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2016
MCM/ICM
Summary Sheet

(Your team's summary should be included as the first page of your electronic submission.)
Type a summary of your results on this page. Do not include the name of your school, advisor, or team members on this page.

In order to model the dynamic nature of refugee migration, our ICM-RUN team employed non-stationary Markov chains. Using an iteratively updated transition matrix, we effectively simulated the rapidly changing flows of migrants between host nations. We introduced stochastic parameters in order to investigate the effects of varying resources, unpredictable conditions, and rare high-impact events.

Our research and analysis of the model led us to the conclusion that an optimal set of policies will prioritize the even distribution of refugees across safe haven nations through an efficient transportation network. Following the implementation of our proposed policies, our model predicts a 38.3% improvement in the distribution of economic burden on host countries, and an 89% improvement in the number of critically overburdened host nations overall. Results such as these are critical to convince the international community to act swiftly and decisively to end the refugee crisis once and for all.

UN Policy Brief

The following policies are the best attempt to mitigate the current international refugee crisis, while maximizing the safety of safe haven countries, and preserving their cultural identities.

A concerted global effort needs to be made to ensure the safety of refuges crossing both the Mediterranean Sea, and the continent of Europe. This, combined with the need for the refugee population to be successfully integrated into the host countries culture, leads to the inevitable need for dedicated men and women to work with refugees from the moment they reach the shores of the Mediterranean. To that end, we propose the creation of the International Refugee Network Fund (IRNF) whose sole purpose will be to fund local and international NGO's so they may assist refugees during their migration, and help them integrate into their host country's social environment.

For many refugees, the most dangerous portion of the trip lies in the crossing of the Mediterranean. Article 33 of the 1951 Refugee Convention expressly forbids the *refoulement* of refugees once they reach shore. In order to avoid the legally ambiguous language of the Article, and to prevent the interdiction of refugee craft, any state that encounters a refugee craft shall, in the context of the Article, be defined as a Contracting State. The obligations of this Contracting State shall not extend beyond those required in Article 33.

Finally, using up to date population demographics acquired from IRNF, the CEAS (Common European Asylum System) shall, once monthly, update the flow of refugees to countries as to ensure the burden of care is equally distributed.

As tragic as this crisis is, it is also a unique opportunity for the Western world to reconnect with the Middle East. After centuries of violence and mistrust, this may be the single most important olive branch to have been offered to a desperate people.

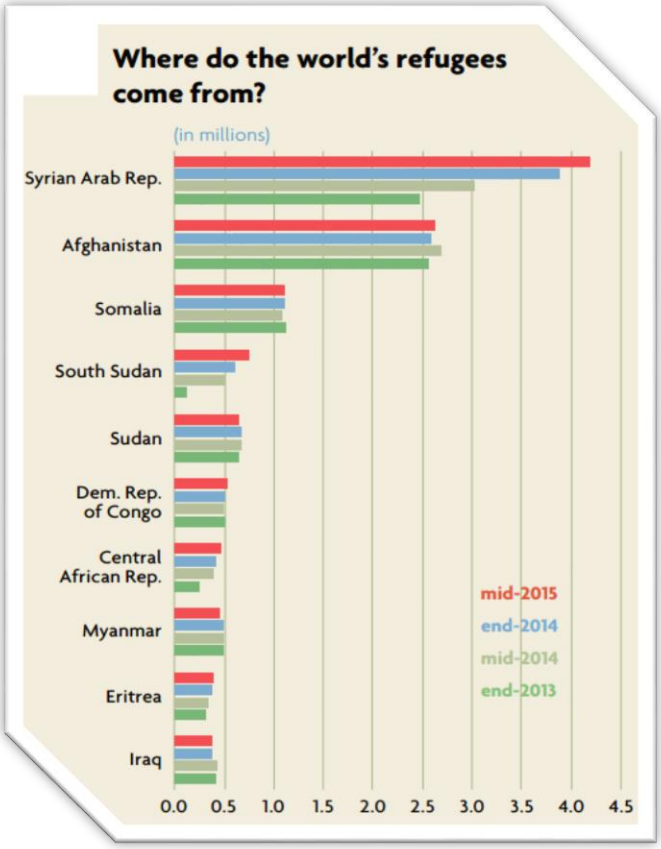
Solution Paper

Introduction

The refugee crisis the world now faces is extraordinary in both complexity, and scope. Not since WWII have we faced such a mass movement of peoples, forcibly evicted and thrust into the role of refugee. While there are several resources and opportunities for refugees, there exists many opportunities for a better, more efficient way to help these people in need. Before the ICM-RUN team presents policy adjustments, it is important to first understand the complexity of the issue.

From information provided by UNHCR 2015 mid-year report, there are more than 4 million refugees from Syria, 2.5 from Afghanistan, a million from Somalia, and more than three million more from, South Sudan, Democratic Republic of Congo, Central African Republic, Myanmar, Eritrea and Iraq. These refugees make up the bulk of the current refugee population, but are by no means the only populations to be displaced by violence, or threat of violence.

Figure 1: Estimated Refugee Population UNHCR Mid-Year Report, June 2015



As one might imagine most of these countries are impoverished, and all have armed conflict raging across their borders, with no end in sight. Thus there are two different components of the current situation that need to be addressed.

Firstly the number of refugees seeking

asylum in neighboring countries and secondly the number fleeing to the EU, USA, and Canada. It is outside the scope of this model and paper to discuss the solutions for the refugees fleeing to their neighbors. However, it is important to note that: Turkey, Pakistan, Lebanon, Iran, Ethiopia, Jordan, Kenya, Uganda, Chad and Sudan host close to 8.7 million refugees. Of the estimated 4 million refugees from Syria, Turkey alone hosts close to half of them (UNHCR 2015).

Historical Context

To solve European migrant crisis, one must first recall the history of the refugee, and of the dynamics between them and the host country. Finally, the relationship between the West and the Middle East must be briefly examined.

There has always existed tension between refugees and the host country. The economic and material burden placed on the host country can cause the government and people to react negatively toward the refugees, which in turn can cause the refugees to react negatively toward the host country, and its citizens, leading to an escalation of tension between the two. Often times, refugee camps are severely under-managed and maintained. Currently, there exists no precisely defined legal obligation of the global community to provide adequate nutrition to refugees. Combine this with the emotional and physical trauma refugees often experience, and history has shown that impoverished areas are hotbeds for disease, illegal activity, and radicalism. These attitudes may help explain why, in an analysis of both Humanitarian and Scholarly literature; three common themes dominate the discussion about refugees (Napier-Moore 2005).

- Hungry, helpless and displaced, refugees have identities and entrenched characteristics of dependency;
- Uprooted and pathologically problematic, refugees must be helped back to stability;
- Untrustworthy and 'bandit like' refugees need to be controlled.

The historic relationship between the West and the Middle East, and how those events play into the cultural zeitgeist of the 21st century is a critically important area for consideration. From 336-323 BC, Alexander the Great waged war across modern Turkey, Iraq, Egypt and Syria into India. During his campaign hew put thousands of men, women and children to death. In the intervening years, violence and conflict has continued to divide the Middle East and the West: The crusades in the middle ages, the declaration of a holy jihad on the triple entente during WWI, the creation of the state of Israel, the terrorist attacks of 9/11, and the recent ISIS attack on Paris, have culminated in a lack of empathy for the plight of the millions of refugees fleeing the middle east.

This is not to proclaim that the western world, and specifically the EU is indifferent to the suffering, but to illustrate the many, valid, political obstacles one must overcome before major changes can be made to current policy to increase the number of refugees being granted asylum, and decrease the human suffering. The ICM-RUN model can account for massive volumes of people, great distances, storms and geographic obstacles, but it cannot account for cultural xenophobia, animosity, or fear. The single missing element from this model, and thus the largest assumption we have made, is the desire of the countries involved to offer asylum and aid within reason.

Specific Changes

While this issue has no clear solution, the ICM-RUN team believes specific policy changes can help decrease the level of human suffering, more evenly distribute the economic and material burden, and prevent the introduction of radical militants into peaceful countries. In order to solve this crisis, we looked primarily at the distribution of refugees across the EU. The majority of refugees have found a temporary haven in Greece, Hungary, and Italy yet the problem becomes the transportation of these people into new countries, and decisions regarding the required refugee population per country. Deciding the refugee population per country was carefully considered, and referencing theoretical models on the introduction of foreign elements into business in order to change a business culture, great care was taken to maintain the host country's cultural identity in order to avoid a sense of a cultural coup. Thus, we have modeled the following:

- The transportation of the refugee populations across the Mediterranean Sea, and then to their designated country.
- Changes in climate conditions, leading to an increase or decrease in refugees seeking asylum in the EU.
- The unstable nature of the European political sphere, and the potential countries will not accept their allocated refugee populations the ideal population of refugees per country to equally distribute the workload between nations.

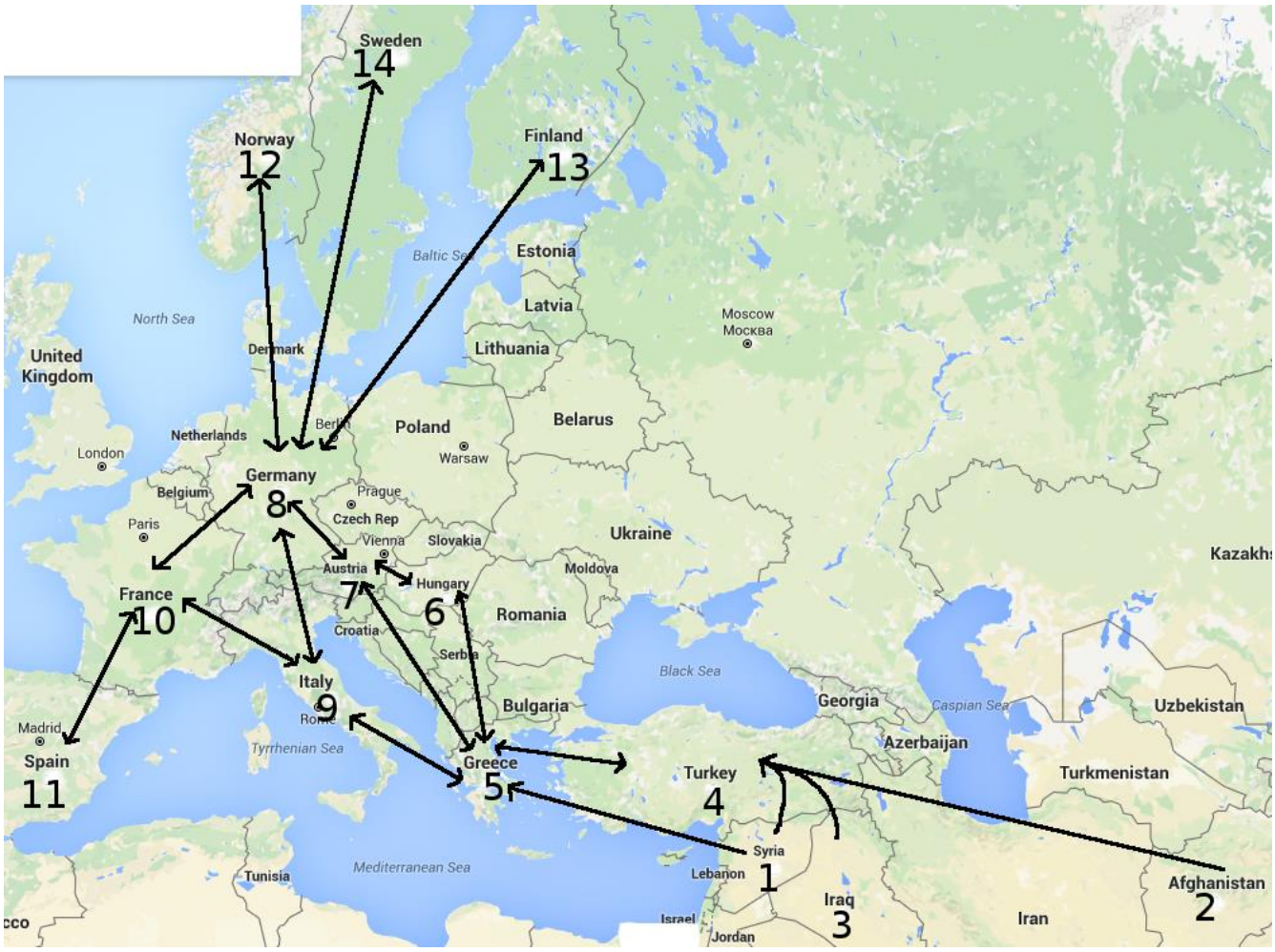
The Model

Assumptions

- If a country has hit their maximum capacity for refugees, they will not accept any more until the current refugees have been relocated elsewhere.
- Applications for asylum have been granted to all refugees, and thus they are free to move to their designated country.
- Neither Italy, Greece, nor Spain shall interdict refugee transports along the Mediterranean.
- Every country listed complies with Article 33 of the 1951 Convention Relating to the Status of Refugees (UNHCR 1951).

The Network

Our approach to modelling refugee movement began by developing a network to describe the paths available to an average refugee headed for Europe. The majority of refugees flooding to Europe originate from Syria, Afghanistan, or Iraq. We did not consider other sources of refugees in the model. Modern transportation makes virtually every major city in the world interconnected, but throngs of impoverished refugees in reality have only a few routes open to them. This narrowed the available routes to Central Mediterranean, Eastern Mediterranean, West Balkans, and Albania to Greece. The number of refugees that utilize the Western Mediterranean and Eastern Borders routes are small enough in scale that they do not effect overall model behavior. Since the refugees we consider will be travelling primarily by bus, boat, or foot, we represent their paths on the following map.



Refugee Movement Network

The nations at the head and tails of the paths are nodes in our network. Each path represents the total of all transportation options open to a refugee population at any particular node. At any given time, a percentage of the population at a node will choose one of the paths available to them, and the rest will stay at their current node. Many factors determine the specific refugee flow rates at each location, such as weather, transportation options, resources, and individual motivations. In order to make sense of all of the information, we chose to focus on the number of political asylum applications in a country relative to its neighbors and relative to the number of refugees passing through the region. A nation with a relatively high percentage of applications will see a smaller portion of its refugee population pass on to other

nations in search of permanent refuge. Furnished with data from Eurostat (Eurostat 2016), we created the following flow matrix.

Refugee Flows

Flow Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1: Syria	0.125			0.82	0.035									
2: Afghanistan		0.45		0.5										
3: Iraq			0.008	0.99										
4: Turkey				0.598	0.4									
5: Greece					0.002	0.541	0.221		0.221					
6: Hungary						0.25	0.748							
7: Austria							0.1	0.898						
8: Germany								0.756		0.07		0.023	0.025	0.124
9: Italy								0.5	0.101	0.487				
10: France										0.717	0.281			
11: Spain											0.99			
12: Norway												0.628	0.37	
13: Finland												0.058	0.625	0.313
14: Sweden													0.368	0.63

Migration as a Non-Stationary Markov Chain

Let Q be the flow matrix as represented above. Let $D(t)$ be the distribution of refugees over the network after t months. Let m be the initial distribution of refugees in our network. If we add an imaginary location at node 0 for refugees that perish on the way to safety and freedom, we find that our flow matrix is part of a Markov chain transition matrix P with one absorbing state at node 0, where the entries in the 0^{th} column represent the node mortality rate. We calculated estimated fatality rates by the following equation, where for each node i, f is the fatality rate, r is the recorded number of deaths, and t is the total recorded number of refugees observed.

$$f_i = \frac{r_i}{t_i}$$

If we assume Q to be stationary, we have

$$D(t) = mQ^t$$

In other words, if there are no changes in refugee flows, we can easily model the distribution of refugees, and thus their movement, as time passes. However the refugee situation is extremely dynamic, and thus cannot warrant such an assumption. For example, the countries that serve as nodes in our network have capacities in the amount of resources they can devote to assisting refugees. Additionally, transportation networks can only be loaded so much before they cease to function efficiently. Therefore we allow Q to be non-stationary. Thus we have

$$D(t) = m \prod_{i=1}^{t} Q_i$$

In order to model the dynamics of refugee flows, we created a vector c containing each nation's capacity for refugees as a function of GDP, population, and geographic size (Statistics Times 2015). If the distribution of refugees exceeds a particular nation's capacity, it will cease accepting incoming refugees, and will send the refugees over its capacity evenly out any available connection. This can often create a backflow of refugees to nations already passed through. Additionally it often creates a cascade effect, sending large waves of refugees rippling through the network. We often find such complications in our current real world crisis, accounting for much of the congestion in critically overburdened regions such as Greece.

Stochastic Flows and Capacities

In a model of this scope, the number of variable parameters are staggering. We determined that the most efficient way of simulating the uncertainty that surrounds a serious model was random variation.

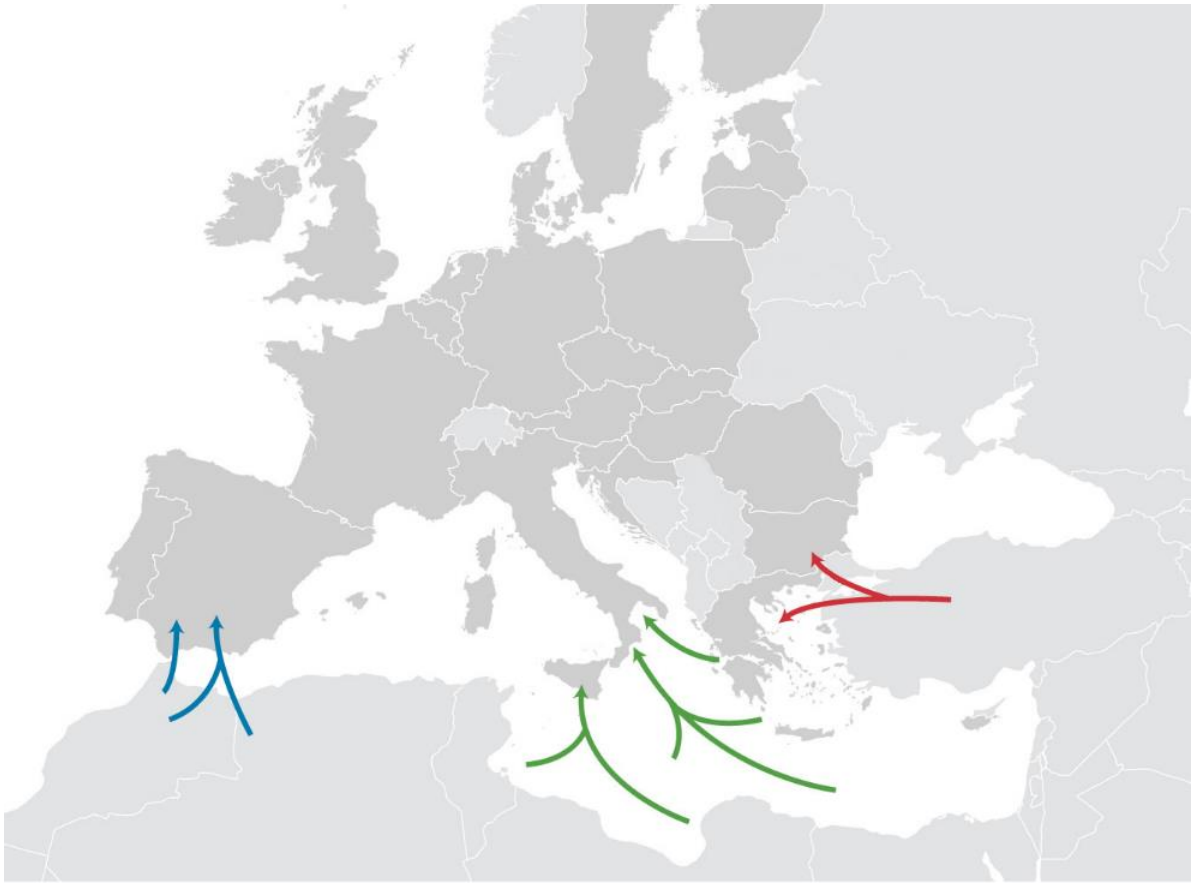
We allowed our flow matrix to vary by a factor with uniform distribution from .95 to 1. Another major source of instability are exogenous events that dramatically alter the system. One possible effect of such events would be a sizeable shift in a nation's capacity, possibly because public perception turns against refugees with certain origins, or because a massive amount of resources must be reallocated. To simulate this in our model we allowed our capacities to change every time period by a factor with normal distribution, mean of 0.75, standard deviation of .08. The combination of these two stochastic elements, along with a non-stationary transition matrix, captures the dynamic nature of refugee flows.

Solution

The ICM-RUN model demonstrates the existence of a solution to the current refugee crisis. In order to fully realize such a solution, the following policies need to be implemented.

I. **The designation of 3 travel routes across the Mediterranean Sea, coinciding with the three most frequently used paths by refugees. Namely, the Western Mediterranean Route (WMR), the Central Mediterranean Route (CMR), and the Eastern Mediterranean Route (EMR).**

1. Any state that encounters a refugee craft along the aforementioned routes shall be defined as a Contracting State according to the 1951 Refugee Convention whose obligations shall not extend beyond those defined in Article 33 regarding the *refoulement* of refugees.



II. The creation of the International Refugee Network Fund, (IRNF) an organization that will assist with the following: refugee transportation across the Mediterranean, transportation to their designated country, and social integration within said country.

1. This network shall be maintained by guides, who shall be tasked with the general wellbeing of the refugees they escorting.
2. The guides shall facilitate the movement of refugees across the Mediterranean in a safe and expeditious manner.

3. The guides shall aid in procuring transportation from Greece, Italy or Spain to the refugee's designated country.
4. Guides shall, upon arrival at destination country and specific region, spend no less than one week with the refugees under their care in order to provide cultural and social integration with the host country. The guide shall work with the refugees in rudimentary social niceties, and the beginnings of the language of the host country.

III. Using the refugee numbers generated by the IRNF, the CEAS (Common European Asylum System) shall update the distribution of refugees requirements monthly

1. Using the numbers generated by the IRNF Guides, the CEAS shall, at the start of each month, re-designate the flow of refugees as follows
    - Each country shall be required to accept refugees up to a capacity defined by this equation

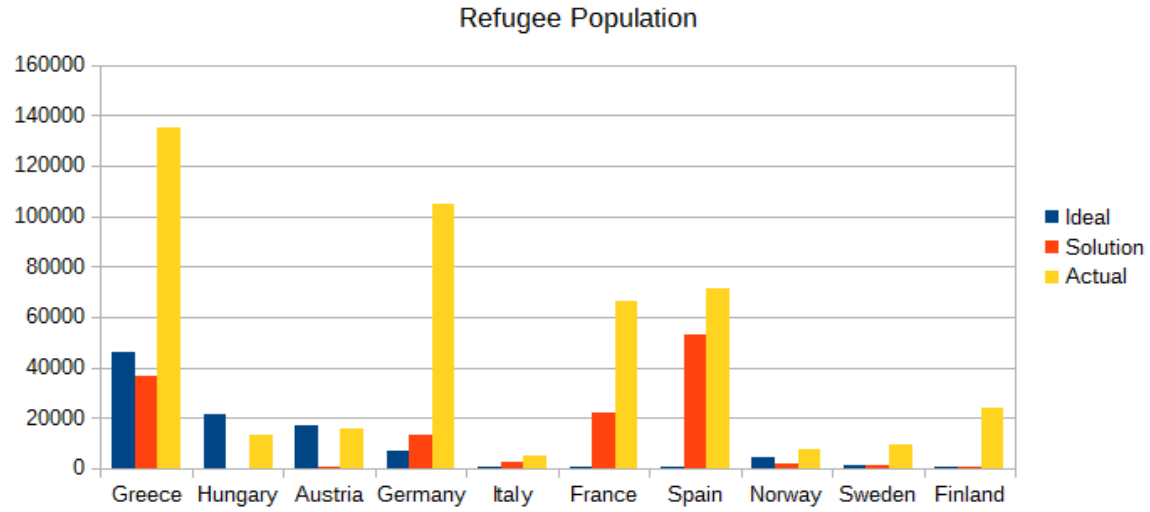
$$c_i = T \times \frac{g_i v_i}{\sum_{j \in V} g_j v_j}$$

Where T is the total current population of refugees, g is the GDP, v is the population density, and V is the set of all safe haven nations.

    - Should a country reach its capacity, all refugees are sent along all connection lines to adjacent countries.

Real World Translation

Should these policies be implemented, there will be a definite decrease in the economic and material burden placed on all countries, including Greece, Italy and Spain. From our model we project an improvement of 38.3% in the total mean variance of population distribution. After a year, it is estimated that 40.9% of the countries included will be over their ideal refugee population. With the policy suggestions implemented, after a year only 18.2% of countries will be over populated in terms of refugees.



Further Considerations

Exogenous Events

In an attempt to consider exogenous events that would alter the dynamics of the European political sphere, we formulated our model to deal with a sudden and drastic decrease in a countries ideal refugee population. Presumably, this would be from the country refusing to take any more refugees. In this event, our model simply routed refugees to other locations, and did not have a significant impact on the

projected population variance, or number of nations over capacity after a year's time.

Scaling

In order to analyze our model's sensitivity to scaling, we increased the number of refugees by a factor of 10. Additionally, we considered our model's behavior when the number of refugees decreased dramatically. We calculated the solution's variance in burden, along with the number of months it took for the solution to return the minimum variance distribution (abbreviated as MLV).

Scale	Variance	MLV
10%	0.005	8
100%	1.1083	11
1000%	2.5605	13

Conclusion

Refugee migration flows cannot be viewed as static patterns. In many ways, the movement of displaced people defies traditional models. We tackled this challenge by incorporating highly adaptable flows in the form of non-stationary transition matrices, and stochastic variation in model parameters. Our model is sensitive to the high variation in resources and capacities at every point in the network. After perturbing and scaling our inputs, we were very satisfied with the stability of our solution. We incorporated highly dynamic capacities in our model to account for both dramatic shifts in the political sphere and for everyday variations in essential resources like food, fuel, and healthcare. While there is much more work

that could be done to improve the model, we have implemented a very promising approach to the problem.

Refugees present a difficult policy problem because they are at once a local and a global issue. Communities must maintain their identities while remaining compassionate to the plight of unfortunate displaced foreigners. On the international level, nations must guard the interests of their citizens without becoming insular and inflexible. Additionally, by the time the political machine grinds long enough to create a new policy, it is often too late to help those who initially inspired it. An accurate model of a problem can help at least with the last flaw. Our proposed policies help to effectively spread the burden across nations who can most bear the load, encouraging cooperation and swift action. Testing our policies in the model yielded consistent, stable results. Thus we can say with confidence that our approach can withstand the rapid changes of the modern political sphere.

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