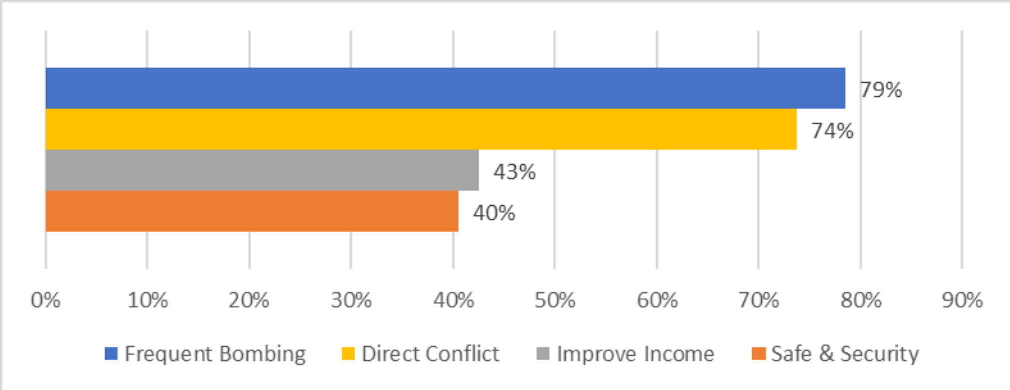


Figure 3.9. Reasons behind Displacement (multi-selection is allowable)

3.2.6. Shelter Type and Occupancy Arrangement

Shelter types are assessed as being solid finished house, solid finished apartment, informal setting or other types. Occupancy arrangements are evaluated according to ownership, renting, hosting without rent and other arrangements. These results are given at Figure 3.10.

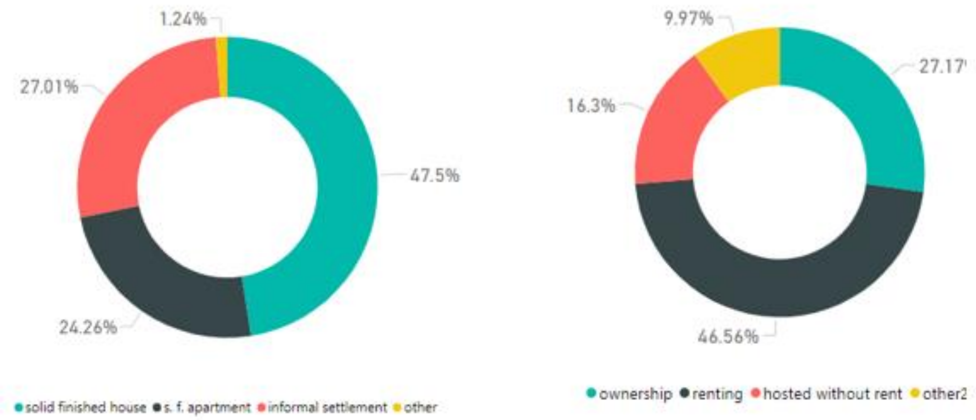


Figure 3.10. Different shelter & ownership types

3.2.7. Tracking of IDPs from First Origin to Recent Destination

In this section, in order to provide the origin area that IDPs moved from at the beginning of the conflict, we have asked this to them and wrote down the destination that they placed in. The results are given at Figure 3.11.

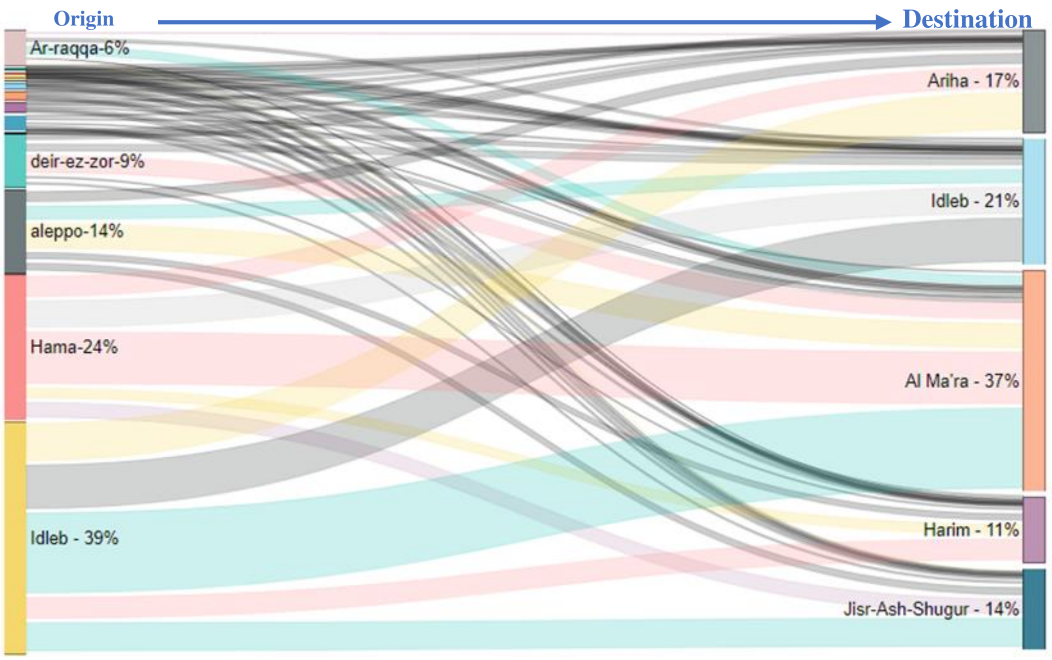
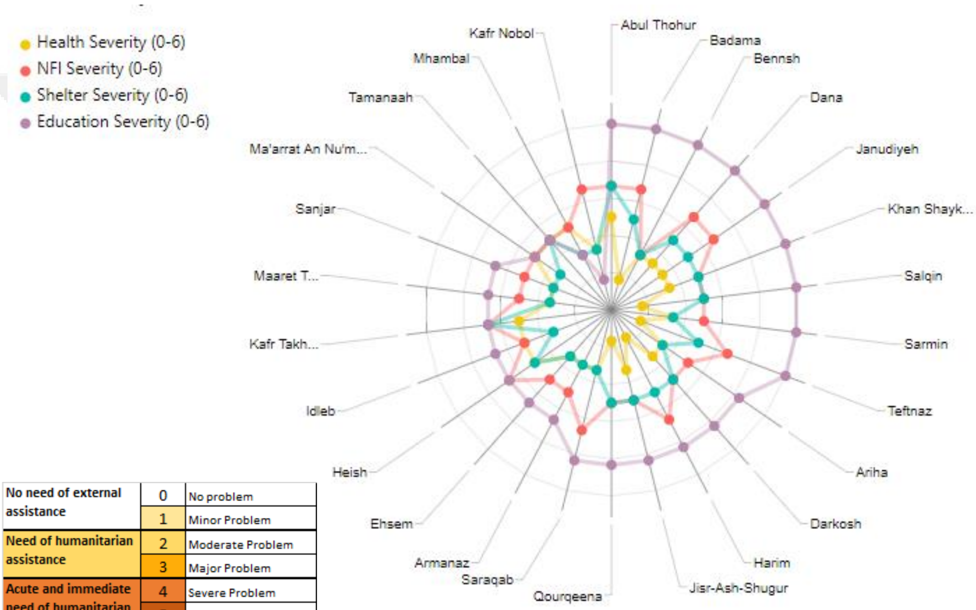


Figure 3.11. IDPs moving ratio from the origin to destination

Tracking of IDPs in Idleb governorate proposed that the first origin of IDPs came at most from Idleb, Hama, then Aleppo and the recent destination that they displaced to at most Al-Mar'a, Idleb city then Ariha.

3.2.8. Sector Severity in Idleb Sub-districts

In this section, four sectors (health severity, non-food item severity, shelter severity and education severity) are compared as categories from 0 "no problem" to 6 "catastrophic problem". Results are shown at Figure 3.12 and showed that the most in need sector in Idleb is education, non-food items (NFI), shelter then health, respectively.



No need of external assistance	0	No problem
	1	Minor Problem
Need of humanitarian assistance	2	Moderate Problem
	3	Major Problem
Acute and immediate need of humanitarian assistance	4	Severe Problem
	5	Critical Problem
	6	Catastrophic Problem

Figure 3.12. Sector severity in sub-districts (categories from “0” to “6”)

More clarifications on the above findings are described and demonstrated through dashboard in the link (https://goo.gl/Pbng98) interactively.

3.3. Method and Model

3.3.1. Methodology

Figure 3.13 demonstrates the adopted approach used in this thesis, the aim is to choose the best shelter places in the conflict area and simultaneously allocating the most in need IDPs to those chosen shelters

As Figure 3.13 demonstrates, the approach is mainly based on direct affected beneficiaries in the targeted area since they are the most important stockholders looking forward to overcoming their sufferings from the conflict.

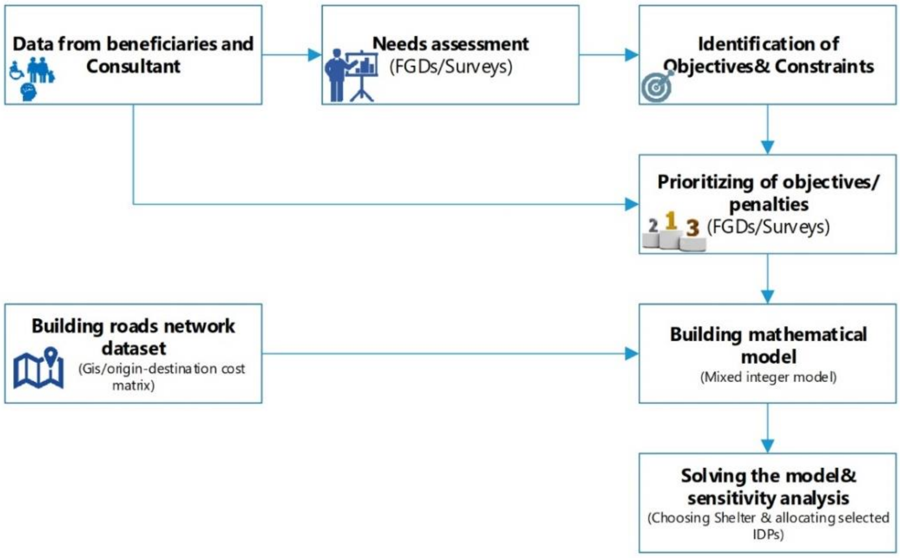


Figure 3.13. The proposed methodology suggested in the thesis (Hallak et al. 2019) .

The methodology is used mainly in four steps: the first step of the process is handling a needs assessment using FGDs, surveys, etc. to evaluate the needs and most critical factors according to all relevant direct beneficiaries in absences of authorized organizations who can consider this data within the conflict. Information and data about the governorate of Idleb are extracted from a sample of 425 families and representatives across all the 26 sub-districts within the targeted area by direct beneficiaries and key informant discussions with representatives who aware and understand what is going on in the affected community on the ground. Data was collected between 10 December 2017 and 25 February 2018. The next stage is the objectives' and constraints' identification in addition to prioritizing them according to experts and beneficiaries where they've given each object weight throughout

FGDs/Surveys starting from IDPs amount covered and cost needed objectives to vulnerability ones such as chronic diseases, pregnant/lactating women, disabilities and so on for all objectives. Then, by using GIS, the roads network database is built in the affected targeted region, and it is revised according to risk roads to determine the origin-destination (OD) cost matrix throughout the spent distance between the nodes of IDPs and locations of shelters (Stage three). Building mathematical model is the last step where a mixed integer model is proposed and solved by optimization computerized tool to select shelters and allocate IDPs in the last stage, operating sensitivity analysis, the results are presented and discussed (Hallak et al. 2019).

3.3.2. Building the Model

In this thesis, a multi objective model based on a mixed integer model is proposed which contains fixed charged cost, capacitated maximum covering and contextual humanitarian criteria in the targeted area, we can sum it up this way:

1) Humanitarian vulnerability criteria:
    a. Displaced people who having chronic diseases,
    b. Displaced people with pregnant/lactating women,
    c. Displaced people and having kids attending school,
    d. Displaced people with disabilities.
2) Having a portable WASH (WAter, Sanitation and Hygiene) facilities or not. This criterion considers the amount of WASH facilities that could be transferred to be used in another location as needed.
3) Financial factors such as cash for work (CFW): CFW is a part of costs that is related to rehabilitated the candidate shelters such as fees for non-skilled worker to fix the shelter and make it habitable to host IDPs.
4) The ability to extend and scale up the location in the near future or not. This criterion part defines the flexibility of a shelter location to be

expanded in the near future vertically by the ability to build more levels to the existing ones or horizontally the ability to build more rooms to existing ones.

The proposed model is considered the following assumptions as below:

1. Each IDPs demand community can be transferred as an entire unit or nowhere (binary amount 0 or 1 without any fraction).
2. All demands, IDPs nodes and candidate shelter location positions and their features are defined throughout the conducted needs assessment.
3. Amount of IDPs living in each demand is known and timely fixed.
4. Running expenses of locating affected people in each place is only related to the number of IDPs placed in the chosen shelter and it's independent in the targeted area. This means the expenses of placing a person to a shelter is similar to expenses of placing people to another location in other areas.
5. Positions of IDPs demand nodes are known and fixed.
6. Movable facilities of WASH and ability of extending /scaling up in the near future for each site is binary variables (0,1).
7. Distances through the renewed collected streets networks are accessible, and there are no blocked barriers.

Model Variables/Parameters:

J : Set of proposed shelter positions ; $j \in J$

I : Set of displaced people in the communities ; $i \in I$

d_{ij} : Distance from IDPs community i to proposed shelter position j (acquired throughout building a GIS-OD streets network)

M : Set of target objectives; $m \in M$

Vd_i : Amount of displaced people who have disabilities at each community i /vulnerability criteria/

Vp_i : Amount displaced women who are pregnant/lactating at each community i /vulnerability criteria/

h_i : Amount of displaced people need to be moved at community i

Vc_i : Amount of kids who are going to school at each community i /vulnerability criteria/

cr_i : Coverage range for each demand position i (acceptable distance for each node i to be moved)

Vcd_i : Amount of displaced people who have chronic diseases at each community i /vulnerability criteria/

R_j : Running cost of placing a person at a shelter place j

f_j : Cost of placing a candidate shelter at position j (Fixed cost)

Cfw_j : The amount of money needed to be given to workers for rehabilitate a shelter place (cash for work)

K_j : Candidate shelters' location capacity at each site j

p_n^+ : Penalty of not obtaining desired amount of goal linked to deviation d_n^+

p_n^- : Penalty of not obtaining desired amount of goal linked to deviation d_n^-

a_{ij} : $\begin{cases} 1 & if\ demand\ at\ node\ i\ can\ be\ covered\ by\ location\ j \\ 0 & otherwise \end{cases}$

(Covering matrix)

TG_n : the aspired amount of objective n in accordance with goal programming (Target goals)

fs_j : $\begin{cases} 1 & if\ site\ j\ has\ flexiblitiy\ in\ scaling\ up\ in\ the\ future \\ 0 & otherwise \end{cases}$

fw_j : $\begin{cases} 1 & if\ site\ j\ has\ portable\ wash\ facilities \\ 0 & otherwise \end{cases}$

Model decision variables:

Z_{ij} : $\begin{cases} 1 & if\ demand\ at\ node\ i\ is\ served\ by\ a\ shelter\ at\ location\ j \\ 0 & otherwise \end{cases}$

X_j : $\begin{cases} 1 & if\ we\ locate\ a\ shelter\ at\ candidate\ location\ j \\ 0 & otherwise \end{cases}$

d_n^- : the amount of an underachieved target objective n (Negative deviational variable)

d_n^+ : the amount of overachieved target objective n (Positive deviational variable)

Goals/ Objective functions:

$$Maximize \sum_{i\in I}\sum_{j\in I} a_{ij}\, Z_{ij}\, h_i \tag{3.1.}$$

$$Minimize \sum_{j\in J} f_j\, X_j + \sum_{i\in I}\sum_{j\in J} Z_{ij}\, h_i\, R_j \tag{3.2.}$$

$$Maximize \sum_{i\in I}\sum_{j\in I} a_{ij}\, Z_{ij}\, Vd_i \tag{3.3.}$$

$$Maximize \sum_{i\in I}\sum_{j\in I} a_{ij}\, Z_{ij}\, Vc_i \tag{3.4.}$$

$$Maximize \sum_{i\in I}\sum_{j\in I} a_{ij}\, Z_{ij}\, Vp_i \tag{3.5.}$$

$$Maximize \sum_{i\in I}\sum_{j\in I} a_{ij}\, Z_{ij}\, Vcd_i \tag{3.6.}$$

$$Maximize \sum_{j\in J} cfw_j\, X_j \tag{3.7.}$$

$$Maximize \sum_{j \in J} fw_j \, X_j \tag{3.8.}$$

$$Maximize \sum_{j \in J} fs_j \, X_j \tag{3.9.}$$

Subject to

$$\sum_{j \in J} X_j \leq P \tag{3.10.}$$

$$\sum_{j \in J} X_j \geq 5$$

$$\sum_{j \in J} Z_{ij} \leq 1 \qquad \forall\, i \in I \tag{3.11.}$$

$$Z_{ij} \leq a_{ij} \, X_j \qquad \forall\, i \in I, \forall\, j \in J \tag{3.12.}$$

$$\sum_{i \in I} a_{ij} \, Z_{ij} \, h_i \leq K_j \qquad \forall\, j \in J \tag{3.13.}$$

$$d_n^- \leq M \, y_n^- \qquad \forall\, n \in N \; for\ each\ goal \tag{3.14.}$$

M: very high positive number

$$d_n^+ \leq M \, y_n^+ \qquad \forall\, n \in N \; for\ each\ goal \tag{3.15.}$$

M: very high positive number

$$y_n^+ + y_n^- \leq 1 \qquad \forall\, n \in N \; for\ each\ goal \tag{3.16.}$$

$$X_j \, , Z_{ij}, y_n^+, y_n^- \in [0,1] \tag{3.17.}$$

The goals involved in the proposed multi-objective model are the above equations from 3.1 to 3.9, Where equation (3.1) is seeking to maximize the number of displaced people covered from the all community need, while Equation (3.2) is seeking to minimize the whole expenses which contain the fixed cost, set up expenses of rehabilitation of a shelter and the variable cost, the expenses of run a shelter in a year. Equations from (3.3) to (3.6) are seeking to maximize amount of displaced persons under the considered vulnerability criteria through placing them to the chosen housing place: where Equation (3.3) is seeking to maximize the allocated amount of displaced persons with disabilities at demand position i; Equation (3.4) is striving to maximize the amount of allocated kids who are attending educational centres at demand position i; Equation (3.5) is pursuing to maximize the allocated amount of women with pregnant/lactating at demand place i; Equation (3.6) is seeking to maximize the allocated amount of displaced persons with chronic diseases at demand place i, respectively. Equation (3.7) is striving to maximize the amount of cash for work of placing shelters, Equation (3.8) is seeking to maximize the number of shelters that have portable wash facilities and Equation (3.9) is pursuing to maximize the number of shelters that have ability of scaling up in the near future, respectively (Hallak et al. 2019).

Equations from 3.10 to 3.17 are models' restrictions. Equation (3.10) limits the number of opened shelters to be less or equal to a desired amount and higher or equal to 5. While in the Equation (3.11), the model maintain that each community can be allocated once at most; Equation (3.12) guarantees that displaced persons at the in-need community node $i \in I$ cannot be allocated unless at least one of the shelter places that the cover node i is chosen. Equation (3.13) limits each shelter place to cover a community that's demand is less or equal to its own capacity. Equations from (3.14) to (3.16) ensure that both deviations d_n^+ and d_n^- can not be equal zero simultaneously. Eventually, Equation (3.17) shows the binary variables for placed shelters and allocated communities.

Generally, in the previous studies, there are big number of methodologies that have been suggested, to solve such a multi-objective issue as mentioned in the section "Literature Review". In this thesis, weighted goal programming is utilized to address this handled humanitarian issue, where all stockholders are involved in the held FGDs including experts, beneficiaries, community representatives in the communities to identify the effect of each goal consisted of the desired target to be achieved in each objective.

3.3.2.1. Weighted Goal Programming Formulation (WGP)

A goal-programming aims to simultaneously account for different goals that are of concern to a decision-maker. It includes constraints and a set of goals that are in some way prioritized (Ishizaka and Nemery 2013). The final goal is composed of several objectives that may be conflicting such that the main difficulty becomes the modelling of the problem—namely, finding the goal and the soft and hard constraints (Ishizaka and Nemery 2013). The WGP variant is a type of goal program that allows for balancing all desired objectives. This occurs through direct trade-offs between all unwanted deviational variables by placing them in a weighted, normalized single-achievement function that contains all of the goal in just one equation. WGP is sometimes called non-preemptive goal programming. This method of goal programming affords greater flexibility via the weighted variant, where applying decision-makers' desires allows for greater "trade-off" analysis and direct comparisons between goals (Jones and Tamiz 2010).

To address the proposed Syrian humanitarian issue, we have involved all goals mentioned above by Equations (3.1) to (3.9) into a one final entire goal according to weighted goal programming (WGP), and it is described in Equation (3.15) below:

$$Minimize \sum_{n} (p_n^- \, d_n^- + p_n^+ d_n^+) \frac{1}{RHS_n} \ (\%) \tag{3.15.}$$

In the final merging Equation (3.15), are seeking to minimize the sum of total deviations linked to individual goal taking into consideration the penalty of each goal and considering percentage normalization in accordance with the TG_n "Target goals" of target objective for restrictions from $(3.1')$ to $(3.9')$.

The individual goals are transferred into soft constraints (3.1′) to (3.9′) to be taken into consideration in the weighted goal programming as below:

Subject to:

$$\sum_{i\in I}\sum_{j\in I} a_{ij}\, Z_{ij}\, h_i + d_1^- - d_1^+ \quad = TG_1 \tag{3.1′.}$$

$$\sum_{j\in J} f_j\, X_j + \sum_{i\in I}\sum_{j\in J} Z_{ij}\, h_i\, R_j + d_2^- - d_2^+ \quad = TG_2 \tag{3.2′.}$$

$$\sum_{i\in I}\sum_{j\in I} a_{ij}\, Z_{ij}\, Vd_i + d_3^- - d_3^+ \quad = TG_3 \tag{3.3′.}$$

$$\sum_{i\in I}\sum_{j\in I} a_{ij}\, Z_{ij}\, Vc_i + d_4^- - d_4^+ \quad = TG_4 \tag{3.4′.}$$

$$\sum_{i\in I}\sum_{j\in I} a_{ij}\, Z_{ij}\, Vp_i + d_5^- - d_5^+ \quad = TG_5 \tag{3.5′.}$$

$$\sum_{i\in I}\sum_{j\in I} a_{ij}\, Z_{ij}\, Vcd_i + d_6^- - d_6^+ \quad = TG_6 \tag{3.6′.}$$

$$\sum_{j\in J} c4w_{\,j}\, X_j + d_7^- - d_7^+ \quad = TG_7 \tag{3.7′.}$$

$$\sum_{j\in J} fw_{\,j}\, X_j + d_8^- - d_8^+ \quad = TG_8 \tag{3.8′.}$$

$$\sum_{j\in J} fs_{\,j}\, X_j + d_9^- - d_9^+ \quad = TG_9 \tag{3.9′.}$$

The hard restrictions demonstrated by Equations (3.10) to (3.14) are utilized in the same format to be added to the weighted goal programming model.

3.3.3. Model Validation

Validation of the model was applied by considering two data sets. The first is synthetically obtained throughout the FGDs with the dedicated stockholders and resulted to three numerical cases. The second data set is considered as a case study in conflict area from the humanitarian perspective in Syrian crisis, real data from the ground were gathered from the target region (Idleb) to be employed in the proposed model.

To extend and widen the thesis and study the impact of inputs changes, we conducted sensitivity analysis. As well the validation and efficiency of the model were proved throughout its results.

The first dataset contains three numerical cases as below:

1- Numerical Case 1: Selecting two shelters or less from 4 suggested shelters and maximizing the amount covered through 12 demand communities.
2- Numerical Case 2: Selecting 3 shelters or less from 6 suggested shelters and maximizing the amount covered through 20 demand communities.
3- Numerical Case 3: Selecting 3 shelters or less from 6 suggested shelters and maximizing the amount covered through 22 demand communities.

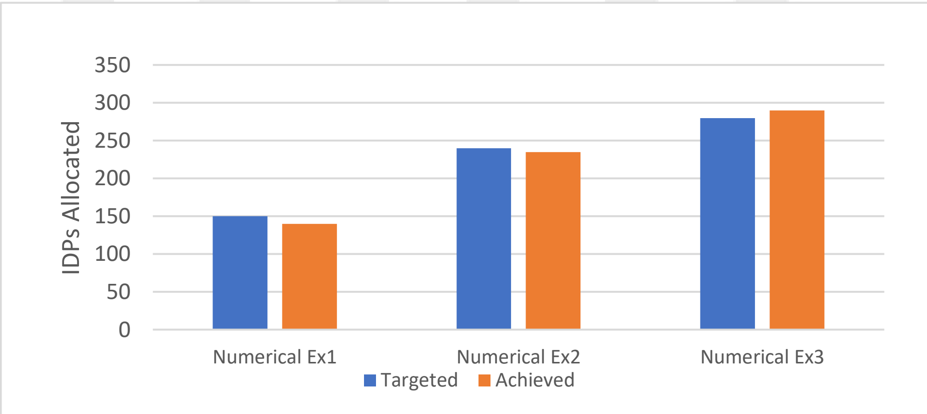
These three numerical cases are performed for same amounts of penalties p_n^-, p_n^+. For more information, the entire numerical cases as well results are attached in in Appendix section “Appendix 1”.

For more clear and general view of results of solving these numerical cases, a comparison in terms of the main goals of model in the 3 numerical cases are demonstrated in Figures 3.14, 3.15, 3.16 and 3.17; Figure 3.14 presents the amount of displaced persons selected; Figure 3.15 depicts the whole cost; Figure 3.16 presents the amount of displaced people with disabilities; and figure 3.17 shows amount of displaced kids attending the schools. In all charts within Figure 3.14, 3.15, 3.16 and 3.17, we can notice that as much as the target of IDPs or the other objectives' targets raised, the model seeks to obtain a compromised solution to these desired amounts.

Additionally, the results of these 3 numerical cases are demonstrated in Appendix 1. where the targeted amount value is compared with the obtained amount and finally calculated as a percentage in each relevant goal.

Also, the values are described in Appendix1. where the desired amount is compared with the obtained amount and calculated as a percentage in each main goal.

Figure 3.14. IDPs allocated for numerical examples



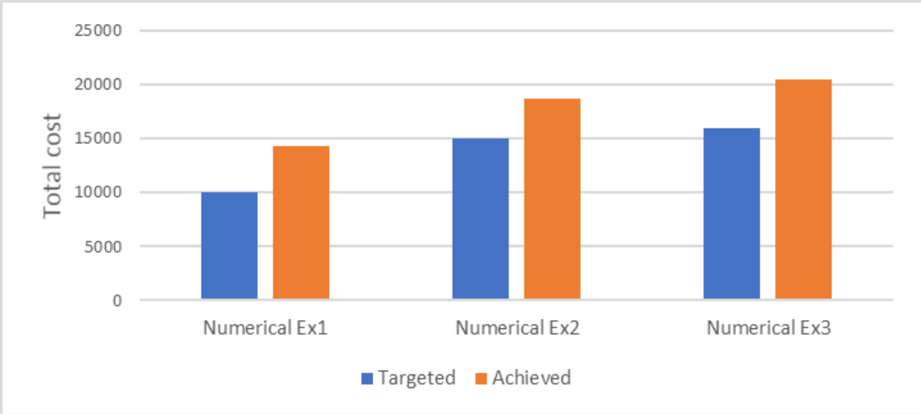


Figure 3.15. Total cost for numerical examples

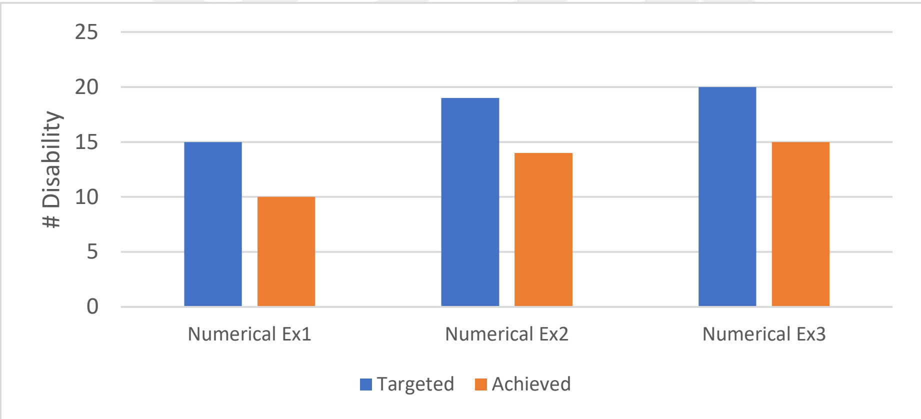


Figure 3.16. Disability for numerical Examples

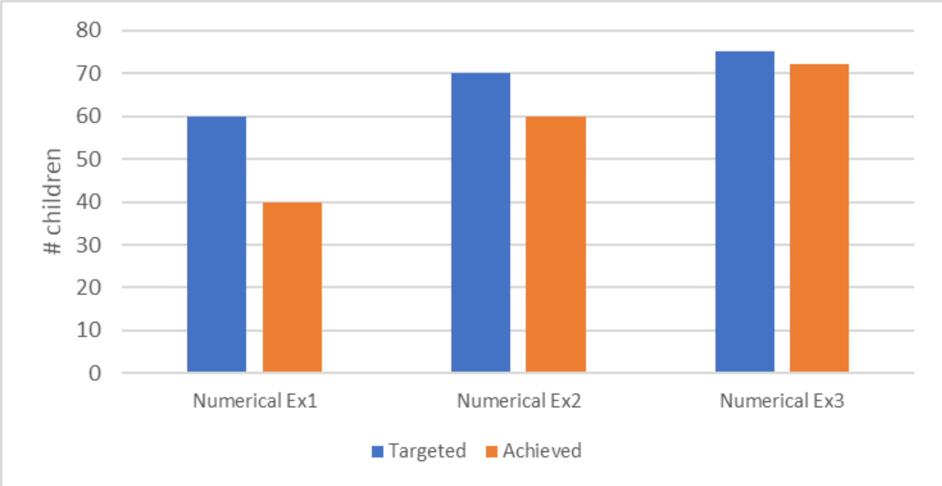


Figure 3.17. Number of Children for Numerical Examples

4. RESULTS AND DISCUSSION

4.1. Case Study

Following the validation of the proposed model by the numerical three cases in Section 3.3.3., we aimed to conduct implementation of the suggested humanitarian shelter location- allocation methodology in a case study of Syrian context/Idleb governorate in this section.

Geographically, Idleb governorate is placed in North-West region of Syrian Arab Republic, south of Turkey. It has approximately area of 6,097 km², and population of the governorate is 1,464,000 (2010-year estimation).

For preparation of the proposed thesis, we conducted a needs assessment in the targeted region of Idleb to demonstrate the circumstances there in terms of housing solutions took place there and the situation of displaced persons in the North of Syria-Idleb governorate which had described in detail Section 3.2.

Figure 4.1 demonstrates the distribution and amount of displaced people and the suggested locations of shelters in the Idleb.

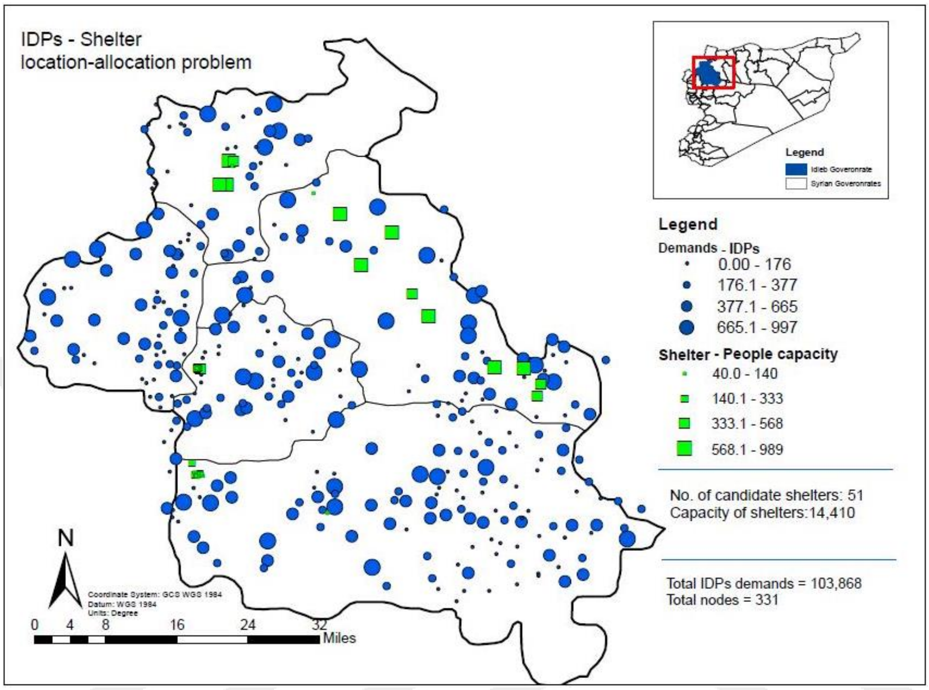


Figure 4.1. Distributions and amount of displaced people and suggested shelters' locations of handled case study.

Data about IDPs characters, demands, vulnerability ratio, and an acceptable distance of IDPs to move, are gathered by applying surveys and FGDs involving the beneficiary's representative, experts, and key informants. 331 nodes are included in the study and a total of 51 possible housing facilities positions with different internally displaced people, fixed, and variable expenses are involved in. Locations which can scale up in the future and flexibility of having movable wash facilities are identified by the authorities and the beneficiaries spread over the governorate.

By using GIS (ArcMap 10.4.1), the distance matrix is formed, where each community of displaced people is determined by geographical positions "longitude and latitude" as well to each shelter. Afterward, the shortest possible way between each shelter to each node is calculated throughout the drawn road paths in the study area using this software by creating a roads matrix throughout to find the optimal path between the community demand node and the candidate shelters' location.

As a result of FGDs/surveys with the key stockholders involving the beneficiary's representative, experts, and key informant, through the Figure 4.2, we reached the desired amounts in each goal to be employed in the weighted goal programming methodology as described by Table 4.1 and 4.2 below:

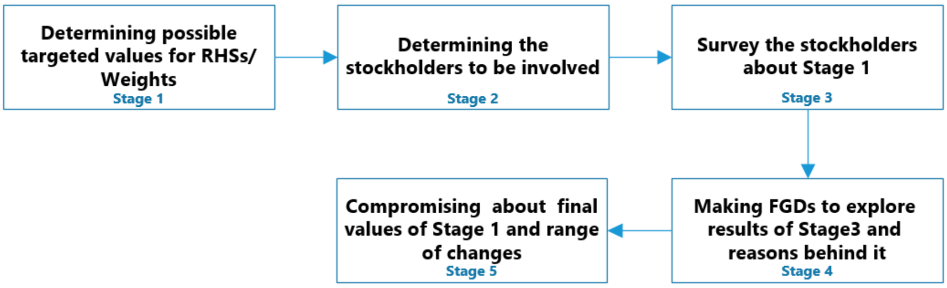


Figure 4.2. Steps of determining the amounts of aspired value, penalties, and considered change rates

Table 4.1. Desired amount in the proposed goals

TG_n	Description	Targeted
TG_1	IDPs Allocated	12,000
TG_2	Total Cost [$]	1,000,000
TG_3	# Disability	1,500
TG_4	# Children Attending School	6,000
TG_5	# Chronic Diseases	1,000
TG_6	# Pregnant /Lactating Women	3,000
TG_7	Cash for Work [$]	300,000
TG_8	# Portable Wash Facilities	25
TG_9	# Flexibility of Scaling up	30

Table 4.2 Obtained penalties from FGDs

TG_n	**Description**	p_n^-	p_n^+
TG_1	IDPs Allocated	10	0
TG_2	Total Cost [$]	0	9
TG_3	# Disability	4	0
TG_4	# Children Attending School	3	0
TG_5	# Chronic Diseases	2	0
TG_6	# Pregnant /Lactating Women	1	0
TG_7	Cash for Work [$]	1	0
TG_8	# Portable Wash Facilities	1	0
TG_9	# Scale Up Facilities	1	0

To define the number of located/selected shelters, in case the experts and beneficiaries consider a larger quantity to be chosen, that means that they will be in need for more protection policies, managemental staff, and rules to deal and handle the housing in shelters. If the experts consider a small number of allowed chosen shelters, that will mean they will not be allowed to place a larger number of displaced people. Consequently, steps of finding a comprising value is described in detail at Figure 4.2, it based mainly on discussions groups/surveys. Including that the whole possible candidate shelters are suggested as 51 in the targeted area, the maximum number of allowed shelters to be opened are considered as less or equal to 40.

The main steps of determining the above values of p_n^- , p_n^+ and TG_n include five process which is described in Figure 4.2:

- In the first process, we identified possible desired amounts of each goal as well penalties to be taken into account considering similar projects and context of the conflict studied region.
- In the second process, the direct beneficiaries and stockholders are defined based on the particular filed/value (humanitarian, financial,

administration/as well implementing partner, the donors, beneficiaries' representative, etc.) to be considered in the following stages and agreed on the related desired amount to be counted.

- The third step includes surveying the stockholders about their views and suggestions supporting the causes and descriptions.
- In the fourth step, the FGDs are conducted to examine the results obtained in Step 3 and discussions made about it.
- The fifth and the last step of this process is completed by reaching the most agreement value for most of the stockholders taking into consideration a various range for each amount to be counted in applying sensitivity analysis; the assessed values are compromised. For instance, in previous steps; we can handle by putting the number of desired selected of IDPs as 12000. It was considered as an average compared with the prior same projects in the region and according to the approximately available set budget by discussing to the related stockholders. Moreover, we will study the behaviour of the model with changes rates of this target value as +400% (60000) and less as -40% (7200) which is will be checked in applying the sensitivity analysis and got results will be discussed.

Finally, when formulating the model with all goal and restrictions is conducted, the issue is resolved by optimization tool, considering the extent of community demands, positions of shelters and features in Idleb governorate.

4.2. Results

After running the model using optimization software, we obtained the results depicted in Figure 4.3, which shows the outputs reached in each goal in terms of percentage format against the line of 100%. It showed that many objectives have arrived at the aspired amount; starting from the amount of displaced people we obtained about 99% with the occupancy ratio of 97 % and so on. The values which are greater than the aspired amount "100%" as in CFW is favoured including that the model is attempting to increase this goal as much as it possible. While, the model resulted in exceeding the desired amounts in whole expenses objectives by 111%. The 104% obtained amount at chronic diseases corresponds that the allocated amount of internally displaced people with chronic diseases to an opened shelter is greater than the aimed value. Moreover, we realized that a few objectives such as number of disabilities (71.93%), pregnant/lactating women (54.70%) and number of kids (63.37%) have not arrived at the desired level.

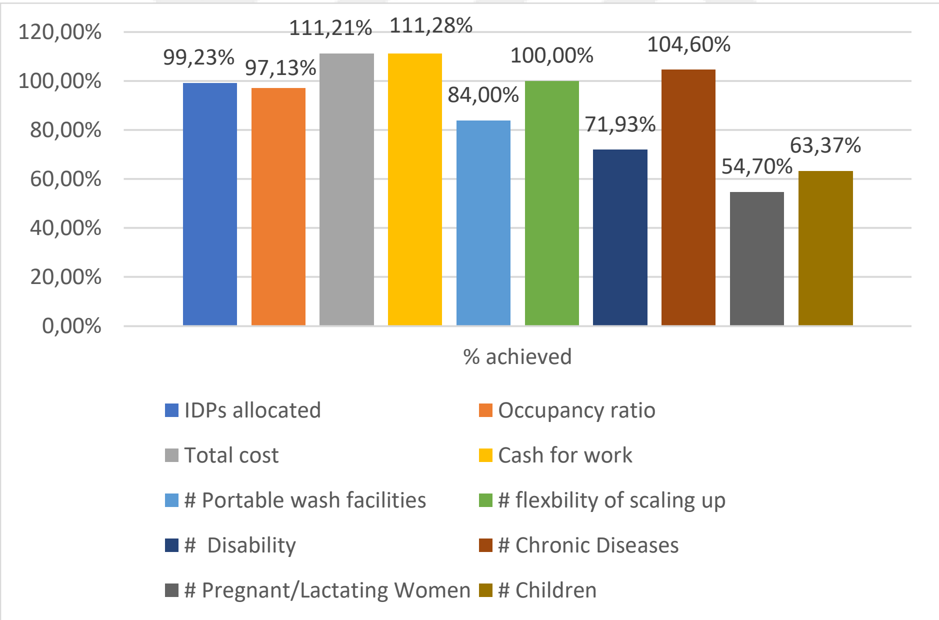


Figure 4.3. Outputs achieved as a percent of the aspired amount

Table 4.3. Comparison between the desired and obtained amounts reached in each goal

	Targeted	Achieved	% Achieved	desired
IDPs Allocated	12,000	11,907	99.23%	Max
Occupancy Ratio	100	97,13	97.13%	Max
Total Cost [$]	1,000,000	1,112,053	111.21%	Min
Cash for Work [$]	300,000	333,830	111.28%	Max
# Portable Wash Facilities	25	21	84.00%	Max
# Flexibility of Scaling up	30	30	100.00%	Max
# Disability	1,500	1,079	71.93%	Max
# Chronic Diseases	1,000	1,046	104,60%	Max
# Pregnant /Lactating Women	3,000	1,641	54.70%	Max
# Children Attending School	6,000	3,802	63,37%	Max

Table 4.3 demonstrates the correlation between the aimed and obtained amounts performed in each goal. We intended to select 12,000 displaced people within the developed model, and we allocated 11,907 out of 12,000 which corresponds to the achievement of 99%. Since the capacity of 51 candidate shelters was 14,410; the full capacity of chosen 40 shelters was 12,259 (which equivalents to more than 85% of the whole capacity of all 51 shelters) where after the model run; 11,907 displaced persons are selected within the 40 elected facilities. Thereby, we obtained 97% occupancy ratio out of 100% desired. Main causes behind not selecting the other communities' demands node can be summed up by:

1) The candidate shelters' capacities were low and bounded to 14,410 displaced persons where the total amounts of demands were 103,868.
2) Some communities' demands positions are relatively far to the suggested shelters and not in the allowable distance.

3) The cost of allocating a node is greater sometimes compared with the other covered nodes.
4) There is a greater amount of IDPs compared to the capacity of the nearby shelter (or the remaining capacity of the chosen shelter).
5) The model enables for a balance between all desired objectives considering not to pass the upper limit of allowed taken shelter ($p \leq 40$) and sometimes the target values are considered in a more optimistic or pessimistic way.

Our target total cost budget of locating shelters was 1,000,000$ and the CFW was 3,000,000$ and after running the model for 40 shelters to be selected out of 51; our costs have reached up to 1,112,053$ and 333,830$ respectively. Amongst 40 shelters, we intended to have 25 located shelters having movable WASH facilities and 30 shelters having the flexibility of scaling up; as a consequence, we achieved to locate 21 shelters with movable wash and 30 shelters with ability of scaling up. Our goal was allocating 1,500 displaced people with disabilities to placed facilities, and we've reached 71% achievement by allocating 1,079 IDPs with disabilities. Since we target to select 1,000 displaced people with chronic diseases and we allocated 1,046; we gained 104% achievement. We target to select 3,000 pregnant/lactating women and 6,000 kids attending educational centres and our achievement values for these vulnerability humanitarian criteria are 54% and 63%, respectively.

Figure 4.4 shows the outputs of the issue “IDPs-Shelter location-allocation problem” discussed within the research by illustrating the demands covered, shelters located and allocated covered demand to located shelters, all of them on the map. The figure as well include a conclusion of demonstrating the outputs in geographical places.

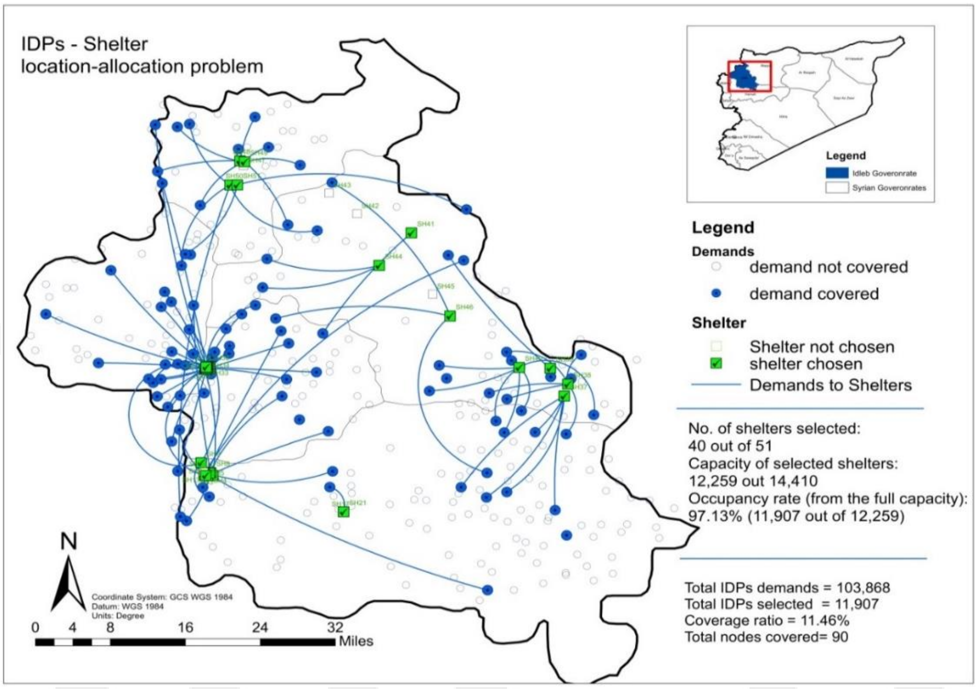


Figure 4.4. Results of IDPs-Shelter issue handled in the thesis.

Figure 4.4 demonstrates that there were 331 nodes including IDPs, and the total number of IDPs was 103,868. We identified 51 candidate shelter sites that their total capacity is 14,410 people. As the maximum amounts of housing solutions "shelters" to be opened is defined as 40 within our study; the model resulted in locating 40 shelters, and the total capacity of these shelters was 12,259. The model insured 90 of 331 community demand nodes by selecting 11,907 IDPs to these shelters which correspond to approximately. 11% coverage ratio.

Figure 4.5 demonstrates the expenses, flexibilities, and CFW outputs of IDPs-Shelter issue. The blue circles symbolize the full flexibility shelters which means that the related shelter has both scaling up feature and movable WASH facilities. The located shelters which have either scaling up feature or movable WASH facilities are indicated with yellow charts. The located shelters which have no flexibilities are coloured with orange ones in the figure. The cost/cash for work bars on located shelters shows the expenses of placing shelters. The CFW amount are expressed by an orange bar chart, setting up expenses are by a purple one, and running expenses are by green one.

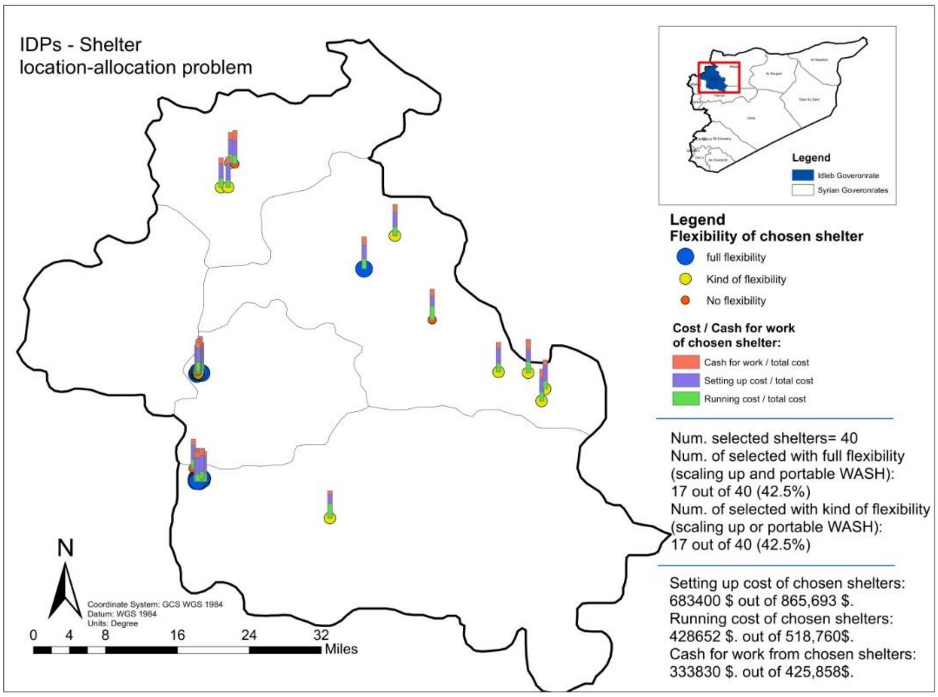


Figure 4.5. Flexibility, expenses and CFW outputs of the opened shelters

4.3. Sensitivity Analysis

By changing in one input or more, inclusion/exclusion of inputs while remaining the others to get information about how sensitive the output is, the sensitivity analysis were implemented, as well to study the behaviour of the model and its influences on outputs. Inputs/cases, which are taken into consideration to be changed and tested on outputs' impact and are shortened by the cases as below:

1) Case1: Changing in number of allowed opened housing facilities "shelter" (or totally eliminate the related Equation (3.10));

2) Case2: Taking into account the population growth rate (PGR) in the last 10 years;
3) Case3: Changing in TG_n amounts (aspired levels);
4) Case4: Changing in p_1^- (penalty of covered goal);
5) Case5: Changing in TG_1;
6) Case6: Changing in p_1^- &RHS_1;
7) Case7: Changing in p_2^+ (penalty of the whole expenses goal);
8) Case8: Changing in TG_2;
9) Case9: Changing in p_2^+ &RHS_2.

Results obtained from operating the model in each of the above inputs/cases (from Case1 to Case9) are presented and demonstrated by Figures 4.6, 4.7, 4.8 and 4.9, which represents the main variables judged by stockholders' perspective as follows; (i) the quantity of displaced people covered and (ii) the whole expenses, respectively. The Figure 4.6 represents the obtained and desired amounts in covering goal and the whole expenses made throughout implementing sensitivity analysis for the Case1, where we changed the number of allowed chosen shelters as well as excluding the constraint totally as described by Equation (3.10).

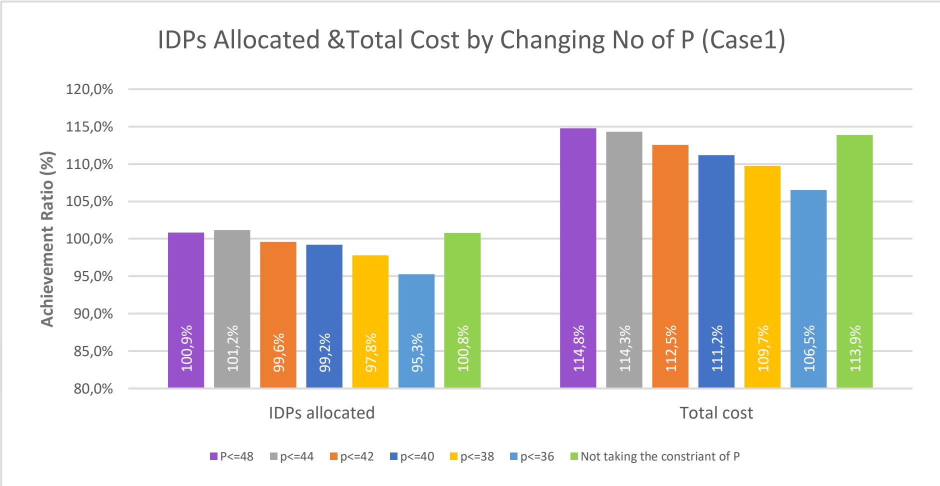


Figure 4.6. IDPs allocated &total cost by changing Number of P (Case1)

Beginning from an essential case where number of allowed opened shelters are less of equal to 40, then increasing, reducing this number or even eliminating the relevant restriction, the following can be observed; reducing the number of the allowed taken shelter drives to a reduction in the number of allocated IDPs. On the other hand, raising this number will let the model allocate more IDPs, and as a consequence, it will lead to raising the whole expenses. However, when the relevant restriction was eliminated, the model will stay with the limited feasible area due to the presence of whole expenses restriction. In this case, the outputs took the value of "P=44", which means that this value is the optimum amount of P to optimize the model and satisfy as many goals as possible (but it cannot be used as the decision-makers favoured to not exceed the amount of "40").

The Figure 4.7 represents obtained and desired amounts in covered amount goal and the whole expenses throughout implementing the sensitivity analysis for Case2 where population growth rate (PGR) in Syria was taken into concern. Considering there are no official organizations "authorities" in gathering data in this target region, we acquired three amounts of PGR from world bank website "www.worldbank.org", which presents the amounts in the previous ten years as following:

a) The highest rate of increasing +3.72%,
b) The lowest rate of decreasing -3.10%,
c) The last previous year rate -0.87%.

As a result of solving the model in these above cases, there are no main changes in the amount of displaced people selected and the whole expenses required amount since the growth rate will seek to small variances in the amount of community demands nodes.

Figure 4.7. IDPs allocated & total cost by changing PGR (Case2)

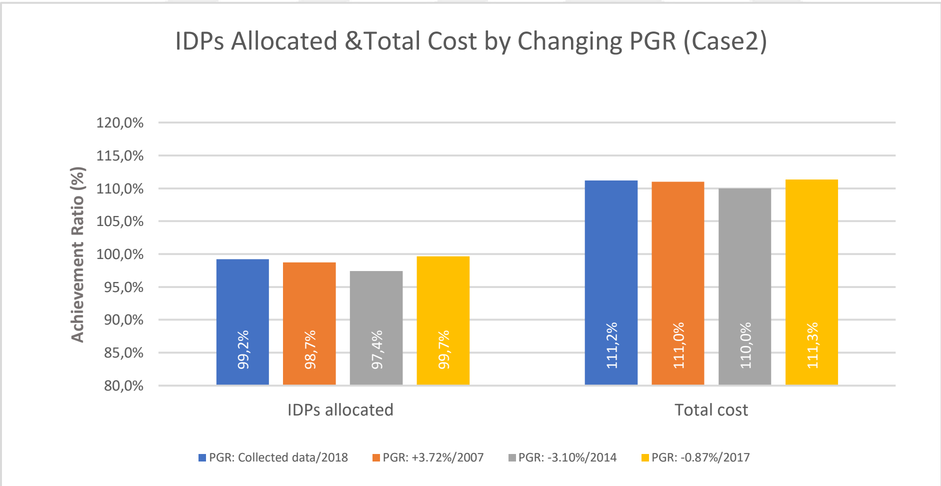


Figure 4.8, 4.9 illustrates the obtained and desired amounts in the goals of covered displaced people and the whole expenses in accordance with the Case3, where the below findings can be realized:

1) Displaced people selected by conducting changes in aspired levels: When the aimed amount of selected displaced people is comparatively

lower, the target amount can be obtained by the model and this situation keeps going till a determined amount (approximately 13,200), where the model is unable to reach the higher desired amount, where the major reasons behind that are:

- The model arrived at the relatively maximum amount of selected displaced people which was gained by getting results from solving the model taking into consideration the highest priority level of equation (3.1') linked to displaced people utilizing pre-emptive "lexicographic goal programming" skipping the other goals' priorities amounts.
- In case of setting a higher aspired levels/amounts, selecting higher amounts of IDPs are not obtained due to the bounded of suggested candidate shelters' capacities or the farness path between demand communities and the suggested shelters (which is described by the covered matrix) and other mentioned reasons in the discussion under the Table 4.3.

2) The whole expenses' impact when changes in aspired levels are occurred: due to the whole expenses are associated in the first place with the selected displaced people amounts, and due to the higher increase of the desired amount of selected people is unable to raise the obtained amounts of selected displaced people, so that raising the desired amount of expenses will not be utilized due to there is no more people to be selected as well.

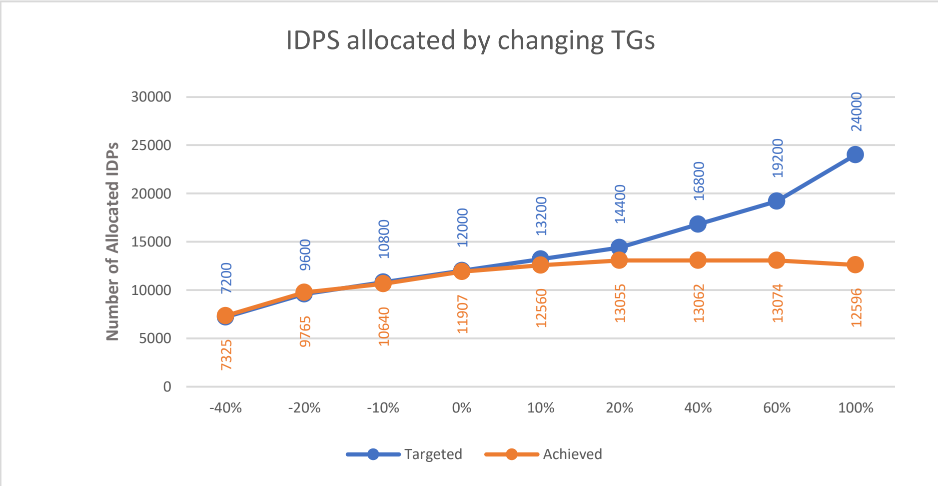


Figure 4.8. IDPS allocated by changing TGs (case 3)

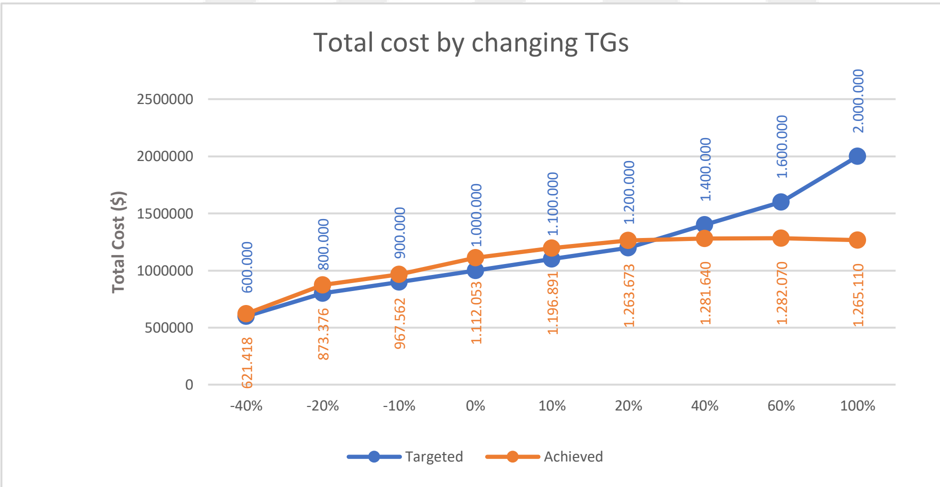


Figure 4.9. Total cost by changing TGs (case 3)

Figure 4.10 depicts the obtained and desired amounts in covering amount according to Case 4, where the amounts of p_1^- (penalty of not reaching the objective) was changed "+Percent Changed/ - Percent Changed". The following findings can be realized: As much as the p_1^- amounts increase, the model strives to obtain the aimed amount of selected displaced people. This is logical since the increasing of p_1^-

value will increase the significance of this goal. But still, there are some points where there is no more positive progress due to the exact reason stated in the prior situation.

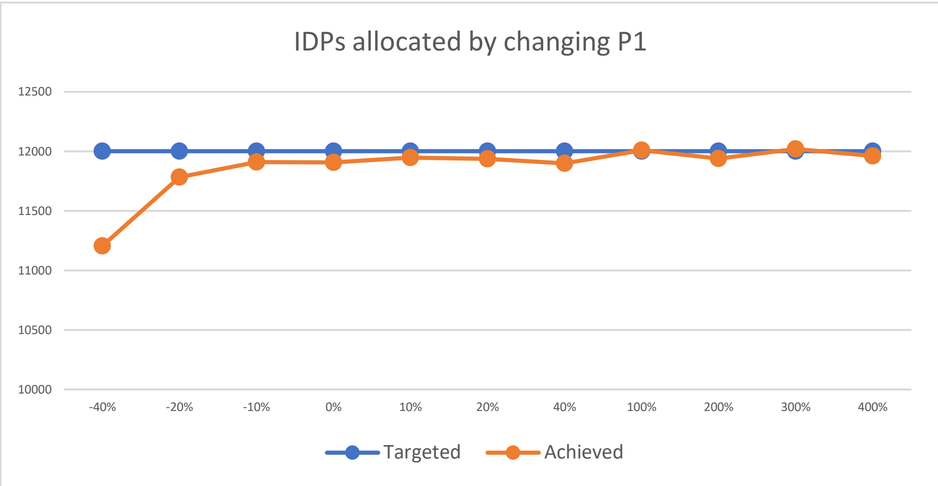


Figure 4.10. IDPs allocated by changing P1 (case 4)

In case 5, figure 4.11 presented that the model behaves relatively the same (increasing the % changes leads to increases in the reached amount), the maximum obtained of selected displaced people occurred between the changes +10% and +40% reach the numbers between (12750,12696), where the maximum amounts of IDPs allocated was 13,221.

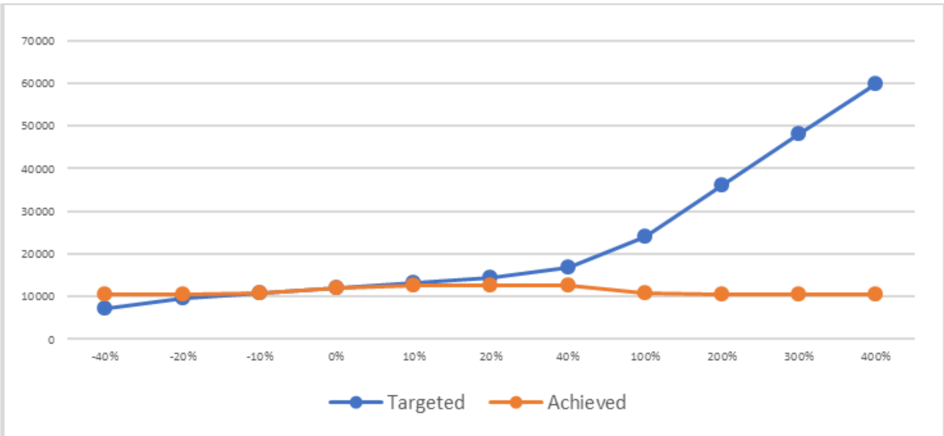


Figure 4.11. IDPs allocated by changing TG1 (case 5)

Figure 4.12 depicts the obtained and desired values in the whole expenses in accordance with Case 6. When the p_2^+ is lower, the obtained expenses passed the aimed expenses. While the p_2^+ amount is changed by after +10%, the expenses started to be closer to the aimed amount of total cost, however, that affects in negative way the selected displaced people goal amount. While p_2^+ amount is changed from +10% to +20%; the amount of selected displaced people reduces from nearly 99% to 94% (Please refer to Appendix 2) which means seeking to enhancing of a certain goal will affect the other conflicting goals.

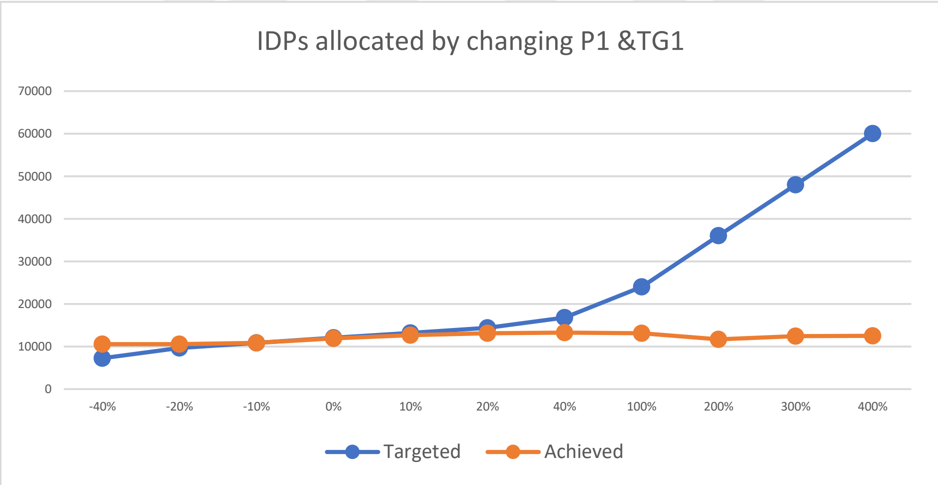


Figure 4.12. IDPs allocated by changing P1 &TG1(case 6)

If we move to Figure 4.13, it illustrates that the model is not able to achieve the low amount of the aimed expenses since there is another conflicted goal amount that the model is seeking to, which was covering amount 12,000 as a desired for displaced persons selected in each point (amounts of covered people goal and whole expenses goals conflicted goals). Besides, the model is not able to utilize the great amount of aimed expenses since the selected displaced people are not able to be raised because of the reasons mentioned in Case3.

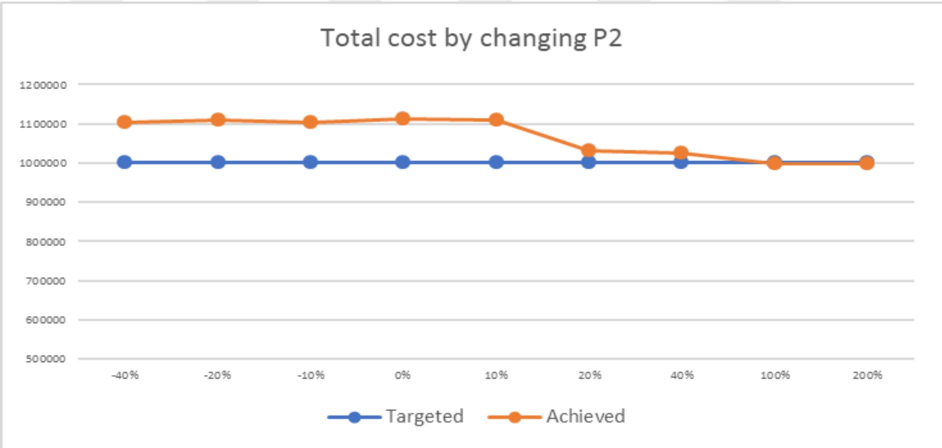


Figure 4.13. Total cost by changing P2 (case 7)

Figure 4.14 shows that the model cannot achieve a low targeted total cost since there is another conflicting target value that the model is struggling with—namely, 12,000 as the target for IDPs allocated at each point (covering and total cost are conflicted objective functions). Furthermore, the model cannot utilize a high targeted total cost since the allocated IDPs cannot be increased for the reasons mentioned in Case 3.

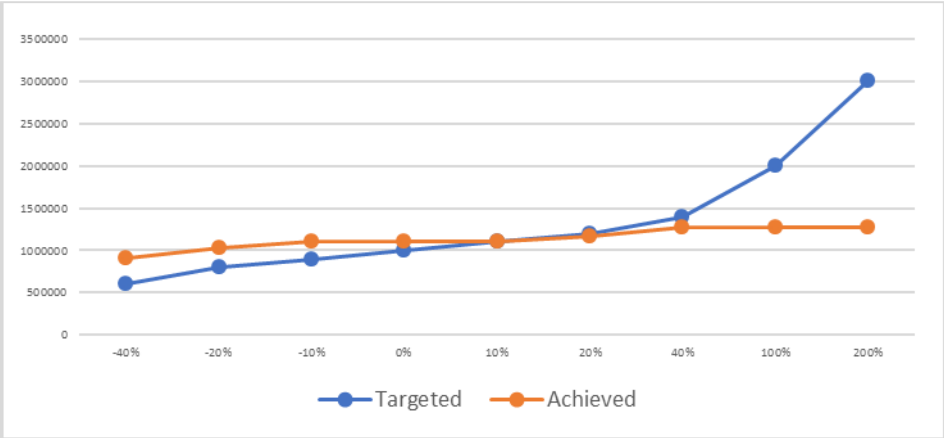


Figure 4.14. Total cost by changing TG2

Returning to the Figure 4.15; at the start when the aimed total cost is high and p_2^+ value is low, the model strives to obtain the target total cost and tries to achieve the other conflicting objective as much as it can to reach a higher amount of allocated IDPs (at the beginning the model achieved 13,068 IDPs (109% achievement ratio) since its related p_1^- which is 10 and higher compared to p_2^+ which is 6). As much as the aimed total cost is lower and p_2^+ value is higher, the model tried to reach and not pass the total cost. When the model is not able to achieve the targeted total cost even with a higher p_2^+ value (at +10% and +20%), we can notice that it is reasonable since it is not able to achieve the other objective function as well in the same situation.

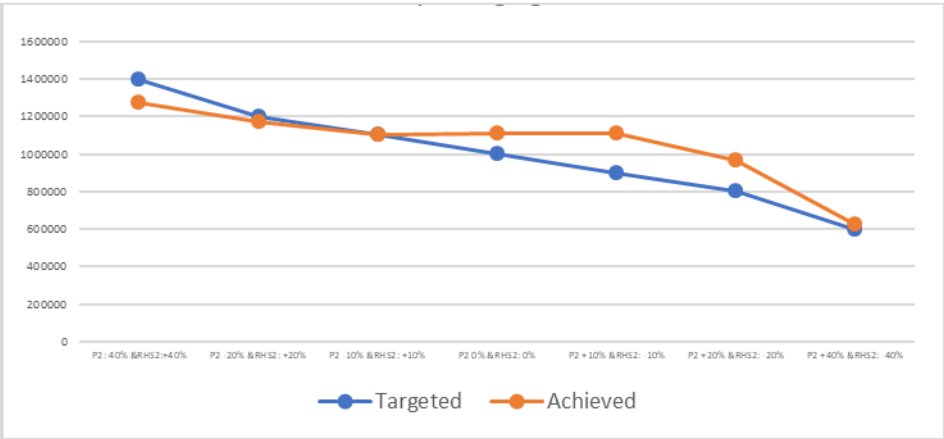


Figure 4.15. Total cost by changing P2 & TG2

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Within the proposed research, a multi-objective decision-making approach has been proposed and applied. It will assist decision makers to determine the optimum shelter places for affected displaced persons in the northern zone of Syria, then place the most in shortage displaced people to the chosen shelters which will lead to promote and facilitate the recovery process. Furthermore, this thesis was aimed to mitigating the negative consequence of such crisis and alleviating the suffering of affected IDPs in zones of humanitarian crisis.

The major contribution of proposed thesis can be divided into four trends: First, the introduced methodology will present a helpful tool to decision-makers to interact with analysing multi-objective problems, find out all potential solutions and the extent of its inputs' variations on results. While the second contribution shows the applicability in such crisis regions to get the best feasible solution from the humanitarian prospect. Third, it describes the feasibility of merging the multi-objective mathematical model with GIS technique employing real information. Last but not least, the main objective of this paper was that; any country, community, state or organization can gather related data and can access this methodology. This is not a particular case for humanitarian crisis in Syrian context; it is beneficial for every similar context. Certainly, the inputs, information, and weights may differ according to the studied circumstances of the associated problem state; but the suggested model could be adopted for alike situations in another country.

In this research, we have focused essentially on the direct beneficiaries (affected people from the crisis) for identifying the problem more closely than just consulting the donor and the implementing partners. Discussing with the direct displaced people is crucial in humanitarian context, since they are suffering and we are trying to alleviate their suffering and misery; and due to the absences of official organizations that can afford the information directly, in the first stage of this four-phase study, we implement a needs assessment utilizing real information acquired from the ground to determine the problem and major criteria from the perspective of direct beneficiaries in coordination with society councillors. In the second phase, we formulate the restrictions and goals, humanitarian multi-objectives (vulnerability criteria, cash for work, people covered, total cost and so on...); then prioritized them according to experts and beneficiaries' representatives. Roads channels dataset was drawn and built in the studied region applying GIS, then we revised them according to unsafe streets in the third stage. Eventually, a mathematical model was formed where a mixed integer model was suggested, solved by optimization computer software and conducted sensitivity analysis.

As a conclusion, 40 housing solutions “shelters” were settled taking into account the pre-determined restrictions and goals in accordance with the humanitarian context in the targeted area and the criteria from stakeholders' perspective. As a results, 90 demand community have been allocated in the 40 selected shelters with an occupancy ratio of 97%.

5.2. Recommendations

Consideration of only the northern region of Syria as a case study and estimating the candidate locations with only 9 criteria in humanitarian sectors are the limitations of the thesis, as well the proposed model is bounded only to a single period problem of multi-objective location-allocation. To mark these shortcomings, researchers can progress with the following recommendations for future studies:

1. Apart from the analysed 9 goals, other criteria such as; infrastructure, education, environment, health, risks, protection, and others may be marked.

2. Taking into account introducing a dynamic model might be approached by requiring a high degree of uncertainty of these kinds of issues in crisis areas.
3. In addition to the considered region, the other areas of Syria or neighbourhood countries can be joined to extend the study and obtain more comprehensive research.
4. Designing a comprehensive web-based/software application by merging the mathematical model, FGDs and GIS together to promote and to adjust to varies related issues.

6. REFERENCES

Abdelmoneium, A. 2015. 12 *Internally Displaced Families in Khartoum-Sudan: Challenges and Policy of Migration, Health and Social Care, : . Http://Dx.Doi.Org/10.1108/IJMHSC-05--0017.*

Abounacer, R, M Rekik, and J Renaud. 2013. 41 *An Exact Solution Approach for Multi-Objective Location-Transportation Problem for Disaster Response, Computers & Operations Research, : . Http://Dx.Doi.Org/10.1016/j.Cor..08.001.*

Aiello, G., M. Enea, and G. Galante. 2006. “A Multi-Objective Approach to Facility Layout Problem by Genetic Search Algorithm and Electre Method.” *Robotics and Computer-Integrated Manufacturing*.

Ali, H E. 2012. 24 *Estimate of the Economic Cost of Armed Conflict: Study from Darfur, Defence and Peace Economics, : . Http://Dx.Doi.Org/10.1080/10242694..723154.*

Arslan, Hakan. 2007. “Re-Design, Re-Use and Recycle of Temporary Houses.” *Building and Environment*.

Ashmore, J. 2004. “Tents: A Guide to the Use and Logistics of Family Tents in Humanitarian Relief,.” *United Nations* OSHA (Ed.).

Attfield, Ian, Mathewos Tamiru, Bruno Parolin, and Anton De Grauwe. 2002. *Improving Micro-Planning in Education through a Geographical Information System: Studies on Ethiopia and Palestine. School Mapping and Local-Level Planning*. ERIC.

Ay, M. 2012. “Design of Road-Crossing Drainage Culverts Using GIS Data.” (Gaziantep University).

Barzinpour, F., and V. Esmaeili. 2014a. “A Multi-Objective Relief Chain Location Distribution Model for Urban Disaster Management.” *International Journal of Advanced Manufacturing Technology*.

Barzinpour, F, and V Esmaeili. 2014b. *Relief Chain Location Distribution Model for*

Urban Disaster Journal of Advanced Manufacturing Technology, 70: 1291-1302. Http://Dx.Doi.Org/10.1007/S00170-013-5379-X.

Bayram, Vedat, and Hande Yaman. 2018. "A Stochastic Programming Approach for Shelter Location and Evacuation Planning." *RAIRO - Operations Research*.

Boonme, C, A Arimura, and T Asada. 2017. 24 SRC- *Facility Location Optimization Model for Emergency Humanitarian of Disaster Risk Reduction, . Http://Dx.Doi.Org/10.1016/j.Ijdrr..01.017.*

Bozorgi-Amiri, Ali, M. S. Jabalameli, and S. M.J. Mirzapour Al-e-Hashem. 2013. "A Multi-Objective Robust Stochastic Programming Model for Disaster Relief Logistics under Uncertainty." *OR Spectrum*.

Çetinkaya, Cihan, Eren Özceylan, Mehmet Erbaş, and Mehmet Kabak. 2016. "GIS-Based Fuzzy MCDA Approach for Siting Refugee Camp: A Case Study for Southeastern Turkey." *International Journal of Disaster Risk Reduction*.

Chen, Z, X Chen, Q Li, and J Chen. 2013. 27 *The Temporal Hierarchy of Shelters: Location Model for Earthquake-Shelter of Geographical Information Science, : . Http://Dx.Doi.Org/10.1080/13658816..763944.*

Curry, D W Rattan, J, Nzau, J J, Giria, K, Settings, I. 2015. 3 *Delivering High-Quality Family Planning Services in Crisis-Affected Program Science and Practice, : . Http://Dx.Doi.Org/10.9745/GHSP-D-14-00164.*

Daskin, Mark S. 2008. "What You Should Know about Location Modeling." *Naval Research Logistics*.

Daskin, Mark S. 2011. "Introduction to Location Theory and Models." *Network and Discrete Location*: 1–19.

Dean, Mark S. Daskin and Latoya K. 2004. "Location of Health Care Facilites." *Health Care*.

Emami, Saeed, and Ali S. Nookabadi. 2013. "Managing a New Multi-Objective Model for the Dynamic Facility Layout Problem." *International Journal of Advanced Manufacturing Technology*.

Engstrom, Ryan Hersh, Jonathan, Newhouse, David, Giordan, Daniele, Hayakawa, Yuichi, Nex, Francesco C.. 2018. “OpenStreetMap in GIScience.” *Natural Hazards*.

Esri. 2011. “ArcGIS Desktop: Release 10.” *Redlands*.

Félix, Daniel, Jorge M. Branco, and Artur Feio. 2013. “Guidelines to Improve Sustainability and Cultural Integration of Temporary Housing Units.” *6th International i-Rec Conference*.

Ferris, E, and J Bergmann. 2017. 8 *Soft Law, Migration and Climate Change Governance, Journal of Human Rights and the Environment,: . Http://Dx.Doi.Org/10.4337/Jhre..01.01*.

International Bank for Reconstruction and Development. 2017. “FORCIBLY DISPLACED.”

Goodchild, Michael, and Karen Kemp. 1990. “NCGIA Core Curriculum in GIS.” *National Center for Geographic Information and Analysis.*

Hadafi, Farzaneh, and Alireza Fallahi. 2010. “Temporary Housing Respond to Disasters in Developing Countries-Case Study: Iran-Ardabil and Lorestan Province Earthquakes.” *World Academy of Science, Engineering and …*.

Hallak, Jamil, Melik Koyuncu, and Pınar Miç. 2019. “Determining Shelter Locations in Conflict Areas by Multiobjective Modeling: A Case Study in Northern Syria.” *International Journal of Disaster Risk Reduction*: 101202.

Hathhorn, Jonathan, Esra Sisikoglu, and Mustafa Y. Sir. 2013. “A Multi-Objective Mixed-Integer Programming Model for a Multi-Floor Facility Layout.” *International Journal of Production Research*.

Heudtlass, Peter, Niko Speybroeck, and Debarati Guha-Sapir. 2016. “Excess Mortality in Refugees, Internally Displaced Persons and Resident Populations in Complex Humanitarian Emergencies (1998-2012) - Insights from Operational Data.” *Conflict and Health*.

Ho, E L. 2017. 42 *Mobilising Affinity Ties: Kachin Internal Displacement and the Geographies of Humanitarianism at the China-Myanmar Border, Transactions of the Institute of British Geographers,: .*

Http://Dx.Doi.Org/10.1111/Tran.12148.

Horner, M W, and J A Downs. 2010. 34 *Optimizing Hurricane Disaster Relief Goods Distribution: Model Development and Application with Respect to Planning Strategies, Disasters, : . Http://Dx.Doi.Org/10.1111/j.1467-7717..01171.X.*

Humayun, A Azad, N, Haq, I, Khan, F R, Ahmad, A, Farooq, R K. 2016. "Mental Health and Psychosocial Support for the Internally Displaced Persons in Bannu, Pakistan, Intervention, : ." 14(1 SRC-BaiduScholar FG-0): 33–49.

Humayun, A, Haq, I, Khan, F R, Azad, N, Khan, M M, Weissbecker, I. 2017. *Implementing Mhto Strenghten Existing Services for an Internally Displaced Population in Health, 4(E6): . Http://Dx.Doi.Org/10.1017/Gmh..1.*

Huot, S, E Kelly, and S J Park. 2016. 63 SRC- *Occupational Experiences of Forced Migrants: Therapy Journal, . Http://Dx.Doi.Org/10.1111/1440-1630.1226.*

International Federation of Red Cross and Red Crescent Societies. 2011. "The Red Cross Red Crescent Approach to Disaster and Crisis Management." http://www.ifrc.org/PageFiles/91314/1209600-DM-Position-Paper-EN.pdf.

IOM. 2012. "Transitional-Shelter-Guidelines."

Ishizaka, Alessio, and Philippe Nemery. 2013. Multi-Criteria Decision Analysis: Methods and Software *Multi-Criteria Decision Analysis: Methods and Software*.

Johnson, Cassidy. 2007. "Strategic Planning for Post-Disaster Temporary Housing." *Disasters*.

Johnson, Russ. 2000. "GIS Technology for Disasters and Emergency Management." *GIS Technology for Disasters and Emergency Management*.

Jones, Dylan, and Mehrdad Tamiz. 2010. *Practical Goal Programming*.

Kisindja, R Kimona, C, Etoy, M, Dorme, F, Benfield, N. 2017. 138 *M, . Family Planning Knowledge and Use Among Women in Camps for Internally Displaced People in the Democratic Republic of the of Gynecology & Obstetrics, : . Http://Dx.Doi.Org/10.1002/Ijgo.12220.*

Kınay, Ömer Burak, Francisco Saldanha-da-Gama, and Bahar Y. Kara. 2019. "On

Multi-Criteria Chance-Constrained Capacitated Single-Source Discrete Facility Location Problems.” *Omega (United Kingdom)*.

Kleist, J. Olaf. 2017. “The History of Refugee Protection: Conceptual and Methodological Challenges.” *Journal of Refugee Studies*.

Kongsomsaksakul, S, and C Yang. 2005. “Shelter Location-Allocation Model for Flood Evacuation Planning.” *of the Eastern Asia Society for*.

Kranz, O, A Sachs, and S Lang. 2014. 36 *Assessment of Environmental Changes Induced by Internally Displaced Person (IDP) Camps in the Darfur Region, Sudan, Based on Multitemporal International Journal of Remote Sensing, : . Http://Dx.Doi.Org/10.1080/01431161..999386.*

Lagos-Gallego, M, J C Gutierrez-Segura, G J Lagos-Grisales, and A J Rodriguez-Morales. 2017. 16 *Post-Traumatic Stress Disorder in Internally Displaced People of Colombia: An Ecological and Infectious Diseases, : . Http://Dx.Doi.Org/10.1016/j.Tmaid..02.008.*

Lauras, Matthieu, Jorge Vargas, Lionel Dupont, and Aurelie Charles. 2014. “A Location-Allocation Model for More Consistent Humanitarian Supply Chains.”

Leppold, C , Ozaki, A, Shimada, Y, Morita, T, Tanimoto, T. 2016. 5 *Defining and Acting on Global Health: The Case of Japan and the Refugee of Health Policy and Management, : . Http://Dx.Doi.Org/10.15171/IJHPM..68.*

Li, Hui Sun, Ren Jin, Dong, Kang Yin, Dong, Xiu Cheng, Zhou, Zhong Bin

Leng, Xia. 2017. “Selecting China’s Strategic Petroleum Reserve Sites by Multi-Objective Programming Model.” *Petroleum Science*.

Li, Huiyong, Laijun Zhao, Rongbing Huang, and Qingmi Hu. 2017. “Hierarchical Earthquake Shelter Planning in Urban Areas: A Case for Shanghai in China.” *International Journal of Disaster Risk Reduction*.

Matai, Rajesh. 2015. “Solving Multi Objective Facility Layout Problem by Modified Simulated Annealing.” *Applied Mathematics and Computation*.

Moghaddam, H T Sayedi, S J, Moghadam, Z E, Bahreini, A, Abbasi, M A, Saeidi,

M. 2017. 5 *Refugees in the Eastern Mediterranean Region: Needs, Problems and of Pediatrics.*

Mollah, Amlan K., Sounak Sadhukhan, Prasun Das, and Md Zafar Anis. 2018. "A Cost Optimization Model and Solutions for Shelter Allocation and Relief Distribution in Flood Scenario." *International Journal of Disaster Risk Reduction*.

Nigg, Joanne M., John Barnshaw, and Manuel R. Torres. 2006. "Hurricane Katrina and the Flooding of New Orleans: Emergent Issues in Sheltering and Temporary Housing." *The ANNALS of the American Academy of Political and Social Science*.

NPM. 2018. "Needs and Population Monitoring SITE PROFILES." (June): 1–13. http://iom.maps.arcgis.com/.

Ocha., UN. 2017. "Needs Overview Syria Reference Map."

Ozbay, Eren, Özlem Çavuş, and Bahar Y. Kara. 2019. "Shelter Site Location under Multi-Hazard Scenarios." *Computers and Operations Research*.

Perruchoud, Richard, and Jillyanne Redpath-Cross. 2011. "Glossary on Migration." *International Migration Law*.

Quarantelli, E. L. 1995. "Patterns of Sheltering and Housing in US Disasters." *Disaster Prevention and Management: An International Journal*.

Raju, P L N. 2003. "Fundamentals of Geographical Information System." *Satellite Remote Sensing and GIS Applications in Agricultural Meteorology - Proceedings of the training workshop*.

Shah, Nirav, and Amrutaunshu Nerurkar. 2012. "A GIS Based E-Governance Solution for School Mapping and Educational Micro-Planning – a Case Study of the State of Maharashtra, India." In *9th International Conference on E-Governance (ICEG 2012),*.

Shavarani, Seyed Mahdi. 2019. "Multi-Level Facility Location-Allocation Problem for Post-Disaster Humanitarian Relief Distribution: A Case Study." *Journal of Humanitarian Logistics and Supply Chain Management*.

Sheikh, T L Mohammed, A, Eseigbe, E, Adekeye, T, Nuhu, F T, Lasisi, M, Muhammad, A, Sulaiman, Z T, Abdullateef, A A, Hayyatudeen, N, Akande, Y. 2016. 7 *Descriptive Characterization of and Post-Traumatic Stress Disorder Among Children and Adolescent Internally Displaced Persons in Kaduna, Nigeria, Frontiers in Psychiatry, : . Http://Dx.Doi.Org/10.3389/Fpsyt..00179.*

Sherali, Hanif D., Todd B. Carter, and Antoine G. Hobeika. 1991. "A Location-Allocation Model and Algorithm for Evacuation Planning under Hurricane/Flood Conditions." *Transportation Research Part B*.

Singh, S. P., and V. K. Singh. 2011. "Three-Level AHP-Based Heuristic Approach for a Multi-Objective Facility Layout Problem." *International Journal of Production Research*.

Song, Shuyang, Hong Zhou, and Wenyan Song. 2019. "Sustainable Shelter-Site Selection under Uncertainty: A Rough QUALIFLEX Method." *Computers and Industrial Engineering*.

Sphere Project. 2011. Charter *The Sphere Project*.

Subasinghe, C. 2013. 6 SRC-B *Spatial Confrontations: Abandonment of Self-Labor in Transitional Sheltering After a Natural of Disaster Risk Reduction, . Http://Dx.Doi.Org/10.1016/j.Ijdrr..09.005.*

The Institute of Structural Engineers. 2017. 1 CIBSE Knowledge Series: KS6 *Temporary Demountable Structures*.

Toole, MJ, and RJ Waldman. 2002. "THE PUBLIC HEALTH ASPECTS OF COMPLEX EMERGENCIES AND REFUGEE SITUATIONS." *Annual Review of Public Health*.

Turner, A, S Pathirana, A Daley, and P S Gill. 2009. 9 *Sri Lankan Tsunami Refugees: Sectional Study of the Relationships Between Housing Conditions and Self-Reported Health, Health and Human Rights, :. Http://Dx.Doi.Org/10.1186/1472-698X-9-16.*

UN. 2006. "Exploring Key Changes and Developments in Post-Disaster

Settlement „." : 1982–2006.

UNHCR. 2010. "UNITED NATIONS HIGH COMMISSIONER FOR REFUGEES." : 1–63.

UNOCHA. 2018. "Global Humanitarian Overview 2018." *United Nations*.

Vaz, E, K Lee, V Moonilal, and K Pereira. 2017. 72 SRC- *Potential of Geographic Information Systems for Refugee Crisis: Syrian Refugee Relocation in Urban* .

Ward, J., and Reproductive Health Refugees Consortium. 2002. Proceedings of the SIGCHI conference on Human factors in computing systems *If Not Now, When?: Addressing Gender-Based Violence in Refugee, Internally Displaced, and Post-Conflict Settings: A Global Overview*.

Wei, L Wei, Liang, Li, Weiping, Li, Kailing, Liu, Hongjia, Cheng, Liangxia. 2012. 43 SRC- *Decision Support for Urban Shelter Locations Based on Covering* .

Wise, Stephen. 2000. "GIS Data Modelling-Lessons from the Analysis of DTMs." *International Journal of Geographical Information Science*.

Wu, Jie Ying, and Michael K. Lindell. 2004. "Housing Reconstruction after Two Major Earthquakes: The 1994 Northridge Earthquake in the United States and the 1999 Chi-Chi Earthquake in Taiwan." *Disasters*.

Xu, J , Xu, J, Yin, X, Chen, D, An, J, Nie, G, Kabak, M. 2016. 20 SRC- *Multi-Criteria Location Model of Earthquake Evacuation Shelters to Aid in Urban of Disaster Risk Reduction, . Http://Dx.Doi.Org/10.1016/j.Ijdrr..10.009. [40] Çetinkaya, C., Özceylan, E., Erbaş, M. & . GIS-Based Fuzzy for Sititng Refugee Camp: Study For* .

Xu, Jiuping, and Zongmin Li. 2012. "Multi-Objective Dynamic Construction Site Layout Planning in Fuzzy Random Environment." *Automation in Construction*.

Xu, Jiuping, Qiurui Liu, and Xiao Lei. 2016. "A Fuzzy Multi-Objective Model and Application for the Discrete Dynamic Temporary Facilities Location

Planning Problem." *Journal of Civil Engineering and Management*.

Ye, M., and G. Zhou. 2007. "A Local Genetic Approach to Multi-Objective, Facility Layout Problems with Fixed Aisles." *International Journal of Production Research*.

Zhao, Laijun , Zhao, Laijun, Li, Huiyong, Sun, Yan, Huang, Rongbing, Hu, Qingmi, Wang, Jiajia, Gao, Fei. 2017. "Planning Emergency Shelters for Urban Disaster Resilience: An Integrated Location-Allocation Modeling Approach." *Sustainability (Switzerland)*.

Zhao, Xiujuan, Graham Coates, and Wei Xu. 2017. "Solving the Earthquake Disaster Shelter Location-Allocation Problem Using Optimization Heuristics." *14th International Conference on Information Systems for Crisis Response and Management (ISCRAM 2017)*.

CURRICULUM VITAE

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APPENDIXES

Appendix 1. Numerical Examples:

Dn: Demand node.
Rd: Requested demand in the defined node.
Ii: IDPs have inability.
Ik: Affected IDPs' kids who are in educational centres.
Ic: IDPs ^who has chronic diseases.
Iw: Women with the situation of lactating/ Pregnant.
Slr: Shelter.
Sc: Candidate shelters' capacity.
Cs: Cost of shelters' Placing.
Vc: Value of CFW.
Pw: Portable WASH building included.
Ac: Ability of scaling up.

Table 1. Data utilized in numerical examples

Dn	Rd		Ii	Ik	Ic	Iw
dn1	10		0	3	0	0
dn2	20		0	5	2	3
dn3	20		1	4	2	2
dn4	20		2	5	2	3
dn5	25		2	6	2	3
dn6	25		2	7	2	4
dn7	20		2	7	3	4
dn8	20		2	7	2	4
dn9	25		2	6	3	4

Table 1. Data utilized in numerical examples (cont.)

dn10	**25**	**2**	**6**	**2**	**3**
dn11	25	1	8	2	4
dn12	25	1	8	2	3
dn13	30	1	10	2	3
dn14	30	1	9	2	5
dn15	35	2	9	2	4
dn16	35	2	8	2	4
dn17	35	1	8	3	4
dn18	40	0	9	3	4
dn19	40	0	9	3	5
dn20	40	0	9	3	5
dn21	40	1	7	2	4
dn22	40	1	7	2	5

Table 2. Covering Distance Matrix

dn	Slr1	Slr2	Slr3	Slr4	Slr5	Slr6	Slr7
dn1	0	0	0	0	1	0	0
dn2	1	1	1	0	1	1	1
dn3	0	0	0	0	1	1	1
dn4	1	0	0	1	0	0	0
dn5	1	1	1	0	0	1	0
dn6	0	0	0	1	0	0	0
dn7	0	0	1	0	0	1	1
dn8	0	0	0	0	0	0	0
dn9	1	1	1	0	0	1	1
dn10	0	0	0	1	0	1	1
dn11	1	1	0	0	0	0	0
dn12	0	0	1	1	0	0	1
dn13	0	0	1	1	0	0	0
dn14	0	0	1	1	1	0	0
dn15	0	0	0	1	1	1	1
dn16	1	0	1	0	0	1	1
dn17	0	1	0	0	1	1	0
dn18	1	1	1	0	0	1	1
dn19	0	0	0	0	0	0	0
dn20	0	1	1	1	1	0	0
dn21	0	1	1	1	1	0	0
dn22	0	0	0	1	1	0	1

Table 3. Shelters' parameters

slr	Sc	Cs	Vc	Pw	Ac
slr1	73	5090	2036	1	0
slr2	92	5232.5	2893	1	1
slr3	77	4160	2464	1	1
slr4	130	8070	3228	1	1
slr5	150	5000	3000	0	0
slr6	160	6000	4000	0	0
slr7	170	5000	1	1	1

Numerical Example 1: 2 shelters selected from 4, 12 demand nodes (Hallak et al. 2019)			
	Targeted	**Achieved**	**% Achieved**
Amount of people placed	150	140	93.3%
Cost	10000	14290	142.9%
#Disability	15	10	66.6%
#Kids	60	40	66.6%
Numerical Example 2: 3 shelters selected from 6, 20 demand nodes.			
	Targeted	**Achieved**	**% Achieved**
Amount of people placed	240	235	97.9%
Cost	15000	18620	124.1%
#Disability	19	14	66.6%
#Kids	70	60	66.6%
Numerical Example 3: 4 shelters selected from 7, 22 demand nodes.			
	Targeted	**Achieved**	**% Achieved**
Amount of people placed	280	290	103.5%
Cost	16000	20440	127.7%
#Disability	20	15	66.6%
#Kids	75	72	66.6%

Appendix 2. Data and results obtained about the case study Idleb-Syria.

Pc: People capacity [Persons]
Cs: Cost of setting [$]
Pw: Portable wash facilities
As: Ability of scaling up
Rc: Running Cost
Cw: Cash for work
Ch: Chosen
Ta: Times allocated
Ac: Allocated Capacity

Table 1. Results from solving the Shelter location-allocation problem

no	Pc	Cs	Pw	As	Rc	Cw	Ch	Ta	Ac
Slr1	73	5,090	1	0	8256	2036	1	1	72
Slr2	92	7,233	1	1	9124	2893	1	1	90
Slr3	77	6,160	1	1	8044	2464	1	1	76
Slr4	130	8,070	1	1	13464	3228	1	3	130
Slr5	79	6,155	1	1	13342	2462	1	2	74
Slr6	96	6,118	0	1	9412	2447	0	0	0
Slr7	48	5,030	1	0	5956	2012	0	0	0
Slr8	80	6,590	1	1	10524	2636	1	1	80
Slr9	288	16,448	0	0	24612	6579	1	2	281
Slr10	192	15,393	1	1	18108	6157	1	1	192
Slr11	156	13,562	1	1	13232	5425	1	2	156
Slr12	76	7,152	1	1	10812	2861	1	1	76
Slr13	94	6,316	0	1	10728	4000	0	0	0
Slr14	40	5,404	1	1	5880	2162	1	1	40
Slr15	78	6,749	1	0	10704	2700	0	0	0
Slr16	73	6,182	1	1	9876	2000	1	1	72

Table 1. Results from solving the Shelter location-allocation problem (cont.)

Slr17	**60**	**5,827**	**1**	**0**	**8712**	**2000**	**0**	**0**	**0**
Slr18	192	12,957	1	0	20580	10060	1	2	185
Slr19	104	4,335	1	1	11196	1734	1	1	84
Slr20	411	19,347	1	1	31592	9500	1	2	408
Slr21	83	1,810	0	1	8476	724	1	2	83
Slr22	110	6,524	0	1	13566	4000	1	2	110
Slr23	213	16,266	1	0	20676	6506	1	2	207
Slr24	252	15,476	1	1	23280	9609	1	2	251
Slr25	46	3,369	1	1	5312	1347	1	1	46
Slr26	97	7,771	1	1	11076	3108	1	1	96
Slr27	86	9,583	1	1	10368	3000	1	1	86
Slr28	97	6,970	1	1	11376	2788	1	1	97
Slr29	91	2,881	0	0	10428	1152	1	1	90
Slr30	156	10,649	0	1	15468	4260	0	0	0
Slr31	165	3,872	0	1	15840	1549	1	2	160
Slr32	121	5,577	0	0	11212	2231	1	2	121
Slr33	162	10,210	0	0	14164	4084	0	0	0
Slr34	252	8,567	0	1	22776	3427	1	2	252
Slr35	140	3,846	0	1	13716	1539	1	2	138
Slr36	333	18,242	0	0	28200	7297	1	2	332
Slr37	390	22,323	0	1	34825	12459	1	5	386
Slr38	458	32,333	0	1	38621	10865	1	4	455
Slr39	897	34,345	0	1	68037	27400	1	4	879
Slr40	856	52,234	0	1	66166	21027	1	3	837
Slr41	834	44,073	0	1	64668	24429	1	4	833
Slr42	778	62,325	1	0	62470	24930	0	0	0
Slr43	128	12,800	1	0	12216	5120	0	0	0
Slr44	678	33,454	1	1	54120	20340	1	2	663
Slr45	568	55,080	1	1	45336	40000	0	0	0
Slr46	989	23,424	0	0	76772	17980	1	3	988
Slr47	99	6,435	0	1	12792	2574	0	0	0
Slr48	779	45,555	0	1	59700	21033	1	7	778

Table 1. Results from solving the Shelter location-allocation problem (cont.)

Slr49	**559**	**34,444**	**0**	**0**	**45804**	**22919**	**1**	**1**	**512**
Slr50	769	42,342	0	1	61835	17687	1	3	747
Slr51	785	62,800	1	0	63166	25120	1	4	778

Appendix 3. Demand nodes and which shelter has allocated to.
Note: if there no value in the column "Allocated to shelter" that's mean this node has not been allocated.

Table 1. Results from solving the IDPs location-allocation problem

Code	IDPs	Selected	Allocated to Shelter	Code	IDPs	Selected	Allocated to Shelter
dn1	20	1	SH44	dn167	257	1	SH9
dn2	20	1	SH48	dn168	259	1	SH51
dn3	20	1	SH41	dn169	259	0	
dn4	20	1	SH24	dn170	262	0	
dn5	21	1	SH46	dn171	263	0	
dn6	23	1	SH32	dn172	264	0	
dn7	24	0		dn173	264	0	
dn8	24	1	SH9	dn174	266	0	
dn9	24	1	SH41	dn175	268	0	
dn10	25	0		dn176	270	0	
dn11	25	0		dn177	273	0	
dn12	25	1	SH11	dn178	274	0	
dn13	25	1	SH5	dn179	276	0	
dn14	28	1	SH22	dn180	277	0	
dn15	30	1	SH21	dn181	286	0	
dn16	30	1	SH4	dn182	286	0	
dn17	31	1	SH46	dn183	287	1	SH50
dn18	31	1	SH23	dn184	289	1	SH36
dn19	35	1	SH37	dn185	289	0	
dn20	36	1	SH34	dn186	293	0	
dn21	37	1	SH37	dn187	295	0	
dn22	40	1	SH48	dn188	295	0	
dn23	40	1	SH14	dn189	296	0	
dn24	43	1	SH36	dn190	300	0	
dn25	44	1	SH48	dn191	300	0	
dn26	45	0		dn192	300	0	

Table 1. Results from solving the IDPs location-allocation problem (cont.)

dn27	**46**	**1**	**SH25**	dn193	**304**	**0**	
dn28	48	1	SH4	**dn194**	305	0	
dn29	48	1	SH20	**dn195**	308	0	
dn30	48	0		**dn196**	309	0	
dn31	48	1	SH39	**dn197**	311	0	
dn32	48	1	SH18	**dn198**	312	0	
dn33	49	0		**dn199**	314	0	
dn34	49	1	SH5	**dn200**	317	0	
dn35	50	1	SH35	**dn201**	319	0	
dn36	52	1	SH39	**dn202**	321	0	
dn37	52	1	SH4	**dn203**	322	0	
dn38	52	1	SH31	**dn204**	324	0	
dn39	52	1	SH48	**dn205**	325	0	
dn40	53	1	SH21	**dn206**	328	0	
dn41	56	0		**dn207**	335	0	
dn42	65	0		**dn208**	335	0	
dn43	69	1	SH51	**dn209**	344	0	
dn44	70	0		**dn210**	349	0	
dn45	70	0		**dn211**	350	0	
dn46	71	1	SH38	**dn212**	350	1	SH51
dn47	72	0		**dn213**	350	0	
dn48	72	0		**dn214**	350	0	
dn49	72	1	SH16	**dn215**	353	0	
dn50	72	1	SH1	**dn216**	360	0	
dn51	76	1	SH50	**dn217**	360	0	
dn52	76	1	SH3	**dn218**	360	0	
dn53	76	1	SH12	**dn219**	360	1	SH20
dn54	76	0		**dn220**	364	0	
dn55	80	1	SH8	**dn221**	366	0	
dn56	82	0		**dn222**	377	0	
dn57	82	1	SH22	**dn223**	382	0	

Table 1. Results from solving the IDPs location-allocation problem (cont.)

dn58	**84**	**1**	**SH38**	dn224	**384**	**1**	**SH50**
dn59	84	1	SH48	**dn225**	386	0	
dn60	84	1	SH19	**dn226**	391	0	
dn61	85	1	SH37	**dn227**	393	0	
dn62	86	1	SH27	**dn228**	393	0	
dn63	88	0		**dn229**	399	0	
dn64	88	0		**dn230**	406	0	
dn65	88	1	SH35	**dn231**	408	0	
dn66	90	1	SH29	**dn232**	417	0	
dn67	90	0		**dn233**	421	0	
dn68	90	0		**dn234**	423	0	
dn69	90	1	SH2	**dn235**	423	0	
dn70	94	1	SH37	**dn236**	424	0	
dn71	94	1	SH48	**dn237**	432	0	
dn72	96	0		**dn238**	434	0	
dn73	96	1	SH26	**dn239**	434	0	
dn74	97	1	SH28	**dn240**	440	0	
dn75	98	0		**dn241**	440	0	
dn76	98	1	SH32	**dn242**	443	0	
dn77	100	1	SH51	**dn243**	443	0	
dn78	100	0		**dn244**	443	0	
dn79	102	1	SH38	**dn245**	444	1	SH48
dn80	105	0		**dn246**	445	0	
dn81	105	0		**dn247**	449	0	
dn82	107	0		**dn248**	450	0	
dn83	108	0		**dn249**	454	0	
dn84	108	1	SH31	**dn250**	456	0	
dn85	111	0		**dn251**	458	0	
dn86	111	0		**dn252**	461	0	
dn87	113	0		**dn253**	464	0	
dn88	113	0		**dn254**	466	0	

Table 1. Results from solving the IDPs location-allocation problem (cont.)

dn89	**115**	**0**		dn255	**473**	**0**	
dn90	115	0		**dn256**	474	0	
dn91	123	0		**dn257**	475	0	
dn92	126	0		**dn258**	475	0	
dn93	128	0		**dn259**	481	0	
dn94	131	1	SH11	**dn260**	482	0	
dn95	134	0		**dn261**	484	0	
dn96	135	0		**dn262**	489	0	
dn97	135	1	SH37	**dn263**	496	0	
dn98	136	0		**dn264**	497	1	SH40
dn99	137	1	SH18	**dn265**	498	0	
dn100	139	0		**dn266**	498	0	
dn101	141	0		**dn267**	502	0	
dn102	141	0		**dn268**	502	0	
dn103	143	0		**dn269**	506	0	
dn104	144	0		**dn270**	512	1	SH49
dn105	144	0		**dn271**	512	0	
dn106	146	0		**dn272**	514	0	
dn107	148	0		**dn273**	518	0	
dn108	150	0		**dn274**	528	0	
dn109	151	0		**dn275**	529	0	
dn110	151	0		**dn276**	539	0	
dn111	152	0		**dn277**	540	0	
dn112	154	0		**dn278**	550	0	
dn113	155	0		**dn279**	552	1	SH41
dn114	155	0		**dn280**	553	0	
dn115	156	0		**dn281**	553	0	
dn116	157	1	SH40	**dn282**	555	1	SH39
dn117	166	0		**dn283**	557	0	
dn118	167	0		**dn284**	572	0	
dn119	168	0		**dn285**	581	0	

Table 1. Results from solving the IDPs location-allocation problem (cont.)

dn120	**170**	**0**		dn286	**584**	**0**	
dn121	171	0		**dn287**	591	0	
dn122	172	0		**dn288**	595	0	
dn123	173	0		**dn289**	606	0	
dn124	175	0		**dn290**	615	0	
dn125	175	0		**dn291**	633	0	
dn126	176	0		**dn292**	643	1	SH44
dn127	176	1	SH23	**dn293**	651	0	
dn128	183	1	SH40	**dn294**	665	0	
dn129	184	0		**dn295**	688	0	
dn130	185	0		**dn296**	704	0	
dn131	185	0		**dn297**	716	0	
dn132	186	0		**dn298**	727	0	
dn133	190	0		**dn299**	736	0	
dn134	192	0		**dn300**	741	0	
dn135	192	1	SH10	**dn301**	744	0	
dn136	195	0		**dn302**	757	0	
dn137	198	1	SH38	**dn303**	770	0	
dn138	199	0		**dn304**	774	0	
dn139	202	0		**dn305**	776	0	
dn140	204	0		**dn306**	788	0	
dn141	208	0		**dn307**	791	0	
dn142	208	0		**dn308**	812	0	
dn143	216	0		**dn309**	816	0	
dn144	216	1	SH34	**dn310**	818	0	
dn145	217	0		**dn311**	818	0	
dn146	217	0		**dn312**	834	0	
dn147	220	0		**dn313**	836	0	
dn148	221	0		**dn314**	862	0	
dn149	222	0		**dn315**	862	0	
dn150	224	1	SH39	**dn316**	869	0	

Table 1. Results from solving the IDPs location-allocation problem (cont.)

dn151	**224**	**0**		dn317	**876**	**0**	
dn152	225	0		**dn318**	876	0	
dn153	225	0		**dn319**	884	0	
dn154	231	1	SH24	**dn320**	906	0	
dn155	236	0		**dn321**	909	0	
dn156	237	1	SH41	**dn322**	916	0	
dn157	238	0		**dn323**	923	0	
dn158	241	0		**dn324**	931	0	
dn159	243	0		**dn325**	936	1	SH46
dn160	244	0		**dn326**	942	0	
dn161	246	0		**dn327**	949	0	
dn162	246	0		**dn328**	977	0	
dn163	249	0		**dn329**	977	0	
dn164	250	0		**dn330**	983	0	
dn165	251	0		**dn331**	997	0	
dn166	254	0					

Appendix 4. Outputs form running the proposed model in mentioned cases sensitivity analysis above are showed in Annex 2 where Ovrg1 to ovrg9 corresponds to the following, respectively:

Ovrg1: Obtained value related to the goal1: amount Coverage;
Ovrg2: Obtained value related to goal2: Cost;
Ovrg3: Obtained value related to goal3: CFW;
Ovrg4: Obtained value related to goal4: Portable facilities;
Ovrg5: Obtained value related to goal5: Ability to scaling up;
Ovrg6: Obtained value related to goal6: # Disability;
Ovrg7: Obtained value related to goal7: # Chronic Diseases;
Ovrg8: Obtained value related to goal8: # lactating/ Pregnant women;
Ovrg9: Obtained value related to goal9: # Kids.

Table 1. Comparison between target and achieved goals

		Ovrg1	***Ovrg2***	***Ovrg3***	***Ovrg4***	***Ovrg5***	***Ovrg6***	***Ovrg7***	***Ovrg8***	***Ovrg9***
P<=48	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	12,102	1,147,750	362,940	25	31	1,099	1,079	1,676	3,889
p<=44	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	12,140	1,143,010	342,528	25	30	1,102	1,065	1,675	3,897
p<=40	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,907	1,112,053	333,830	21	30	1,079	1,046	1,641	3,802
p<=42	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,952	1,125,450	338,542	23	30	1,085	1,057	1,651	3,820
p<=38	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,733	1,097,331	330,447	21	30	1,071	1,038	1,626	3,762
p<=36	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,435	1,065,247	321,905	19	30	1,037	1,011	1,585	3,671
Not taking the constraint of P	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	12,096	1,138,810	341,481	25	30	1,097	1,069	1,669	3,885
PGR: Collected data/2018	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,907	1,112,053	333,830	21	30	1,079	1,046	1,641	3,802
PGR: +3.72% /2007	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,849	1,109,960	266,170	21	30	1,087	1,087	1,087	1,087
PGR: -3.10%/2014	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,692	1,100,100	267,855	21	30	1,104	1,104	1,104	1,104

Table 1. Comparison between target and achieved goals (cont.)

PGR: -0.87% /2017	*Targeted*	*12,000*	*1,000,000*	*300,000*	*25*	*30*	*1,500*	*1,000*	*3,000*	*6,000*
	Achieved	11,958	1,113,420	266,360	21	30	1,098	1,098	1,098	1,098
TGs: -40%	Targeted	7,200	600,000	180,000	15	18	900	600	1,800	3,600
	Achieved	7,325	621,418	192,982	15	20	673	657	1,045	2,350
TGs: -20%	Targeted	9,600	800,000	240,000	20	24	1,200	800	2,400	4,800
	Achieved	9,765	873,376	261,243	20	25	893	874	1,374	3,129
TGs: -10%	Targeted	10,800	900,000	270,000	23	27	1,350	900	2,700	5,400
	Achieved	10,640	967,562	295,459	23	27	968	943	1,493	3,417
TGs: 0%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,907	1,112,053	333,830	21	30	1,079	1,046	1,641	3,802
TGs: +10%	Targeted	13,200	1,100,000	330,000	28	33	1,650	1,100	3,300	6,600
	Achieved	12,560	1,196,891	358,362	21	32	1,143	1,109	1,713	4,046
TGs: +20%	Targeted	14,400	1,200,000	360,000	30	36	1,800	1,200	3,600	7,200
	Achieved	13,055	1,263,673	395,915	22	32	1,164	1,163	1,791	4,169
TG: +40%	Targeted	16,800	1,400,000	420,000	35	42	2,100	1,400	4,200	8,400
	Achieved	13,062	1,281,640	301,640	22	30	1,176	1,176	1,773	4,189
TG: +60%	Targeted	19,200	1,600,000	480,000	40	48	2,400	1,600	4,800	9,600
	Achieved	13,074	1,282,070	162,070	22	30	1,163	1,165	1,792	4,158
TG: +100%	Targeted	24,000	2,000,000	600,000	50	60	3,000	2,000	6,000	12,000
	Achieved	12,596	1,265,110	794,950	21	30	1,131	1,135	1,704	4,001
P1: -40%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,205	1,000,064	304,745	23	30	984	975	1,503	3,468
P1: -20%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,783	1,102,340	331,733	22	30	1,073	1,038	1,633	3,801
P1: -10%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,909	1,112,120	333,830	21	30	1,080	1,055	1,654	3,821
P1: 0%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,907	1,112,053	333,830	21	30	1,079	1,046	1,641	3,802
P1: 10%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,947	1,113,490	333,830	21	30	1,086	1,051	1,653	3,825
P1: 20%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,936	1,113,100	333,830	21	30	1,082	1,050	1,652	3,830
P1: 40%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,899	1,111,760	333,830	21	30	1,082	1,053	1,645	3,836
P1: 100%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	12,008	1,115,690	333,830	21	30	1,091	1,057	1,663	3,855
P1:200 %	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,940	1,113,240	333,830	21	30	1,083	1,060	1,655	3,831

Table 1. Comparison between target and achieved goals (cont.)

P1: 300%	*Targeted*	*12,000*	*1,000,000*	*300,000*	*25*	*30*	*1,500*	*1,000*	*3,000*	*6,000*
	Achieved	12,020	1,116,120	333,830	21	30	1,090	1,064	1,657	3,846
P1: 400%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,961	1,114,000	333,830	21	30	1,085	1,064	1,668	3,832
TG1: -40%	Targeted	7,200	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,497	996,954	304,719	25	30	957	951	1,433	3,358
TG1: -20%	Targeted	9,600	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,497	996,954	304,719	25	30	957	951	1,433	3,358
TG1: -10%	Targeted	10,800	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,823	1,010,485	308,482	25	30	986	980	1,489	3,478
TG1: 0%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,907	1,112,053	333,830	21	30	1,079	1,046	1,641	3,802
TG1: 10%	Targeted	13,200	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	12,750	1,201,850	357,608	22	30	1,159	1,128	1,734	4,120
TG1: 20%	Targeted	14,400	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	12,670	1,198,970	357,608	22	30	1,152	1,118	1,750	4,079
TG1: 40%	Targeted	16,800	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	12,696	1,197,210	356,530	22	30	1,154	1,121	1,741	4,098
TG1: 100%	Targeted	24,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,766	983,236	284,039	23	30	965	960	1,493	3,412
TG1: 200%	Targeted	36,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,621	978,016	278,819	23	30	959	960	1,471	3,378
TG1: 300%	Targeted	48,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,373	972,034	273,684	24	30	934	937	1,441	3,286
TG1: 400%	Targeted	60,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,572	979,198	280,848	24	30	959	962	1,457	3,373
TGs & P1: -40%	Targeted	7,200	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,497	996,954	304,719	25	30	957	951	1,433	3,358
TGs & P1: -20%	Targeted	9,600	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,497	996,954	304,719	25	30	957	951	1,433	3,358
TGs & P1: -10%	Targeted	10,800	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,823	1,010,485	308,482	25	30	986	980	1,489	3,478
TGs & P1: 0%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,907	1,112,053	333,830	21	30	1,079	1,046	1,641	3,802
TGs & P1: 10%	Targeted	13,200	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	12,657	1,198,500	357,608	22	30	1,152	1,117	1,722	4,068

Table 1 Comparison between target and achieved goals (cont.)

TGs & P1: 20%	*Targeted*	*14,400*	*1,000,000*	*300,000*	*25*	*30*	*1,500*	*1,000*	*3,000*	*6,000*
	Achieved	13,118	1,260,590	394,608	22	30	1,193	1,163	1,794	4,239
TGs & P1: 40%	Targeted	16,800	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	13,221	1,264,300	394,608	22	30	1,203	1,166	1,803	4,261
TGs & P1: 100%	Targeted	24,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	13,119	1,260,630	394,608	22	30	1,186	1,163	1,766	4,184
TGs & P1: 200%	Targeted	36,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,638	1,207,310	394,608	22	30	1,004	1,019	1,587	3,610
TGs & P1: 300%	Targeted	48,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	12,403	1,213,730	381,285	21	30	1,129	1,103	1,696	3,990
TGs & P1: 400%	Targeted	60,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	12,504	1,240,020	395,221	23	30	1,137	1,109	1,709	4,012
P2: -40%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,722	1,103,470	333,061	24	30	1,071	1,037	1,617	3,776
P2: -20%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,865	1,108,620	333,061	24	30	1,079	1,044	1,648	3,811
P2: -10%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,812	1,103,390	331,733	22	30	1,076	1,046	1,643	3,788
P2: 0%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,907	1,112,053	333,830	21	30	1,079	1,046	1,641	3,802
P2: 10%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,927	1,110,800	333,873	21	30	1,086	1,046	1,650	3,823
P2: 20%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,296	1,030,858	310,984	20	30	1,025	1,001	1,572	3,638
P2: 40%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	11,276	1,025,607	309,171	20	30	1,022	1,008	1,570	3,617
P2: 100%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,860	999,213	303,818	21	30	986	972	1,514	3,464
P2: 200%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,872	999,645	304,250	21	30	985	975	1,515	3,470
P2: 300%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,901	1,000,689	304,604	21	30	990	978	1,525	3,483
P2: 400%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
	Achieved	10,886	1,000,149	304,604	21	30	988	976	1,522	3,479

Table 1. Comparison between target and achieved goals (cont.)

TG2:	*Targeted*	*12,000*	*600,000*	*300,000*	*25*	*30*	*1,500*	*1,000*	*3,000*	*6,000*
-40%	Achieved	9,657	906,680	300,000	20	29	876	873	1,328	3,070
TG2:	Targeted	12,000	800,000	300,000	25	30	1,500	1,000	3,000	6,000
-20%	Achieved	11,183	1,026,790	310,984	20	30	1,007	992	1,557	3,575
TG2:	Targeted	12,000	900,000	300,000	25	30	1,500	1,000	3,000	6,000
-10%	Achieved	11,877	1,099,670	330,141	20	30	1,080	1,042	1,644	3,805
TG2:	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
0%	Achieved	11,907	1,112,053	333,830	21	30	1,079	1,046	1,641	3,802
TG2:	Targeted	12,000	1,100,000	300,000	25	30	1,500	1,000	3,000	6,000
10%	Achieved	11,824	1,104,992	332,201	23	30	1,073	1,044	1,647	3,792
TG2:	Targeted	12,000	1,200,000	300,000	25	30	1,500	1,000	3,000	6,000
20%	Achieved	12,392	1,173,467	324,879	25	30	1,126	1,094	1,705	4,000
TG2:	Targeted	12,000	1,400,000	300,000	25	30	1,500	1,000	3,000	6,000
40%	Achieved	13,073	1,274,510	273,109	25	30	1,181	1,152	1,787	4,170
TG2:	Targeted	12,000	2,000,000	300,000	25	30	1,500	1,000	3,000	6,000
100%	Achieved	13,031	1,272,990	201,401	25	30	1,181	1,161	1,767	4,174
TG2:	Targeted	12,000	3,000,000	300,000	25	30	1,500	1,000	3,000	6,000
200%	Achieved	13,163	1,277,700	201,401	25	30	1,191	1,167	1,795	4,227
P2:-40%	Targeted	12,000	1,400,000	300,000	25	30	1,500	1,000	3,000	6,000
&TG2: +40%	Achieved	13,068	1,274,330	201,401	25	30	1,183	1,152	1,785	4,201
P2 -20%	Targeted	12,000	1,200,000	300,000	25	30	1,500	1,000	3,000	6,000
&TG2: +20%	Achieved	12,401	1,173,791	248,588	25	30	1,127	1,094	1,704	4,007
P2 -10%	Targeted	12,000	1,100,000	300,000	25	30	1,500	1,000	3,000	6,000
&TG2: +10%	Achieved	11,769	1,105,162	266,939	24	30	1,073	1,035	1,623	3,781
P2 0%	Targeted	12,000	1,000,000	300,000	25	30	1,500	1,000	3,000	6,000
&TG2: 0%	Achieved	11,907	1,112,053	333,830	21	30	1,079	1,046	1,641	3,802
P2 +10%	Targeted	12,000	900,000	300,000	25	30	1,500	1,000	3,000	6,000
&TG2: -10%	Achieved	11,870	1,107,570	266,596	20	30	1,081	1,047	1,624	3,807
P2 +20%	Targeted	12,000	800,000	300,000	25	30	1,500	1,000	3,000	6,000
&TG2: -20%	Achieved	10,574	966,700	302,214	21	30	955	953	1,451	3,389
P2 +40%	Targeted	12,000	600,000	300,000	25	30	1,500	1,000	3,000	6,000
&TG2: -40%	Achieved	7,034	621,735	400,110	18	26	640	646	977	2,231

Appendix 5. Code utilized to translate the proposed methodology into Gams programing:

```
set i set of displaced people demand nodes
/dn1,dn2,dn3,dn4,dn5,dn6,dn7,dn8,dn9,dn10,dn11,dn12,dn13,d
n14,dn15,dn16,dn17,dn18,dn19,dn20,dn21,dn22,dn23,dn24,dn25
,dn26,dn27,dn28,dn29,dn30,dn31,dn32,dn33,dn34,dn35,dn36,dn
37,dn38,dn39,dn40,dn41,dn42,dn43,dn44,dn45,dn46,dn47,dn48,
dn49,dn50,dn51,dn52,dn53,dn54,dn55,dn56,dn57,dn58,dn59,dn6
0,dn61,dn62,dn63,dn64,dn65,dn66,dn67,dn68,dn69,dn70,dn71,d
n72,dn73,dn74,dn75,dn76,dn77,dn78,dn79,dn80,dn81,dn82,dn83
,dn84,dn85,dn86,dn87,dn88,dn89,dn90,dn91,dn92,dn93,dn94,dn
95,dn96,dn97,dn98,dn99,dn100,dn101,dn102,dn103,dn104,dn105
,dn106,dn107,dn108,dn109,dn110,dn111,dn112,dn113,dn114,dn1
15,dn116,dn117,dn118,dn119,dn120,dn121,dn122,dn123,dn124,d
n125,dn126,dn127,dn128,dn129,dn130,dn131,dn132,dn133,dn134
,dn135,dn136,dn137,dn138,dn139,dn140,dn141,dn142,dn143,dn1
44,dn145,dn146,dn147,dn148,dn149,dn150,dn151,dn152,dn153,d
n154,dn155,dn156,dn157,dn158,dn159,dn160,dn161,dn162,dn163
,dn164,dn165,dn166,dn167,dn168,dn169,dn170,dn171,dn172,dn1
73,dn174,dn175,dn176,dn177,dn178,dn179,dn180,dn181,dn182,d
n183,dn184,dn185,dn186,dn187,dn188,dn189,dn190,dn191,dn192
,dn193,dn194,dn195,dn196,dn197,dn198,dn199,dn200,dn201,dn2
02,dn203,dn204,dn205,dn206,dn207,dn208,dn209,dn210,dn211,d
n212,dn213,dn214,dn215,dn216,dn217,dn218,dn219,dn220,dn221
,dn222,dn223,dn224,dn225,dn226,dn227,dn228,dn229,dn230,dn2
31,dn232,dn233,dn234,dn235,dn236,dn237,dn238,dn239,dn240,d
n241,dn242,dn243,dn244,dn245,dn246,dn247,dn248,dn249,dn250
,dn251,dn252,dn253,dn254,dn255,dn256,dn257,dn258,dn259,dn2
60,dn261,dn262,dn263,dn264,dn265,dn266,dn267,dn268,dn269,d
n270,dn271,dn272,dn273,dn274,dn275,dn276,dn277,dn278,dn279
,dn280,dn281,dn282,dn283,dn284,dn285,dn286,dn287,dn288,dn2
89,dn290,dn291,dn292,dn293,dn294,dn295,dn296,dn297,dn298,d
n299,dn300,dn301,dn302,dn303,dn304,dn305,dn306,dn307,dn308
,dn309,dn310,dn311,dn312,dn313,dn314,dn315,dn316,dn317,dn3
18,dn319,dn320,dn321,dn322,dn323,dn324,dn325,dn326,dn327,d
n328,dn329,dn330,dn331/;

sets j set of facility sites
/SLR1,SLR2,SLR3,SLR4,SLR5,SLR6,SLR7,SLR8,SLR9,SLR10,SLR11,
SLR12,SLR13,SLR14,SLR15,SLR16,SLR17,SLR18,SLR19,SLR20,SLR2
1,SLR22,SLR23,SLR24,SLR25,SLR26,SLR27,SLR28,SLR29,SLR30,SL
R31,SLR32,SLR33,SLR34,SLR35,SLR36,SLR37,SLR38,SLR39,SLR40,
SLR41,SLR42,SLR43,SLR44,SLR45,SLR46,SLR47,SLR48,SLR49,SLR5
0,SLR51/;
```

```
set n set of penalty
/p1,p2,p3,p4,p5,p6,p7,p8,p9,p10,p11,p12,p13,p14,p15,p16,p1
7,p18/;

parameter h(i) demand at node i /dn1 20,dn2 20,dn3 20,dn4
20,dn5 21,dn6 23,dn7 24,dn8 24,dn9 24,dn10 25,dn11 25,dn12
25,dn13 25,dn14 28,dn15 30,dn16 30,dn17 31,dn18 31,dn19
35,dn20 36,dn21 37,dn22 40,dn23 40,dn24 43,dn25 44,dn26
45,dn27 46,dn28 48,dn29 48,dn30 48,dn31 48,dn32 48,dn33
49,dn34 49,dn35 50,dn36 52,dn37 52,dn38 52,dn39 52,dn40
53,dn41 56,dn42 65,dn43 69,dn44 70,dn45 70,dn46 71,dn47
72,dn48 72,dn49 72,dn50 72,dn51 76,dn52 76,dn53 76,dn54
76,dn55 80,dn56 82,dn57 82,dn58 84,dn59 84,dn60 84,dn61
85,dn62 86,dn63 88,dn64 88,dn65 88,dn66 90,dn67 90,dn68
90,dn69 90,dn70 94,dn71 94,dn72 96,dn73 96,dn74 97,dn75
98,dn76 98,dn77 100,dn78 100,dn79 102,dn80 105,dn81
105,dn82 107,dn83 108,dn84 108,dn85 111,dn86 111,dn87
113,dn88 113,dn89 115,dn90 115,dn91 123,dn92 126,dn93
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202,dn140 204,dn141 208,dn142 208,dn143 216,dn144
216,dn145 217,dn146 217,dn147 220,dn148 221,dn149
222,dn150 224,dn151 224,dn152 225,dn153 225,dn154
231,dn155 236,dn156 237,dn157 238,dn158 241,dn159
243,dn160 244,dn161 246,dn162 246,dn163 249,dn164
250,dn165 251,dn166 254,dn167 257,dn168 259,dn169
259,dn170 262,dn171 263,dn172 264,dn173 264,dn174
266,dn175 268,dn176 270,dn177 273,dn178 274,dn179
276,dn180 277,dn181 286,dn182 286,dn183 287,dn184
289,dn185 289,dn186 293,dn187 295,dn188 295,dn189
296,dn190 300,dn191 300,dn192 300,dn193 304,dn194
305,dn195 308,dn196 309,dn197 311,dn198 312,dn199
314,dn200 317,dn201 319,dn202 321,dn203 322,dn204
324,dn205 325,dn206 328,dn207 335,dn208 335,dn209
344,dn210 349,dn211 350,dn212 350,dn213 350,dn214
350,dn215 353,dn216 360,dn217 360,dn218 360,dn219
360,dn220 364,dn221 366,dn222 377,dn223 382,dn224
384,dn225 386,dn226 391,dn227 393,dn228 393,dn229
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399,dn230 406,dn231 408,dn232 417,dn233 421,dn234
423,dn235 423,dn236 424,dn237 432,dn238 434,dn239
434,dn240 440,dn241 440,dn242 443,dn243 443,dn244
443,dn245 444,dn246 445,dn247 449,dn248 450,dn249
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466,dn255 473,dn256 474,dn257 475,dn258 475,dn259
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497,dn265 498,dn266 498,dn267 502,dn268 502,dn269
506,dn270 512,dn271 512,dn272 514,dn273 518,dn274
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552,dn280 553,dn281 553,dn282 555,dn283 557,dn284
572,dn285 581,dn286 584,dn287 591,dn288 595,dn289
606,dn290 615,dn291 633,dn292 643,dn293 651,dn294
665,dn295 688,dn296 704,dn297 716,dn298 727,dn299
736,dn300 741,dn301 744,dn302 757,dn303 770,dn304
774,dn305 776,dn306 788,dn307 791,dn308 812,dn309
816,dn310 818,dn311 818,dn312 834,dn313 836,dn314
862,dn315 862,dn316 869,dn317 876,dn318 876,dn319
884,dn320 906,dn321 909,dn322 916,dn323 923,dn324
931,dn325 936,dn326 942,dn327 949,dn328 977,dn329
977,dn330 983,dn331 997/;

parameter v1(i) disability at node i /dn1 2,dn2 2,dn3
2,dn4 2,dn5 2,dn6 2,dn7 2,dn8 2,dn9 2,dn10 2,dn11 2,dn12
2,dn13 2,dn14 3,dn15 3,dn16 3,dn17 3,dn18 3,dn19 3,dn20
3,dn21 3,dn22 3,dn23 4,dn24 4,dn25 4,dn26 4,dn27 4,dn28
4,dn29 4,dn30 4,dn31 5,dn32 5,dn33 4,dn34 5,dn35 5,dn36
5,dn37 5,dn38 5,dn39 5,dn40 5,dn41 4,dn42 5,dn43 7,dn44
5,dn45 5,dn46 7,dn47 6,dn48 6,dn49 6,dn50 6,dn51 6,dn52
7,dn53 7,dn54 7,dn55 8,dn56 6,dn57 7,dn58 8,dn59 8,dn60
8,dn61 8,dn62 8,dn63 8,dn64 8,dn65 8,dn66 9,dn67 7,dn68
8,dn69 8,dn70 9,dn71 7,dn72 7,dn73 8,dn74 9,dn75 7,dn76
9,dn77 9,dn78 7,dn79 10,dn80 9,dn81 10,dn82 10,dn83 9,dn84
10,dn85 10,dn86 10,dn87 11,dn88 10,dn89 9,dn90 11,dn91
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16,dn147 18,dn148 18,dn149 16,dn150 21,dn151 18,dn152
21,dn153 16,dn154 21,dn155 22,dn156 22,dn157 20,dn158
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17,dn159 18,dn160 22,dn161 20,dn162 18,dn163 23,dn164
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69,dn315 61,dn316 79,dn317 79,dn318 71,dn319 62,dn320
73,dn321 64,dn322 83,dn323 74,dn324 66,dn325 85,dn326
66,dn327 86,dn328 69,dn329 69,dn330 69,dn331 90/;

parameter v4(i) children at node i /dn1 5,dn2 5,dn3 4,dn4
5,dn5 6,dn6 7,dn7 7,dn8 7,dn9 6,dn10 6,dn11 7,dn12 7,dn13
7,dn14 8,dn15 7,dn16 9,dn17 9,dn18 6,dn19 11,dn20 11,dn21
11,dn22 11,dn23 12,dn24 13,dn25 14,dn26 15,dn27 23,dn28
15,dn29 15,dn30 15,dn31 15,dn32 14,dn33 14,dn34 15,dn35
15,dn36 15,dn37 15,dn38 15,dn39 15,dn40 13,dn41 14,dn42
21,dn43 20,dn44 22,dn45 22,dn46 22,dn47 22,dn48 15,dn49
22,dn50 22,dn51 25,dn52 24,dn53 25,dn54 25,dn55 25,dn56
26,dn57 26,dn58 27,dn59 20,dn60 27,dn61 27,dn62 26,dn63
28,dn64 28,dn65 28,dn66 29,dn67 29,dn68 29,dn69 26,dn70
31,dn71 31,dn72 31,dn73 31,dn74 30,dn75 26,dn76 27,dn77
26,dn78 32,dn79 32,dn80 34,dn81 34,dn82 35,dn83 36,dn84
36,dn85 36,dn86 36,dn87 36,dn88 36,dn89 26,dn90 37,dn91
40,dn92 38,dn93 41,dn94 42,dn95 43,dn96 44,dn97 44,dn98
35,dn99 45,dn100 45,dn101 34,dn102 46,dn103 46,dn104
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46,dn105 44,dn106 47,dn107 48,dn108 49,dn109 50,dn110
44,dn111 45,dn112 47,dn113 50,dn114 50,dn115 50,dn116
51,dn117 54,dn118 55,dn119 49,dn120 55,dn121 55,dn122
55,dn123 50,dn124 46,dn125 48,dn126 57,dn127 57,dn128
60,dn129 55,dn130 60,dn131 60,dn132 60,dn133 62,dn134
58,dn135 62,dn136 64,dn137 65,dn138 57,dn139 56,dn140
52,dn141 67,dn142 67,dn143 71,dn144 71,dn145 60,dn146
71,dn147 72,dn148 72,dn149 72,dn150 73,dn151 60,dn152
73,dn153 73,dn154 76,dn155 76,dn156 77,dn157 70,dn158
77,dn159 73,dn160 74,dn161 80,dn162 80,dn163 60,dn164
59,dn165 64,dn166 84,dn167 84,dn168 85,dn169 60,dn170
86,dn171 86,dn172 86,dn173 86,dn174 86,dn175 87,dn176
89,dn177 90,dn178 90,dn179 90,dn180 90,dn181 87,dn182
94,dn183 94,dn184 94,dn185 86,dn186 96,dn187 97,dn188
97,dn189 85,dn190 80,dn191 80,dn192 98,dn193 100,dn194
100,dn195 90,dn196 101,dn197 92,dn198 96,dn199 99,dn200
88,dn201 83,dn202 105,dn203 100,dn204 89,dn205 96,dn206
107,dn207 85,dn208 100,dn209 94,dn210 101,dn211 115,dn212
115,dn213 115,dn214 102,dn215 108,dn216 118,dn217
118,dn218 118,dn219 118,dn220 119,dn221 121,dn222
125,dn223 110,dn224 125,dn225 126,dn226 104,dn227
105,dn228 117,dn229 120,dn230 133,dn231 134,dn232
123,dn233 139,dn234 139,dn235 139,dn236 139,dn237
142,dn238 143,dn239 133,dn240 123,dn241 145,dn242
146,dn243 146,dn244 146,dn245 146,dn246 146,dn247
132,dn248 148,dn249 145,dn250 156,dn251 150,dn252
151,dn253 153,dn254 153,dn255 155,dn256 156,dn257
154,dn258 134,dn259 124,dn260 134,dn261 145,dn262
160,dn263 164,dn264 164,dn265 164,dn266 164,dn267
165,dn268 165,dn269 166,dn270 169,dn271 154,dn272
145,dn273 134,dn274 167,dn275 167,dn276 156,dn277
159,dn278 181,dn279 181,dn280 183,dn281 170,dn282
183,dn283 183,dn284 188,dn285 191,dn286 193,dn287
194,dn288 196,dn289 199,dn290 204,dn291 208,dn292
212,dn293 214,dn294 201,dn295 227,dn296 232,dn297
235,dn298 202,dn299 243,dn300 244,dn301 245,dn302
249,dn303 234,dn304 255,dn305 256,dn306 233,dn307
244,dn308 245,dn309 267,dn310 270,dn311 270,dn312
275,dn313 276,dn314 284,dn315 284,dn316 287,dn317
289,dn318 289,dn319 292,dn320 298,dn321 300,dn322
302,dn323 305,dn324 307,dn325 309,dn326 311,dn327
314,dn328 300,dn329 322,dn330 302,dn331 327/;
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parameter v2(i) children at node i /dn1 2,dn2 2,dn3 2,dn4
2,dn5 2,dn6 2,dn7 3,dn8 2,dn9 3,dn10 2,dn11 2,dn12 2,dn13
3,dn14 3,dn15 3,dn16 3,dn17 3,dn18 3,dn19 4,dn20 3,dn21
3,dn22 4,dn23 4,dn24 4,dn25 4,dn26 4,dn27 5,dn28 5,dn29
5,dn30 5,dn31 4,dn32 5,dn33 5,dn34 4,dn35 5,dn36 5,dn37
5,dn38 5,dn39 5,dn40 5,dn41 5,dn42 6,dn43 7,dn44 6,dn45
6,dn46 7,dn47 7,dn48 6,dn49 6,dn50 7,dn51 7,dn52 7,dn53
7,dn54 7,dn55 8,dn56 7,dn57 7,dn58 7,dn59 7,dn60 8,dn61
8,dn62 7,dn63 8,dn64 8,dn65 8,dn66 9,dn67 8,dn68 8,dn69
8,dn70 9,dn71 9,dn72 8,dn73 9,dn74 8,dn75 9,dn76 9,dn77
8,dn78 8,dn79 9,dn80 9,dn81 9,dn82 10,dn83 10,dn84 9,dn85
9,dn86 10,dn87 10,dn88 10,dn89 10,dn90 10,dn91 12,dn92
11,dn93 12,dn94 12,dn95 11,dn96 13,dn97 13,dn98 13,dn99
11,dn100 12,dn101 13,dn102 12,dn103 13,dn104 13,dn105
12,dn106 12,dn107 12,dn108 12,dn109 14,dn110 14,dn111
14,dn112 13,dn113 14,dn114 14,dn115 15,dn116 13,dn117
15,dn118 14,dn119 16,dn120 14,dn121 16,dn122 16,dn123
16,dn124 14,dn125 14,dn126 16,dn127 15,dn128 15,dn129
15,dn130 15,dn131 15,dn132 17,dn133 16,dn134 16,dn135
18,dn136 16,dn137 18,dn138 18,dn139 19,dn140 17,dn141
17,dn142 17,dn143 20,dn144 20,dn145 20,dn146 18,dn147
18,dn148 20,dn149 20,dn150 21,dn151 21,dn152 18,dn153
18,dn154 21,dn155 19,dn156 19,dn157 20,dn158 22,dn159
22,dn160 20,dn161 23,dn162 20,dn163 20,dn164 20,dn165
21,dn166 21,dn167 24,dn168 24,dn169 24,dn170 24,dn171
24,dn172 24,dn173 24,dn174 22,dn175 22,dn176 22,dn177
25,dn178 22,dn179 25,dn180 23,dn181 23,dn182 23,dn183
23,dn184 24,dn185 27,dn186 27,dn187 24,dn188 24,dn189
24,dn190 24,dn191 24,dn192 27,dn193 28,dn194 25,dn195
25,dn196 28,dn197 28,dn198 25,dn199 29,dn200 29,dn201
29,dn202 29,dn203 29,dn204 30,dn205 26,dn206 27,dn207
27,dn208 31,dn209 31,dn210 32,dn211 32,dn212 28,dn213
28,dn214 32,dn215 29,dn216 33,dn217 29,dn218 33,dn219
29,dn220 33,dn221 30,dn222 34,dn223 31,dn224 35,dn225
31,dn226 32,dn227 32,dn228 32,dn229 32,dn230 33,dn231
37,dn232 34,dn233 34,dn234 34,dn235 34,dn236 34,dn237
35,dn238 35,dn239 40,dn240 40,dn241 40,dn242 40,dn243
40,dn244 40,dn245 36,dn246 41,dn247 41,dn248 36,dn249
41,dn250 42,dn251 42,dn252 42,dn253 38,dn254 42,dn255
43,dn256 43,dn257 43,dn258 43,dn259 39,dn260 39,dn261
39,dn262 40,dn263 45,dn264 45,dn265 40,dn266 40,dn267
46,dn268 41,dn269 46,dn270 41,dn271 41,dn272 47,dn273
42,dn274 48,dn275 48,dn276 44,dn277 49,dn278 50,dn279
50,dn280 50,dn281 50,dn282 50,dn283 45,dn284 46,dn285
47,dn286 53,dn287 48,dn288 54,dn289 49,dn290 56,dn291
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51,dn292 52,dn293 53,dn294 60,dn295 62,dn296 57,dn297
65,dn298 66,dn299 59,dn300 60,dn301 67,dn302 69,dn303
70,dn304 62,dn305 70,dn306 64,dn307 64,dn308 65,dn309
74,dn310 66,dn311 74,dn312 76,dn313 76,dn314 78,dn315
78,dn316 70,dn317 71,dn318 71,dn319 80,dn320 73,dn321
73,dn322 74,dn323 74,dn324 75,dn325 85,dn326 85,dn327
86,dn328 79,dn329 79,dn330 89,dn331 90/;

parameter v3(i) childnren at nodne i/dn1 3,dn2 3,dn3 2,dn4
3,dn5 3,dn6 4,dn7 4,dn8 4,dn9 4,dn10 3,dn11 4,dn12 3,dn13
3,dn14 4,dn15 4,dn16 4,dn17 4,dn18 4,dn19 5,dn20 5,dn21
5,dn22 4,dn23 6,dn24 7,dn25 6,dn26 6,dn27 6,dn28 7,dn29
7,dn30 7,dn31 8,dn32 5,dn33 8,dn34 8,dn35 5,dn36 6,dn37
8,dn38 6,dn39 7,dn40 6,dn41 7,dn42 8,dn43 8,dn44 7,dn45
8,dn46 8,dn47 9,dn48 11,dn49 11,dn50 11,dn51 12,dn52
11,dn53 11,dn54 11,dn55 12,dn56 12,dn57 11,dn58 10,dn59
9,dn60 12,dn61 11,dn62 9,dn63 11,dn64 12,dn65 10,dn66
13,dn67 11,dn68 11,dn69 13,dn70 15,dn71 14,dn72 15,dn73
12,dn74 13,dn75 15,dn76 15,dn77 13,dn78 14,dn79 11,dn80
14,dn81 16,dn82 12,dn83 15,dn84 13,dn85 14,dn86 15,dn87
15,dn88 12,dn89 13,dn90 14,dn91 18,dn92 17,dn93 16,dn94
20,dn95 18,dn96 21,dn97 15,dn98 21,dn99 21,dn100 20,dn101
19,dn102 16,dn103 22,dn104 16,dn105 22,dn106 19,dn107
20,dn108 21,dn109 19,dn110 23,dn111 22,dn112 22,dn113
18,dn114 24,dn115 22,dn116 18,dn117 20,dn118 21,dn119
24,dn120 24,dn121 21,dn122 18,dn123 18,dn124 27,dn125
20,dn126 18,dn127 22,dn128 24,dn129 23,dn130 23,dn131
28,dn132 27,dn133 23,dn134 20,dn135 22,dn136 22,dn137
28,dn138 30,dn139 29,dn140 29,dn141 23,dn142 21,dn143
31,dn144 29,dn145 33,dn146 33,dn147 25,dn148 34,dn149
27,dn150 34,dn151 32,dn152 23,dn153 32,dn154 35,dn155
24,dn156 36,dn157 34,dn158 34,dn159 25,dn160 35,dn161
28,dn162 25,dn163 38,dn164 38,dn165 38,dn166 26,dn167
39,dn168 34,dn169 26,dn170 35,dn171 32,dn172 32,dn173
27,dn174 38,dn175 41,dn176 36,dn177 33,dn178 28,dn179
34,dn180 31,dn181 32,dn182 38,dn183 44,dn184 44,dn185
32,dn186 44,dn187 30,dn188 36,dn189 39,dn190 39,dn191
30,dn192 30,dn193 43,dn194 46,dn195 37,dn196 31,dn197
47,dn198 38,dn199 32,dn200 32,dn201 42,dn202 39,dn203
33,dn204 39,dn205 49,dn206 37,dn207 37,dn208 51,dn209
35,dn210 35,dn211 46,dn212 49,dn213 35,dn214 49,dn215
50,dn216 40,dn217 36,dn218 51,dn219 54,dn220 44,dn221
41,dn222 38,dn223 58,dn224 58,dn225 43,dn226 59,dn227
48,dn228 48,dn229 48,dn230 61,dn231 49,dn232 42,dn233
43,dn234 47,dn235 51,dn236 64,dn237 44,dn238 66,dn239
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57,dn240 58,dn241 66,dn242 49,dn243 67,dn244 67,dn245
63,dn246 49,dn247 68,dn248 45,dn249 46,dn250 69,dn251
51,dn252 60,dn253 61,dn254 61,dn255 62,dn256 67,dn257
57,dn258 53,dn259 53,dn260 68,dn261 49,dn262 49,dn263
60,dn264 65,dn265 50,dn266 50,dn267 76,dn268 51,dn269
51,dn270 67,dn271 77,dn272 78,dn273 63,dn274 69,dn275
53,dn276 65,dn277 76,dn278 66,dn279 78,dn280 61,dn281
78,dn282 78,dn283 67,dn284 63,dn285 70,dn286 71,dn287
66,dn288 90,dn289 67,dn290 93,dn291 70,dn292 84,dn293
79,dn294 100,dn295 69,dn296 92,dn297 86,dn298 110,dn299
89,dn300 75,dn301 75,dn302 91,dn303 93,dn304 78,dn305
86,dn306 119,dn307 88,dn308 106,dn309 82,dn310 123,dn311
99,dn312 126,dn313 101,dn314 121,dn315 130,dn316 87,dn317
114,dn318 106,dn319 124,dn320 100,dn321 100,dn322
101,dn323 111,dn324 131,dn325 132,dn326 95,dn327 114,dn328
137,dn329 147,dn330 128,dn331 100/;

parameter pp(n) penalty at n /p1 10,p2 0,p3 4,p4 0,p5 3,p6
0,p7 2,p8 0,p9 0,p10 9,p11 1,p12 0,p13 1,p14 0,p15 1,p16
0,p17 1,p18 0/;

parameter norm(n) normalization at n /p1 12000,p2 12000,p3
1500,p4 1500,p5 6000,p6 6000,p7 300000,p8 300000,p9
1000000,p10 1000000,p11 25,p12 25,p13 30,p14 30,p15
1000,p16 1000,p17 3000,p18 3000/;

parameter ad(i) acceptiable dnistance at nodne i /dn1
20,dn2 20,dn3 30,dn4 20,dn5 20,dn6 20,dn7 20,dn8 20,dn9
100,dn10 20,dn11 20,dn12 50,dn13 20,dn14 20,dn15 70,dn16
100,dn17 20,dn18 20,dn19 20,dn20 20,dn21 20,dn22 20,dn23
30,dn24 20,dn25 20,dn26 30,dn27 100,dn28 20,dn29 20,dn30
20,dn31 50,dn32 20,dn33 30,dn34 20,dn35 20,dn36 20,dn37
70,dn38 100,dn39 20,dn40 20,dn41 20,dn42 20,dn43 20,dn44
30,dn45 50,dn46 30,dn47 100,dn48 70,dn49 20,dn50 20,dn51
20,dn52 30,dn53 100,dn54 30,dn55 30,dn56 70,dn57 30,dn58
30,dn59 100,dn60 30,dn61 30,dn62 70,dn63 30,dn64 30,dn65
30,dn66 30,dn67 30,dn68 30,dn69 100,dn70 30,dn71 30,dn72
30,dn73 20,dn74 30,dn75 30,dn76 100,dn77 20,dn78 30,dn79
30,dn80 30,dn81 30,dn82 30,dn83 30,dn84 100,dn85 30,dn86
30,dn87 30,dn88 30,dn89 30,dn90 20,dn91 30,dn92 30,dn93
30,dn94 30,dn95 30,dn96 20,dn97 30,dn98 30,dn99 50,dn100
30,dn101 70,dn102 30,dn103 30,dn104 30,dn105 30,dn106
30,dn107 30,dn108 50,dn109 30,dn110 30,dn111 30,dn112
20,dn113 30,dn114 30,dn115 30,dn116 30,dn117 30,dn118
30,dn119 20,dn120 30,dn121 30,dn122 20,dn123 30,dn124
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30,dn125 30,dn126 30,dn127 30,dn128 30,dn129 30,dn130
30,dn131 30,dn132 30,dn133 30,dn134 30,dn135 30,dn136
30,dn137 30,dn138 30,dn139 50,dn140 30,dn141 70,dn142
30,dn143 30,dn144 100,dn145 30,dn146 30,dn147 30,dn148
20,dn149 30,dn150 30,dn151 100,dn152 30,dn153 50,dn154
50,dn155 50,dn156 50,dn157 50,dn158 50,dn159 30,dn160
50,dn161 20,dn162 50,dn163 50,dn164 50,dn165 50,dn166
50,dn167 50,dn168 70,dn169 50,dn170 50,dn171 50,dn172
50,dn173 50,dn174 100,dn175 50,dn176 50,dn177 50,dn178
50,dn179 70,dn180 50,dn181 50,dn182 50,dn183 50,dn184
30,dn185 50,dn186 50,dn187 20,dn188 50,dn189 50,dn190
50,dn191 100,dn192 30,dn193 50,dn194 100,dn195 50,dn196
30,dn197 50,dn198 50,dn199 50,dn200 30,dn201 50,dn202
50,dn203 30,dn204 20,dn205 50,dn206 50,dn207 50,dn208
50,dn209 50,dn210 50,dn211 50,dn212 50,dn213 50,dn214
50,dn215 50,dn216 50,dn217 50,dn218 30,dn219 50,dn220
50,dn221 70,dn222 50,dn223 50,dn224 50,dn225 50,dn226
50,dn227 50,dn228 50,dn229 50,dn230 50,dn231 50,dn232
50,dn233 50,dn234 50,dn235 50,dn236 20,dn237 50,dn238
50,dn239 20,dn240 50,dn241 50,dn242 50,dn243 70,dn244
50,dn245 50,dn246 100,dn247 50,dn248 50,dn249 50,dn250
50,dn251 50,dn252 50,dn253 100,dn254 50,dn255 50,dn256
50,dn257 50,dn258 50,dn259 50,dn260 50,dn261 50,dn262
50,dn263 50,dn264 50,dn265 50,dn266 50,dn267 20,dn268
50,dn269 50,dn270 50,dn271 70,dn272 70,dn273 20,dn274
70,dn275 70,dn276 70,dn277 70,dn278 70,dn279 100,dn280
70,dn281 70,dn282 70,dn283 20,dn284 70,dn285 70,dn286
70,dn287 70,dn288 70,dn289 70,dn290 30,dn291 70,dn292
70,dn293 70,dn294 70,dn295 30,dn296 70,dn297 70,dn298
70,dn299 70,dn300 70,dn301 50,dn302 70,dn303 70,dn304
70,dn305 70,dn306 70,dn307 50,dn308 70,dn309 70,dn310
70,dn311 50,dn312 70,dn313 70,dn314 70,dn315 70,dn316
100,dn317 70,dn318 70,dn319 70,dn320 70,dn321 70,dn322
70,dn323 50,dn324 70,dn325 100,dn326 70,dn327 100,dn328
30,dn329 70,dn330 70,dn331 70/;
parameter k(j) capacity at site j  /SLR1 73,SLR2 92,SLR3
77,SLR4 130,SLR5 79,SLR6 96,SLR7 48,SLR8 80,SLR9 288,SLR10
192,SLR11 156,SLR12 76,SLR13 94,SLR14 40,SLR15 78,SLR16
73,SLR17 60,SLR18 192,SLR19 104,SLR20 411,SLR21 83,SLR22
110,SLR23 213,SLR24 252,SLR25 46,SLR26 97,SLR27 86,SLR28
97,SLR29 91,SLR30 156,SLR31 165,SLR32 121,SLR33 162,SLR34
252,SLR35 140,SLR36 333,SLR37 390,SLR38 458,SLR39
897,SLR40 856,SLR41 834,SLR42 778,SLR43 128,SLR44
678,SLR45 568,SLR46 989,SLR47 99,SLR48 779,SLR49 559,SLR50
769,SLR51 785/;
```

```
parameter sc(j) fixed cost at site j  /SLR1 5090,SLR2
7232.5,SLR3 6160,SLR4 8070,SLR5 6155,SLR6 6117.5,SLR7
5030,SLR8 6590,SLR9 16447.5,SLR10 15392.5,SLR11
13562.466,SLR12 7151.875,SLR13 6315.7875,SLR14
5404.135,SLR15 6749.0325,SLR16 6181.83,SLR17
5826.5175,SLR18 12957.165,SLR19 4335.4,SLR20
19346.5525,SLR21 1809.79,SLR22 6523.9575,SLR23
16266.08,SLR24 15475.92,SLR25 3368.625,SLR26
7770.845,SLR27 9582.8275,SLR28 6969.565,SLR29
2880.61,SLR30 10648.8375,SLR31 3872.0575,SLR32
5576.7625,SLR33 10210,SLR34 8567.33,SLR35 3846.415,SLR36
18241.86,SLR37 22323,SLR38 32333,SLR39 34345,SLR40
52234,SLR41 44072.5,SLR42 62325,SLR43 12800,SLR44
33454,SLR45 55080,SLR46 23424,SLR47 6435,SLR48 45555,SLR49
34444,SLR50 42342,SLR51 62800/;

parameter c4w(j) c4w at site j  /SLR1 2036,SLR2 2893,SLR3
2464,SLR4 3228,SLR5 2462,SLR6 2447,SLR7 2012,SLR8
2636,SLR9 6579,SLR10 6157,SLR11 5424.9864,SLR12
2860.75,SLR13 4000,SLR14 2161.654,SLR15 2699.613,SLR16
2000,SLR17 2000,SLR18 10060,SLR19 1734.16,SLR20 9500,SLR21
723.916,SLR22 4000,SLR23 6506.432,SLR24 9609,SLR25
1347.45,SLR26 3108.338,SLR27 3000,SLR28 2787.826,SLR29
1152.244,SLR30 4259.535,SLR31 1548.823,SLR32
2230.705,SLR33 4084,SLR34 3426.932,SLR35 1538.566,SLR36
7296.744,SLR37 12459,SLR38 10865,SLR39 27400,SLR40
21027,SLR41 24429,SLR42 24930,SLR43 5120,SLR44 20340,SLR45
40000,SLR46 17980,SLR47 2574,SLR48 21033,SLR49 22919,SLR50
17687,SLR51 25120/;
parameter fw(j) flex in wash at site j/SLR1 1,SLR2 1,SLR3
1,SLR4 1,SLR5 1,SLR6 0,SLR7 1,SLR8 1,SLR9 0,SLR10 1,SLR11
1,SLR12 1,SLR13 0,SLR14 1,SLR15 1,SLR16 1,SLR17 1,SLR18
1,SLR19 1,SLR20 1,SLR21 0,SLR22 0,SLR23 1,SLR24 1,SLR25
1,SLR26 1,SLR27 1,SLR28 1,SLR29 0,SLR30 0,SLR31 0,SLR32
0,SLR33 0,SLR34 0,SLR35 0,SLR36 0,SLR37 0,SLR38 0,SLR39
0,SLR40 0,SLR41 0,SLR42 1,SLR43 1,SLR44 1,SLR45 1,SLR46
0,SLR47 0,SLR48 0,SLR49 0,SLR50 0,SLR51 1/;
parameter fs(j) flex in scaling up at site j/SLR1 0,SLR2
1,SLR3 1,SLR4 1,SLR5 1,SLR6 1,SLR7 0,SLR8 1,SLR9 0,SLR10
1,SLR11 1,SLR12 1,SLR13 1,SLR14 1,SLR15 0,SLR16 1,SLR17
0,SLR18 0,SLR19 1,SLR20 1,SLR21 1,SLR22 1,SLR23 0,SLR24
1,SLR25 1,SLR26 1,SLR27 1,SLR28 1,SLR29 0,SLR30 1,SLR31
1,SLR32 0,SLR33 0,SLR34 1,SLR35 1,SLR36 0,SLR37 1,SLR38
```

```
1,SLR39 1,SLR40 1,SLR41 1,SLR42 0,SLR43 0,SLR44 1,SLR45
1,SLR46 0,SLR47 1,SLR48 1,SLR49 0,SLR50 1,SLR51 0/;
parameter ab(i,j);

PARAMETER  rang /0/;
PARAMETER  rangpp /0/;
parameter p(n);
p(n)=pp(n)*(1+rangpp);

$call GDNXXRW transportationcosts.xlsx trace=3 par=ab
rng=Sayfa1!a1

$GDNXIN transportationcosts.gdnx

$LOADN ab

$GDNXIN

Display ab;

variables
obj
x(j)
z(i,j)
dn(n);


binary variables x if we locate a facility to candnidnate
j,
                 z if nodne i is coveredn by site j;

equations objgoal, constr1,
constr2,constr3,constr4,constr5,constr6,constr7,constr8,co
nstr9,constr10,constr11,constr12,constr13,constr14,constr1
5;

objegoal.. obj =e= sum(n,p(n)*dn(n)/norm(n));
constr1(i)..sum(j, z(i,j))=l= 1 ;
constr2..sum(j, x(j))=l=40;
constr3(j)..k(j)=g= sum(i, ab(i,j)*z(i,j)*h(i));
constr4(i,j)..x(j)=g= z(i,j);
constr5.. sum ((i,j), ab(i,j)*h(i)*z(i,j))+dn('p1')-
dn('p2')=e=12000*(1+rang);
constr6..sum((i,j),z(i,j)*v1(i))+dn('p3')-dn('p4')
=e=1500*(1+rang);
```

```
constr7..sum((i,j),z(i,j)*v4(i))+dn('p5')-dn('p6')
=e=6000*(1+rang);
constr8..sum(j,x(j)*c4w(j))+dn('p7')-dn('p8')
=e=300000*(1+rang);
constr9..sum(j,x(j)*sc(j))+sum((i,j),z(i,j)*h(i)*36)+dn('p
9')-dn('p10') =e=1000000*(1+rang);
constr10(n)..dn(n)=g=0;
constr11(i,j)..ab(i,j)=g= z(i,j);
constr12..sum(j,x(j)*fw(j))+dn('p11')-
dn('p12')=e=25*(1+rang);
constr13..sum(j,x(j)*fs(j))+dn('p13')-
dn('p14')=e=30*(1+rang);

constr14..sum((i,j),z(i,j)*v2(i))+dn('p15')-dn('p16')
=e=1000*(1+rang);
constr15..sum((i,j),z(i,j)*v3(i))+dn('p17')-dn('p18')
=e=3000*(1+rang);
OPTION RESLIM = 5000;

model mcp /all/;

solve mcp using MIP minimizing obj;

execute_unloadn "results.gdnx" z.L x.L dn.L dn.M
execute 'gdnxxrw.exe results.gdnx var=x.L'
execute 'gdnxxrw.exe results.gdnx var=z.L'
execute 'gdnxxrw.exe results.gdnx var=dn.L
rng=Slreet2!a58'
execute 'gdnxxrw.exe results.gdnx var=dn.M rng=Slreet2!a63'
```