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Table of Contents

List of Tables

List of Figures

Abstract

Whether due to customary causes or new emerging ones, the ever-growing refugee population precipitates a variety of issues all around the world. Resettlement of individuals and families is an issue that should be regarded carefully by considering different aspects and periods. Perceiving the refugee resettlement as a layered problem, the purpose of the present study is to help decision-makers with arduous resettlement planning by developing a preliminary optimization model. To that end, we transform the capacitated version of the traditional facility location problem into a multicriteria optimization problem that accounts for the physical capacities to meet the refugee needs, the cultural differences along with the physical distances and travel difficulties between origin and host societies, prioritization of the matchings, and the overall success of the resettlement process.

Keywords: Refugee resettlement, Facility location, Multicriteria optimization

Chapter 1: Introduction and Motivation

According to the UNHCR report of Global Trends: Forced Displacement in 2019, 79.5 million people were forcibly displaced because of persecution, conflict, violence, or human rights violations at the end of 2019 [1], and this number is likely an underestimate [2]. Nearly one person is forcibly displaced every three seconds [3]. Among those displaced people, 26 million were refugees [1], meaning that they were forced to flee their countries and cannot or afraid to return home [4]. Many recent migrations have occurred from Syria, Iraq, Myanmar, and the Congo, and refugees move from camps in places like Lebanon and Jordan to more permanent settlements. The global refugee population is at its highest level on record [3] and suggests that it has become more important than ever to create and implement effective and fast solutions while the global disaster trends signal more refugee crises all around the world.

This study focuses on the resettlement process from the refugee experience. The refugee resettlement experience starts from the origin country. However, a displaced person may not gain refugee status immediately following departure from their origin country. When people are forced to flee from their home countries, they are regarded as "asylum seekers" [4] and are housed at asylum locations, which are typically easily accessible in a bordering country. After that, they return to their country of origin if possible, they can stay in the country of asylum and gain refugee status, or they can be transferred to a new host country and gain refugee status there. The latter option is the resettlement process that is formally defined as relocating refugees from an asylum country to permanent settlements [5]. Considering that the global resettlement need is projected to be nearly 1.5 million persons for 2020 [6], resettlement is an important problem that requires immediate action.

Currently, the resettlement process is mostly organized by agencies, governments, or some collaborative effort between the two. For successful resettlement, decision-makers should understand refugee needs and local integration requirements as well as the resources that host countries can provide in terms of physical and service capacities. Furthermore, they should be able to consider different aspects of the resettlement problem simultaneously and systematically to manage this process fairly and fast.

To help decision-makers in the resettlement process, we conceptualize the refugee resettlement problem as an adaptation of the traditional facility location problem. Families in need of resettlement are represented as demand centers and resettlement locations as facility locations. This adapted formulation accounts for (i) the physical capacities to meet refugee needs, (ii) the physical distance and travel difficulties between origin and host regions, (iii) the cultural differences between origin and host societies, and (iv) prioritization and the feasibility of the matchings. To account for all of these issues, we transform the capacitated version of the facility location problem into a multicriteria optimization problem.

The rest of this paper is organized as follows. In Section Chapter 2:, we introduce the general refugee issues and the specific refugee resettlement studies in the current literature. In Section Chapter 3:, the details of the proposed multicriteria optimization model are presented, as well as the solution approach implemented to obtain Pareto optimal solutions. In Section Chapter 4:, the illustrative example that we created to test the model is described, and the computational results are discussed. Finally, concluding remarks are given in Section Chapter 5:.

Chapter 2: Literature Review

The study of helping refugees is both a planning and a social problem. The current studies in the area of optimization research include issues related to refugee camps, support and service operations, crisis analysis, resettlement, and local integration. Each of these issues corresponds to different parts of the refugee experience and each can be approached from various perspectives. Based on the recent refugee studies, problems in the literature can be grouped according to the categories shown in Figure 1. Note that while the taxonomy in Figure 1 separates the main problems as different categories, some studies combine more than one problem from the figure. The majority of the refugee studies deal with problems related to the establishment of refugee camps or their expansion to satisfy demand based on physical capacity, service requirements, and transportation [7]–[11]. These studies try to find the optimal size, site, layout, or infrastructure planning for the refugee camps. Another important group of studies focuses on site selection, assignment and fair allocation, and routing of the mobile services for the support and service operations related to medical aid, cash distribution, child-friendly spaces, ad education, among others. [8], [10]–[13]. Other work developed simulation models for the analysis of the refugee crisis [14].

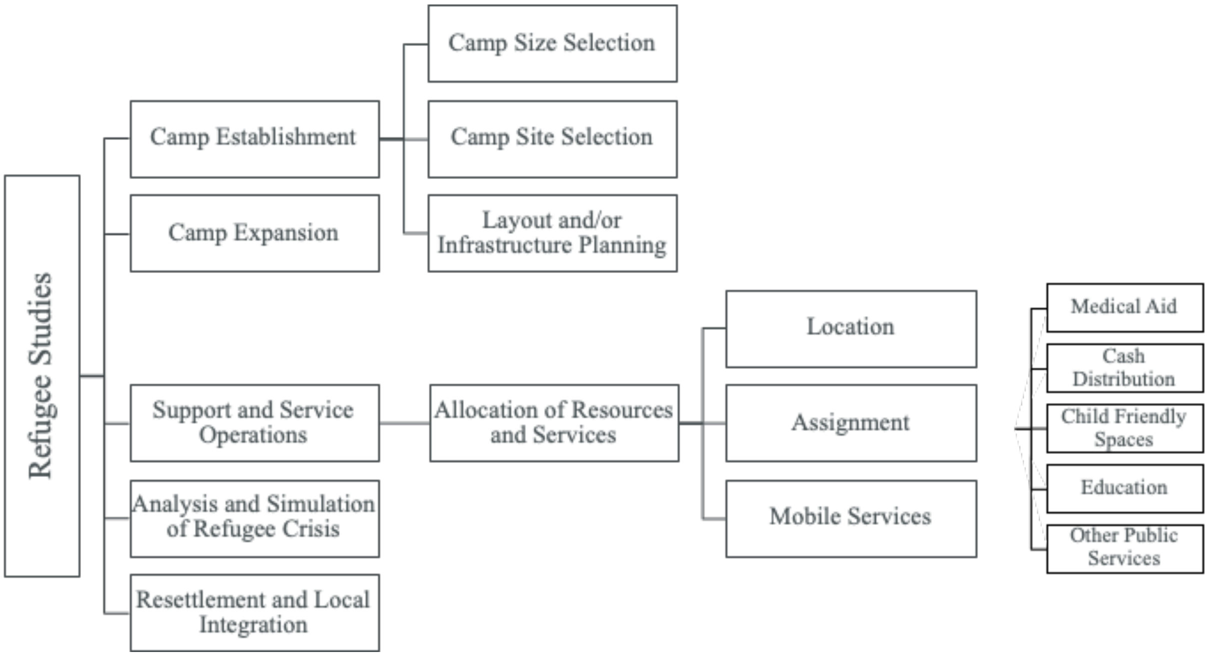


Figure 1: Refugee related problems in the literature.

Many of the recent studies that deal with the refugee matching (i.e., assignment of the refugees to an asylum or a host country for the first time) or resettlement (i.e., relocation of refugees from their asylum locations to permanent settings) regard this problem as an assignment problem wherein candidate refugees (typically measured in individuals or families) are assigned to candidate locations in the broadest sense. The main factor that differentiates these studies are the desired outcomes improved by the assignments. One group of studies focuses on improving integration outcomes, specifically the likelihood of employment due to the availability of appropriate data while matching refugees to specific locations [15], [16]. Bansak *et al.* [16] propose to use an algorithm based on machine learning and linear programming. Further, Trapp *et al.* [15] expand the idea of using machine learning and define a multiple multidimensional knapsack problem. While acknowledging the potential benefits of incorporating the preferences of the refugees and/or priorities of the host societies, they have not included these preferences/priorities explicitly in their studies due to the challenging nature of doing so, the lack of systematic data, and the susceptibility of the preference data to manipulation. On the other hand, the second group of studies builds upon a two-sided matching system that considers the preferences of the refugees and priorities of the host societies in the context of market design [17]–[20]. While all of these studies originate from the similar two-sided matching idea, the study of Andersson *et al* [17] distinguishes by proposing the idea of dynamic matching and the study of Delacrétaz *et al*. [20] by multidimensional constraints. In one of the studies related to two-sided matching, an interesting contribution to refugee resettlement is offered in the general context of using tradable immigration quotas to support international migration [21]. Among the studies related to matching under preferences, a distinct view specifically draws attention to the risk of a trade-off between satisfying preferences and the total number of matches [22]. It is argued that considering preferences is not reasonable when it causes a decrease in the number of matches. Moreover, according to this view, considering only refugee preferences are favored over two-way preferences if any preference should be taken into account. The aforementioned studies related to refugee resettlement, along with the matching issues addressed in these studies, are categorized in Figure 2.

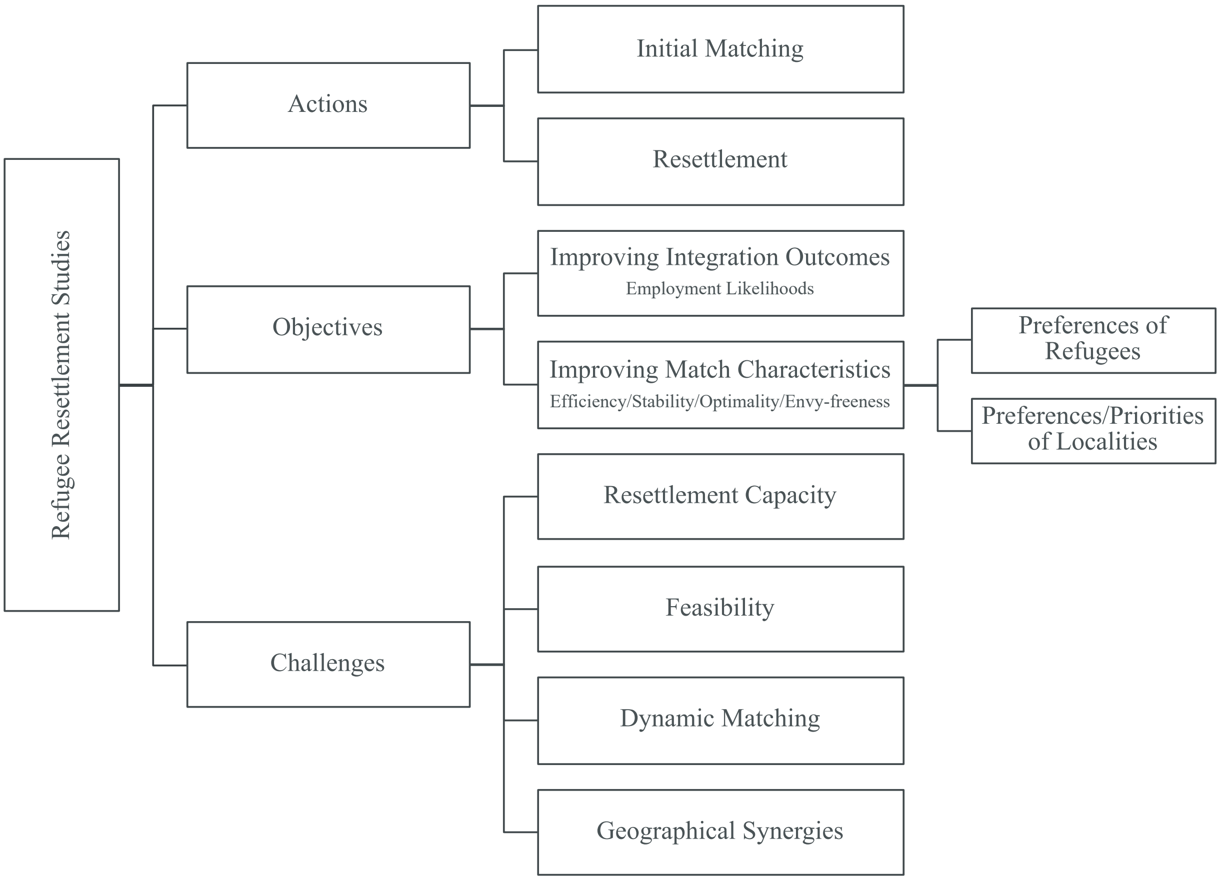


Figure 2: Problems, objectives, and issues related to refugee resettlement studies.

Chapter 3: Refugee Resettlement Multicriteria Optimization Model

This section introduces the multicriteria optimization model for refugee resettlement and a variation to the model obtained by forcing capacity usage above a lower bound for the resettlement locations.

3.1. Assumptions

The model is formulated based on the following assumptions regarding the refugee resettlement process.

- *Assignments are based on the number of individuals that should be relocated from an asylum location to a resettlement location with matching feasibility criteria.* Restricting the possible assignments by feasibility criteria improves the performance, and hence the scalability of the model by reducing the number of decision variables.
- *The capacity of a resettlement location is measured with respect to the number of individuals that can be placed in there.* Measuring the capacity in terms of individuals makes it easier to understand and compare the required and the provided capacities.
- *The total number of families in need of resettlement and the number of members in each family is known, as are the origin regions and the current placements of these families.* Necessary information for submissions for resettlement are gathered by UNHCR resettlement staff case by case interviews where each case consists of members of the same family. Following the interview, assessments are made for individual cases. [23]

- *The emergency level of resettlement needs and the requirements for each family is known.* Considerations including the need for resettlement and vulnerabilities are important determinants for the assessment of resettlement submissions and selections [23]. Considering that resettlement is not only a durable but also a potentially lifesaving solution against immediate risks and safety issues, it may become critical to resettle individuals based on emergency [24].
- *Each family shares the same cultural characteristics with the other families from its origin region and local communities in each resettlement location share the cultural characteristics that are dominant in that specific host region.* Approaching the local integration issue from a regional level culture perspective makes it easier to collect and manage the data. Furthermore, the fact that the scope of a region is subject to how one defines a region adds granularity to the parameter.
- *Potential resettlement locations, their capacities, the fixed costs required to open these locations to service, and refugee requirements that can be provided by these locations (e.g., language, social policies) are known in a binary way.* In a real system, these kinds of restrictions on the resettlement process should be provided by authorities. Managing the requirements on a binary level makes the model more appropriate for large-sized problems with regard to model performance.
- *Physical distances, travel restrictions, and alternatives are known for each pair of asylum and resettlement locations.* The relative distances based on the ease of transportation and the availability are more indicative of an individual's experience than spatial distances.
- *A resettlement location will be opened to service if the number of assigned individuals is greater than zero or a lower bound.* Depending on the way the fixed costs of the resettlement locations are managed, a different capacity constraint could be considered.

3.2. Notation

Table 1, Table 2, and Table 3 present the sets, parameters, and decision variables of the model, respectively.

Table 1. Sets and indices.

A	Set of asylum locations (cities), indexed by a
G	Set of groups according to feasibility criteria, indexed by g
O	Set of refugee origin countries, indexed by o
R	Set of resettlement locations (cities), indexed by r
AGO	Set of possible asylum location, group, and origin country combinations
$AGOR$	Set of feasible asylum location, group, origin country, and resettlement location combinations

Table 2. Parameters.

d_a^r	Geographical distance between asylum location $a \in A$ and resettlement location $r \in R$
t_a^r	Travel difficulty weight between asylum location $a \in A$ and resettlement location $r \in R$
c_o^r	Cultural distance between origin country $o \in O$ and host country in which the resettlement location $r \in R$ is located
l^r	Cost of preparing resettlement location $r \in R$ to service
p^r	Physical capacity (number of individuals) of resettlement location $r \in R$
e_{ago}	Average emergency level for the placement of families located from $(a, g, o) \in AGO$ combination
n_{ago}	Total number of individuals from $(a, g, o) \in AGO$ combination

Table 3. Decision variables.

x_{ago}^r	Number of individuals that are assigned to resettlement location $r \in R$ from asylum location $a \in A$ who belong to feasibility group $g \in G$ and from origin country $o \in O$
y^r	Equal to 1 if resettlement location $r \in R$ is in service

3.3. Objective Functions

To balance different criteria related to the resettlement process, four objective functions are formulated in the Eqs. (1) through (4). Since it is harder to transfer people between two distant locations, the first objective, shown in Eq. (1), minimizes the total weighted physical distance between asylum locations and the resettlement locations of the relocated families. The physical distances are weighted with respect to the difficulty of travel between the two locations. A weight closer to zero implies easier travel (e.g., traveling to a border country, availability of different transportation methods), while a weight of one implies the most difficult (e.g., mountainous terrain, high number of layovers, travel restrictions due to health or political issues). The second objective, shown in Eq. (2), minimizes the total cultural distance between the origin and host regions of the relocated families. This objective reinforces the quality of the matches by incorporating the aspect of local integration after the relocation. Assuming that people can adapt to a new environment with inhabitants from similar cultural backgrounds, we aim to increase the chances of a successful integration by minimizing the total cultural distance between relocated individuals and host societies where similar regions are closer in terms of cultural distance. Contemplating the risks and the negative effects of relocation such as cultural bereavement and problems about mental health [25], [26]; the importance of cultural closeness becomes more apparent. The third objective, shown in Eq. (3), minimizes the total cost of preparing resettlement locations to be able to host incoming families. Finally, the fourth objective, shown in Eq. (4), maximizes the number of placements while prioritizing the assignment of the families whose resettlement situation is critical due to the urgency of the need for relocation, problems due to the current asylum location, lower chance to go back to the origin region in the near future, and special health conditions of the family members, among others. We use the average emergency level of an assignment group to prioritize the relocation of more individuals from the specific group.

$$\min f_1 = \sum_{(a,g,o,r)\in AGOR} d_a^r t_a^r x_{ago}^r \tag{1}$$

$$\min f_2 = \sum_{(a,g,o,r)\in AGOR} c_o^r x_{ago}^r \tag{2}$$

$$\min f_3 = \sum_{r\in R} l^r y^r \tag{3}$$

$$\max f_4 = \sum_{(a,g,o,r)\in AGOR} e_{ago} x_{ago}^r \tag{4}$$

3.4. Constraints

Model constraints are adapted from the capacitated version of the traditional facility location problem to reflect the nature and the requirements of the refugee resettlement process.

We are trying to decide the number of individuals transferred between two locations with a specific feasibility characteristic and a specific origin country. If we are sending individuals from asylum location a to resettlement location r, we are grouping these individuals with respect to their feasibility criteria and origin regions. Then, we are deciding how many individuals to transfer from a to r from a specific group of individuals. As a result, the highest number of individuals that we can transfer from a to r from a group is the total number of individuals from that group in that asylum location. Constraint (5) ensures that the number of individuals that are relocated from an asylum location, group, and origin country combination cannot exceed the number of individuals in that combination. In the case of a failure to relocate any individual from a specific combination, the sum of all the assignment variables for that combination will be equal to zero. On the other hand, in the case of relocation, the size of the assignment will be restricted by the combination size since an individual cannot be assigned more than once. Since resources are limited, the availability of the resources in the host regions is an influential determinant for decisions we should make. One of the first restrictions that come to mind is a very straightforward one: How many incoming refugees can a host region accommodate? It is important to consider physical capacities in a unit that is compatible with the requirements. Since we are making a decision about the number of individuals to send to a resettlement location, we should also consider the number of individuals that the resettlement location can host. Another consideration deals with the fixed costs related to using these locations. A model that does not consider fixed setup costs for establishing resettlement locations may open a location just for one individual. This kind of decisions may cause inefficiencies that are unacceptable when we are struggling with meeting resettlement need that is substantially greater than our scarce resources. As such, constraint (6) manages capacity in terms of the total number of individuals. It simultaneously ensures that the number of individuals that can be placed in a resettlement location is restricted by its physical capacity and an assignment to a resettlement location can be made only when it is open to service. That is, it ensures that the resettlement location will be put into service if a family is assigned to that location. Constraints (7) and (8) enforce the integer and binary nature of the decision variables, respectively.

$$\sum_{r \in R} x_{ago}^{r} \leq n_{ago} \qquad \forall\, (a, g, o) \in AGO \qquad (5)$$

$$\sum_{(a,g,o) \in AGO} x_{ago}^{r} \leq p^{r} y^{r} \qquad \forall\, r \in R \qquad (6)$$

$$x_{ago}^{r} \in \mathbb{Z} \qquad (a, g, o, r) \in AGOR \qquad (7)$$

$$y^{r} \in \{0, 1\} \qquad \forall\, r \in R \qquad (8)$$

3.5. Solution Approach

To deal with the conflicting objectives of the model and to generate Pareto optimal solutions, we implement the augmented ε-constraint method (AUGMECON) [27]. While other methods exist for generating a set of Pareto-optimal solutions (e.g., weighted scalarization method [28]), the variation on the ε-constraint does not depend on subjective weights for the importance of each objective. In AUGMECON, one of the multiple objectives (primary objective) is selected to construct the new objective function while the remaining ones are included in the model as constraints bounded by right-hand side values which are systematically changed to obtain different solutions. The model finds the optimal value/solution for the new objective for each combination of different values of these bounds. By, also, optimizing the difference between these bounds and the values that the constrained objectives really take, the model also tries to find the best possible values for the constrained objectives to take. However, this additional term is added to the new main objective function with an extremely small multiplier. As a result, the solution obtained by the model protects principally the primary objective's interests. In this paper, we select f_4 as the primary objective and update the model by replacing multiple objectives given in Eq. (1) through Eq. (4) with the single main objective given in Eq. (9), where s_1, s_2, s_3 represent the slack variables that help to obtain guaranteed efficiency of the solutions by forcing the model to select the efficient solutions in the case of alternative optima for the main objective and r_1, r_2, r_3 represent the ranges of the objective functions that help to avoid scaling problems by bringing all slack variables to the same scale in the main objective function regardless of the units of the corresponding constrained objectives. ε in this equation represents a significantly small number. We also add the constraints (10)–(13) to use the remaining objectives as the constraints of the new model, where e_1, e_2, and e_3 represent the right-hand side values for the corresponding constrained objective functions.

$$\max f_4 + \varepsilon \times (s_1/r_1 + s_2/r_2 + s_3/r_3) \tag{9}$$

$$\text{s.t.} \quad \text{Constraints (5)–(8)}$$

$$f_1 + s_1 = e_1 \tag{10}$$

$$f_2 + s_2 = e_2 \tag{11}$$

$$f_3 + s_3 = e_3 \tag{12}$$

$$s_1, s_2, s_3 \in R^+ \tag{13}$$

Since it is likely for an LP optimizer to find the dominated alternative optima first for the main objective function, it is important to ensure the selection of a non-dominated alternative in the case of the alternative optima for the main objective of the model. We start the implementation of AUGMECON by generating the payoff table with lexicographic optimization to include only the guaranteed Pareto optimal solutions. Applying lexicographic order ensures that each optimal solution in the pay-off table is non-dominated. To do this, we optimize all the remaining objectives in each row of the pay-off table after fixing the value of the previous objectives to the recently found optimal value in that row. Then, we use the payoff table to set ranges along with the upper bounds for minimization objectives. We search the grid through different ε-constraint right-hand side values starting from the upper bounds and gradually decreasing at every grid point with the help of loops while exiting the innermost loop whenever an infeasible solution is encountered.

3.6. Effect of Forcing Full Capacity Usage

Resettlement capacity is often a restrictor since the number of individuals in need of resettlement is often much higher than the capacity. While the intuitive action of a reasonable decision-maker under this restriction is to relocate as many individuals as possible, additional objectives or constraints may prevent the model to exhaust the full capacity of the resettlement locations. As such, we may end up with an unused capacity while we still have individuals in need of resettlement. In order to gain control of this issue, we should base our location opening decisions on an assumption as mentioned in the discussion of the "A resettlement location will be opened to service if the number of assigned individuals is greater than zero or a lower bound" in Section 3.1. Since objectives (1)–(3) can be optimized by not assigning any individual at all, these objectives contribute to the model in the opposite direction of relocating as many individuals as possible. To observe the behavior of the model when different levels of capacity are forced to be used, we create a variation by replacing constraint (6) with constraints (14) and (15) so that a resettlement location will be at least as full as the capacity fill rate f^r.

$$\sum_{(a,g,o)\in AGO} x_{ago}^{r} \leq p^r y^r \qquad \forall\, r \in R \tag{14}$$

$$\sum_{(a,g,o)\in AGO} x_{ago}^{r} \geq p^r y^r f^r \qquad \forall\, r \in R \tag{15}$$

Chapter 4: Illustrative Example

To illustrate the application of the proposed multi-objective model and the solution approach, we generated a small experimental study with the following characteristics which are reasonable based on [6].

- 10 origin countries, nine asylum countries (40 asylum locations), and five host countries (30 resettlement locations)
- 10,000 families with different family sizes
- Other input parameters generated randomly based on similar data

For the depiction of the example, we used a fantasy map generator to graphically depict asylum and resettlement locations for illustrative purposes [29]. We generated random points on the map to locate 40 asylum and 30 resettlement locations, shown in Figure 3 where the sizes of the points are proportional to the capacities.

The map is generated on a grid such that Euclidian distances can be calculated. However, each of these distances represents the distance in the absolute context. It is more realistic to define distances in a relative context that can reflect the time or cost of travelling while measuring the closeness. When this relative context is based on time, as in [30], the distances are adjusted by the factors such as "the mode being used, its efficiency, regulations (e.g. speed limits) and congestion". In this study, we base this relative context upon travel difficulty to reflect an individual's experiences to measure closeness. As a result, the distances are adjusted by factors such as the ease of transportation, the availability of alternative ways and means of transportation, regulations, and restrictions. To represent the travel difficulty between each pair, we generated random values from the uniform distribution on the interval (0,1) since we plan to use them as weights such that the difficult conditions during the travel make the relative distance longer.

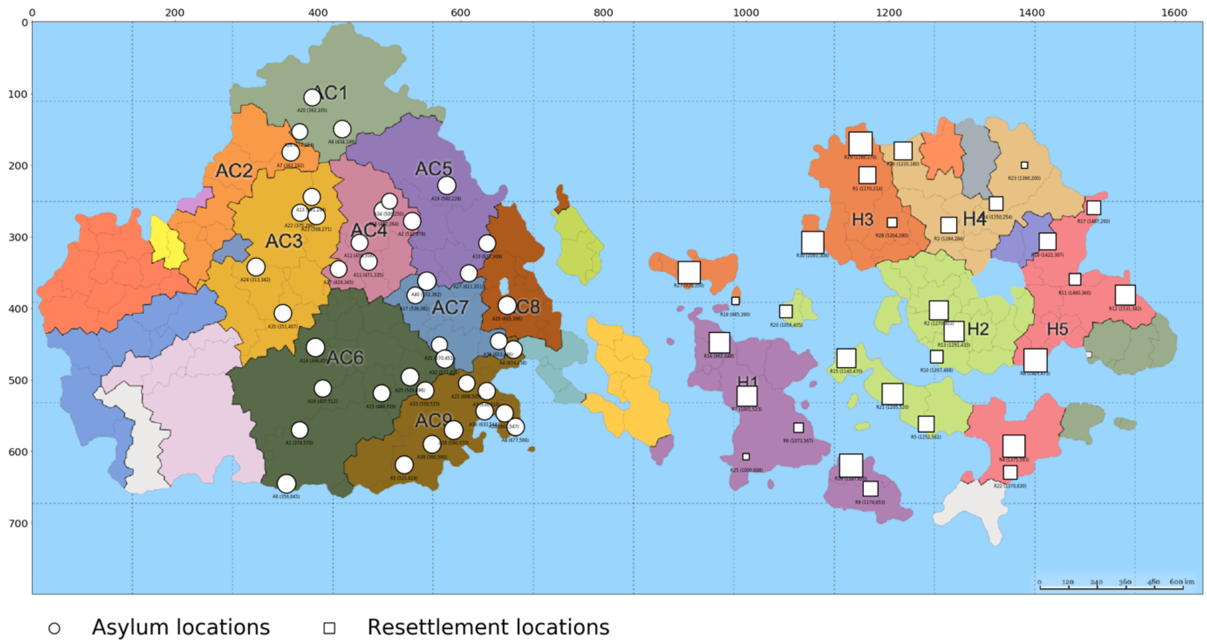


Figure 3: Graphical depiction of the simulated political map used in the illustrative example.

Recall that a smaller cultural distance measure indicates that integration to a local community will be easier. Cultural distance has been in use for a long time in some areas such as international business [31]. It can be calculated for different purposes, on different dimensions, and on various scales [32], [33]. To represent the cultural distance between origin countries and the host countries in which the resettlement locations are located, we generated random numbers uniformly on (0,100) which represents the scale of small resettlement trends discussed in [33].

For the setup costs and the physical capacities (in terms of the number of individuals) of the resettlement locations, we generated random numbers uniformly on the intervals (0, 100) and (100, 2000), respectively, chosen to be compatible with the other parameters and representative of the existing resettlement data [34].

Since the average household size varies from one to nine, and the world average household size is four; the size of each family is generated as a random number from a triangular distribution where minimum, most frequent, and maximum family sizes are one, four, and nine respectively. Prioritization of the refugee cases based on the emergency level is a common practice; however, these levels sometimes can be represented in categories. For example, UNHCR uses three priority levels for refugee submissions: emergency, urgent, and normal [35]. Since we preferred numerical emergency levels on a scale (to be used as weights), the level of resettlement emergency of each family is generated as a random number from the uniform distribution on the interval (0,1) where families in more critical conditions or an immediate need of relocation have higher values of emergency level.

Since it may be infeasible to assign some individuals with certain characteristics (e.g., speaking a certain language, being from a certain social class) to a particular asylum location, we created feasibility groups by aggregating the individuals with the same feasibility requirements. We also assigned a feasibility group for each resettlement location according to the feasibility requirements that can be met in that location. Assuming that there are four binary feasibility requirements, we formed 16 feasibility groups. We assigned a feasibility group for each family and each resettlement location so that the individuals from a specific feasibility group can only be assigned to a location with the same feasibility criteria.

The data preparation explained above resulted in 46,677 individuals who are in need of resettlement. The total physical resettlement capacity can host 31,562 individuals. However, the total physical capacity reduces to 27,176 individuals with the effect of the feasibility groups. Even though the size of the illustrative example might seem small compared to the expected number of total refugees for 2020 (1,440,408 persons) [6], we see that the size of the example is representative when we look at the size of the current resettlement processes: As of September 1st, the total number of UNHCR resettlement submissions are 26,015 persons (since not all refugees require resettlement) and the total number of departures for resettlement is 11,899 persons [34].

4.1. Computational Results: Pareto Optimal Solutions

When we look at the Pareto optimal solutions found for the proposed main model in the context of pairwise comparison for the different objectives, Figure 4, it is seen that the nature of the objectives governs the distribution of the solutions. For example, only one corner of the cultural distance (or physical distance) versus setup cost plot does not contain a solution while the observed solutions are dispersed through the remaining spaces in the plot. This is simply because lower setup costs cut off the capacity of the resettlement, and hence, it is impossible to observe solutions with higher values of cultural distance for lower values of setup cost. And the reason why we observe a large variety of solutions is that increasing the setup cost serves both (i) for increasing the total cultural distance as a result of the increase in the number of resettled individuals, and (ii) for decreasing the total cultural distance as a result of providing more resettlement options. Furthermore, in all of these plots, an increase in the value of the objectives increases the total number of individuals resettled since it corresponds to weakening the restrictions.

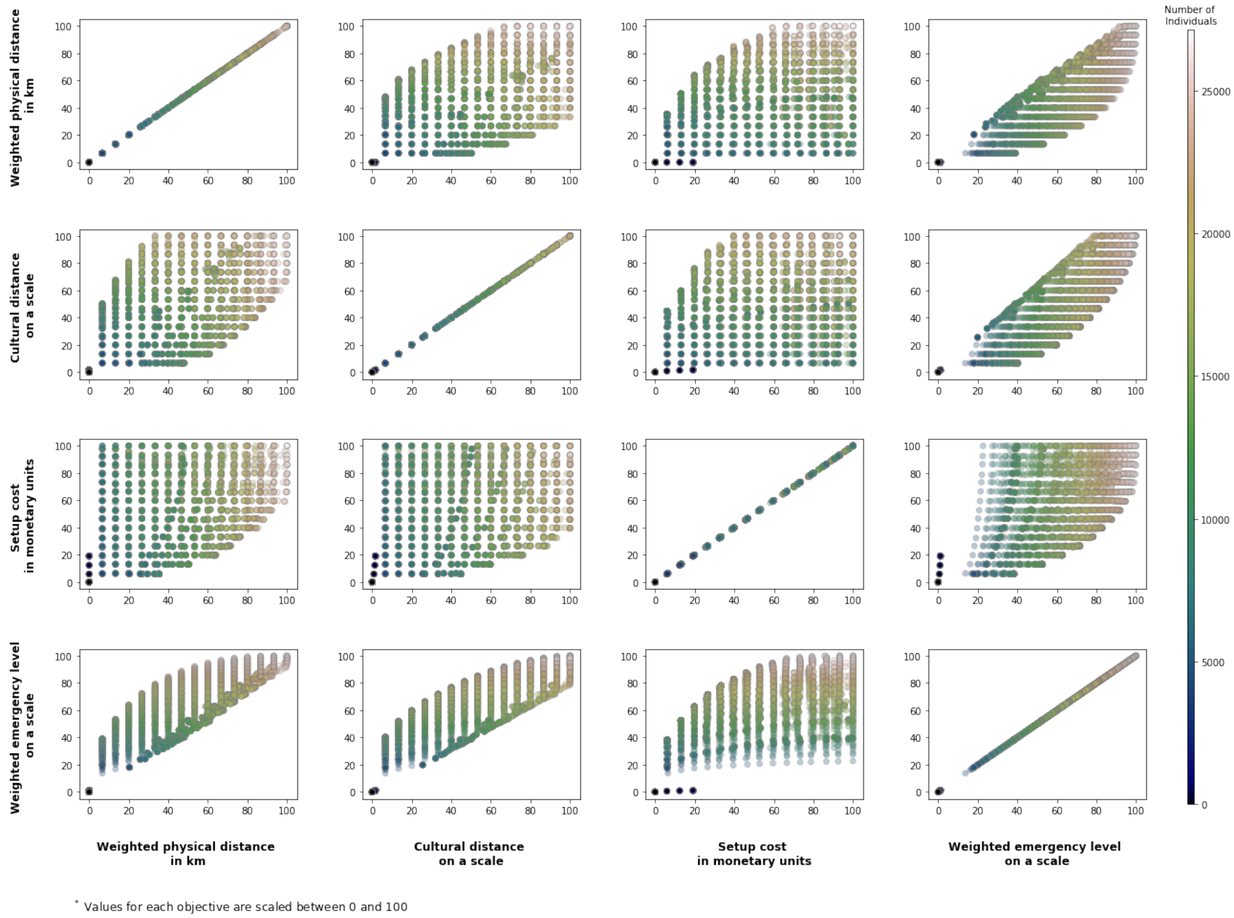


Figure 4: Distribution of the Pareto optimal solutions in a pairwise comparison.

4.2. Computational Results: Solution with the Highest Number of Resettled Individuals

The aggregated flows between asylum and host countries, Figure 5 and Figure 6, show that the original capacities of these countries determine their share in the aggregated flow. For example, the asylum country with the highest number of individuals in need of resettlement (AC9) also has the biggest share of the resettled individuals in each host country. Note that the color scheme for Figure 5 and Figure 6 is the same as that used in the political map in Figure 3.

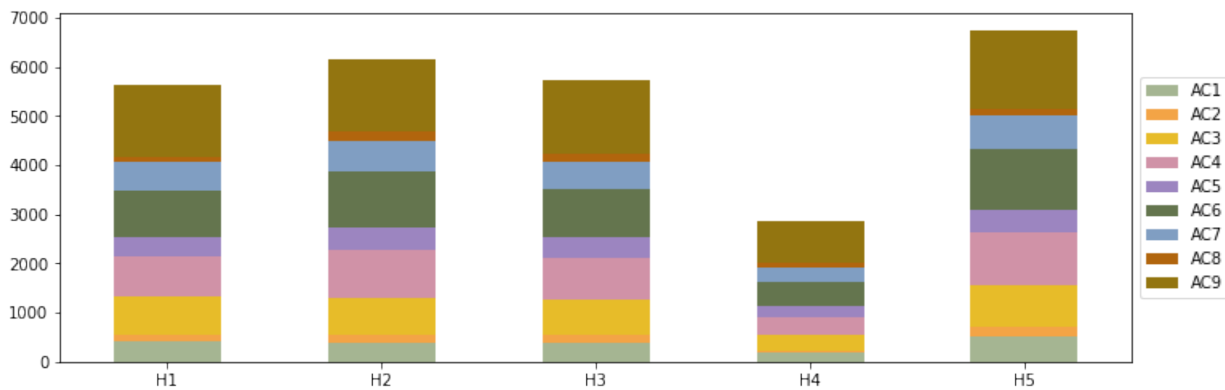


Figure 5: Distribution of resettled individuals from different asylum countries to each host country.

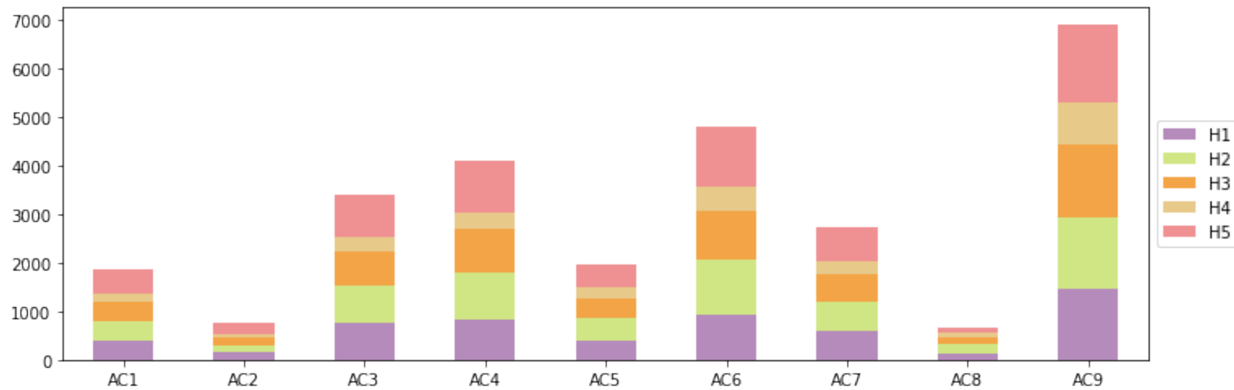


Figure 6: Distribution of resettled individuals to different host countries from each asylum country.

On the other hand, a detailed look into the refugees assigned to resettlement locations with an origin country breakdown in Figure 7 reveals the occupancy rate of the resettlement locations as well as the new formation to be included in the host society. Figure 7 suggests that one resettlement location is not opened, and several are not making use of full capacity. Figure 8 depicts this same distribution under different forced capacity usage percentages.

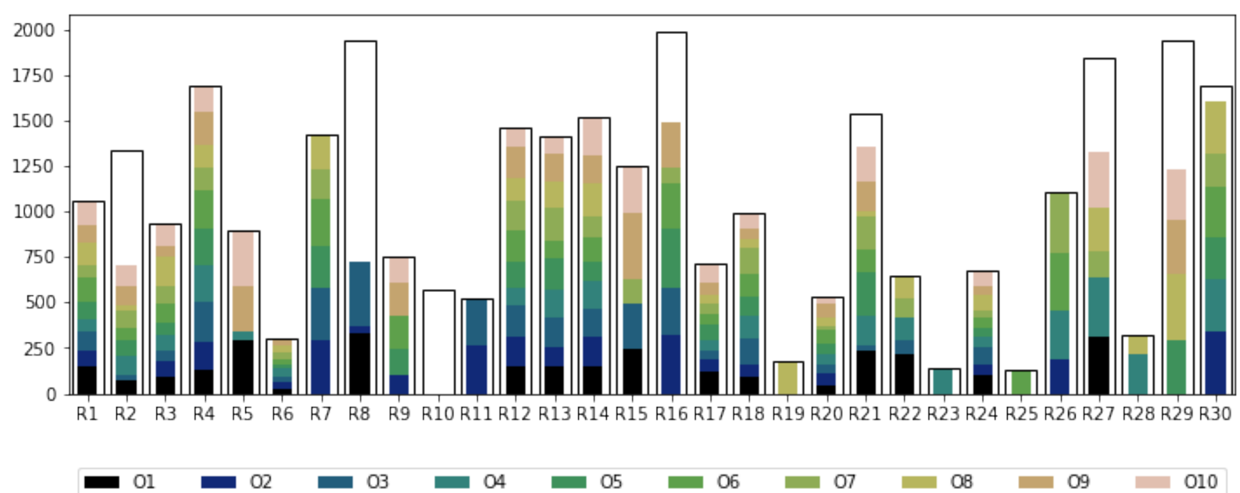


Figure 7: Distribution of resettled individuals to different resettlement locations from each origin country.

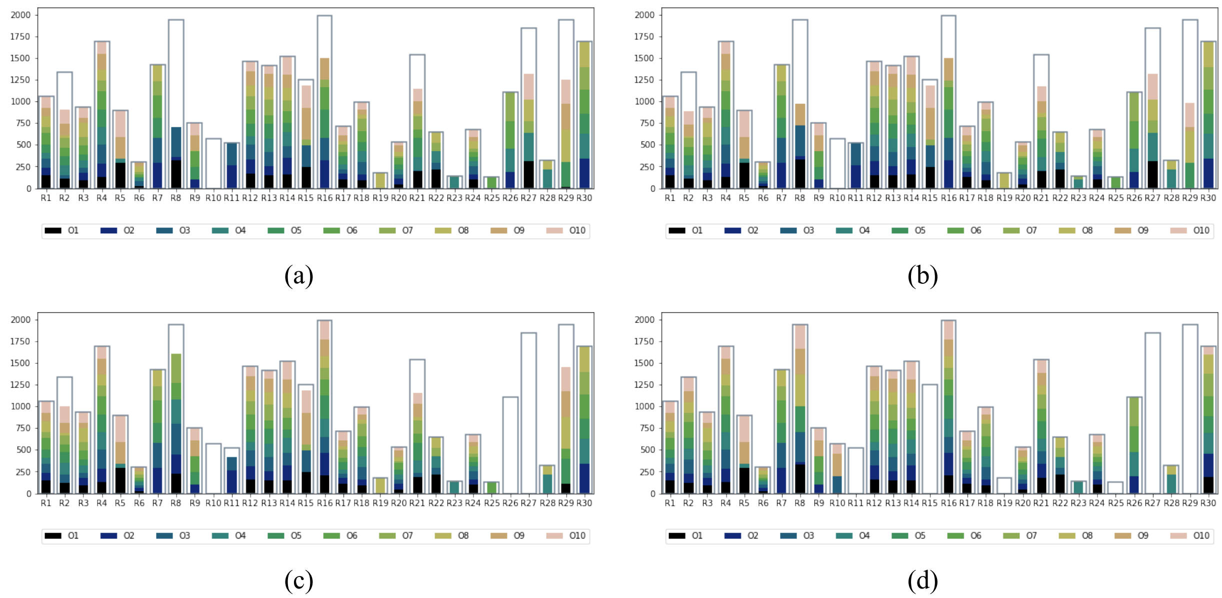


Figure 8: Distribution of resettled individuals to different resettlement locations from each origin country under different forced capacity usage assumptions: (a) 25%, (b) 50%, (c) 75%, and (d) 100%.

As shown in Figure 9, for the solution with the highest number of assigned individuals, the relationship between emergency level and physical distance for fixed values of cultural distance and setup cost shows that restricting objectives related to monetary terms or distances has a significant effect on the total number of resettled individuals.

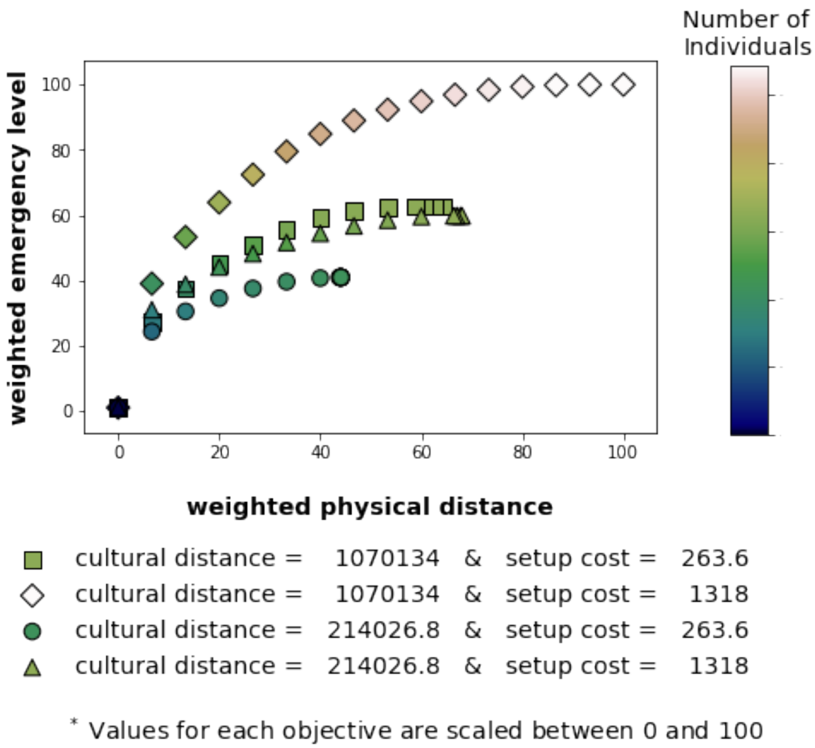


Figure 9: Relationships between emergency level and physical distance for the fixed values of cultural distance and setup cost

The comparison of figures from Figure 10, Figure 11 and Table 4 show that forcing a lower bound on assignments to open a location leads the model to open a fewer number of resettlement locations with mostly lower capacities and the number of resettled individuals decreases with the increase of the forced capacity level. This happens since the model sometimes prefers not to open a resettlement location at all rather than being forced to assign there a certain minimum number of individuals.

Table 4: Result of the decisions of the best solution for each variation of the model.

	Number of open facilities	Number of resettled individuals	Value of the main objective
Main Model	29	27145	15775.2
25% Forced Capacity Usage	29	27169	15776.00
50% Forced Capacity Usage	29	27169	15776.02
75% Forced Capacity Usage	27	26330	15552.9
100% Forced Capacity Usage	4	25692	15414.04

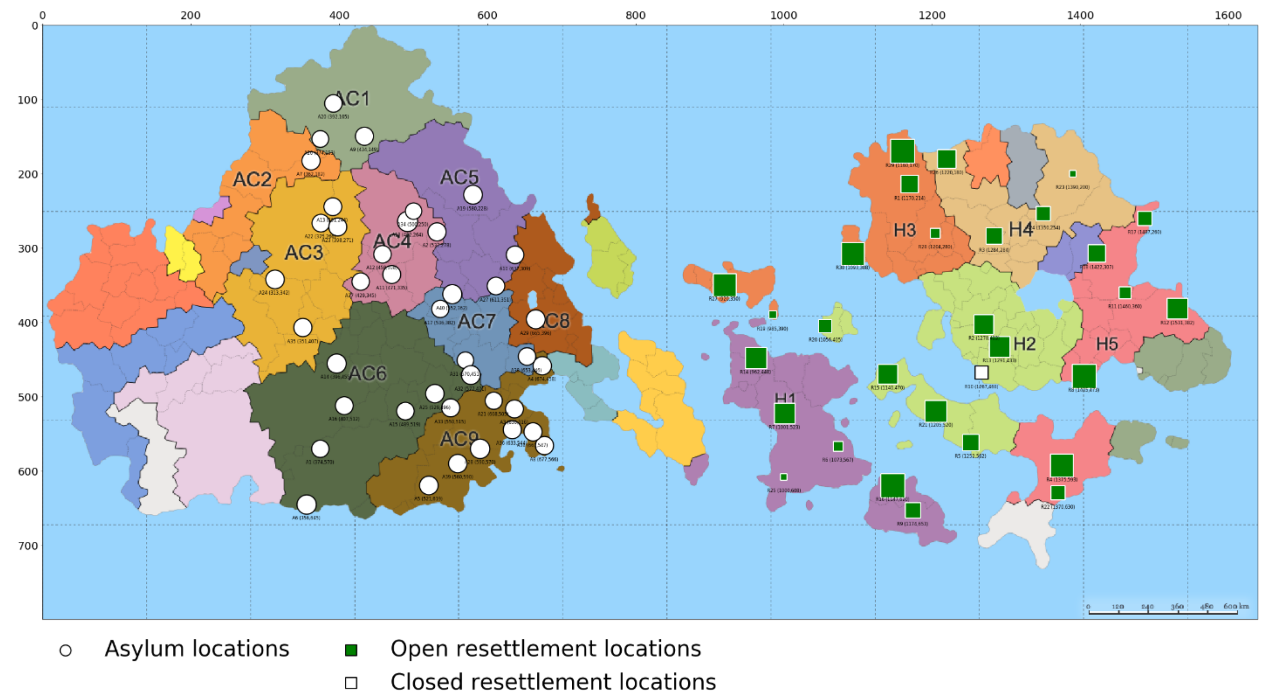
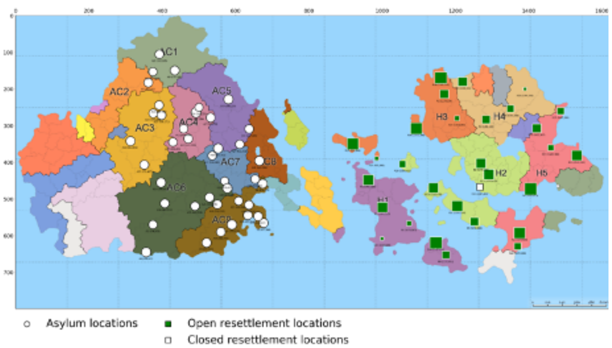
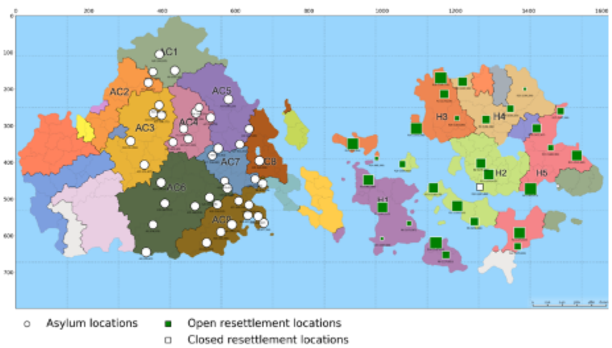


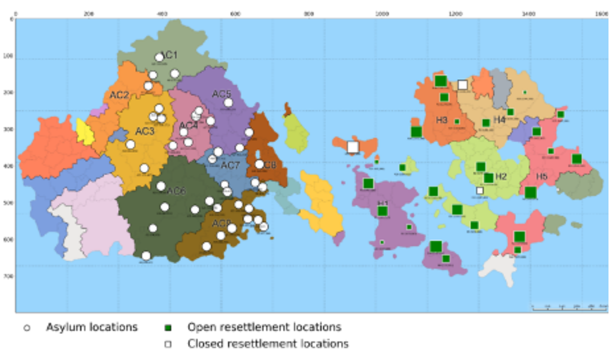
Figure 10: Open resettlement locations for the main model.



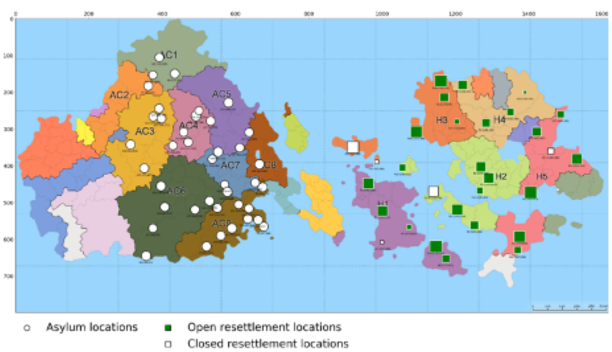
(a)



(b)



(c)



(d)

Figure 11: Open resettlement locations for the forced capacity usage model under different forced capacity usage assumptions: (a) 25%, (b) 50%, (c) 75%, and (d) 100%.

Chapter 5: Concluding Remarks

As a result of the fast and continuous increase in the refugee population, refugee-related processes have proven to be important problems that require immediate attention. One branch of these problems is the relocation of the refugees into permanent settlements in host countries. This process of resettlement involves many internal and external factors that affect the assignments of individuals into resettlement locations and the success of these assignments.

This study focuses on the refugee resettlement decision-making process. We propose a multicriteria optimization model that accounts for the cultural differences between origin and host societies, physical distances between asylum and resettlement locations along with the travel issues, costs related to setting up the resettlement locations, physical capacities to meet the refugee needs, feasibility criteria, and emergency levels.

The results of this study show that including realistic considerations such as monetary and capacity constraints prevents the model from achieving the primary goal of resettling as many individuals as possible. This is a trade-off that should be regarded carefully by the field experts and the decision-makers.

Where this study contributes to the refugee resettlement literature are the factors taken into consideration and the way they are modeled. The success of the relocation assignments and the local integration of the refugees are very important elements of the resettlement process. Current studies make use of feasibility constraints and predicted integration factors or preference information to deal with the assignment and integration issues. However, this study handles the assignment feasibility by forming the assignment groups from binary requirements to concurrently achieve feasibility and model performance. In addition to the existing approaches, this study introduces the concept of cultural distance to the resettlement problem. While it is useful for increasing the chance of a successful assignment by increasing the chance of higher local integration, the main advantage of using cultural distances is that it does not require collecting family or individual-specific information. Cultural distances can be managed at the country level, and hence, they are easier to process.

For future work, including the time aspect of the model should also be considered since refugee resettlement is not a one-time process and requires continuous planning. Including a temporal consideration will involve time-dependent demands and capacities, as well as the uncertainties related to these parameters. Therefore, it will create a need for dynamic capacity management and robust optimization. Another consideration for future work is the fairness of the decisions so that equity in the decision-making process is effectively addressed. A follow-up consideration of this future works is the decision of which refugees to resettle as well as when. This is why creating a fair selection model to determine which refugees to resettle prior to or concurrently with the assignment process should also be a part of the future work.

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