Develop a Better Understanding of the Factors Involved With Facilitating the Movement of Refugees From Their Countries of Origin Into Safe Haven Countries

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Humanitarian organizations that aim to settle refugees in Europe are currently facing new challenges because refugees settling in Europe are coming from outside Europe in larger numbers than ever before[1]. One of these organizations, the office of the United Nations High Commissioner for Refugees (UNHCR) was initially formed in 1950 with the intent to help Europeans displaced by World War II[2]. Since its inception the UNHCR has provided aid to refugees, internally dispaced people, stateless people, and asylum seekers from emergencies originating within Europe and, increasingly, outside of Europe.[3].

According to data from the UNCHCR Global Trends 2014, ongoing conflicts in Syria and Afghanistan are the largest source of refugees[4].

This problem breaks down into multiple problems.

1. **What are the factors involved with moving refugees?**

   What attributes enable or inhibit the safe and efficient movement of refugees. As an example, the individuals (plus resources the individuals have), routes, types of transportation, country capacity (plus entry points). The UN asks us to prioritize the health and safety of refugees.

   Total numbers of refugees in the system and at each node, entry points for refugees, possible routes, popularity and capacity of those routes, length of routes, infrastructure for accommodation along routes, and capacity for receipt of refugees.

   Safety will be optimized by minimizing the risk that any individual may not complete a route. We define a measure of risk that incorporates information about liklihood of illness, death (i.e. drowning on water routes),

[1] http://www.bbc.com/news/world-35091772
[2] http://www.unhcr.org/pages/49c3646cbc.html
[3] http://www.unhcr.org/pages/49c3646cbc.html
[4] $http://ec.europa.eu/echo/files/aid/countries/factsheets/thematic/refugees_en.pdf$

and other dangers of travel that may be exacerbated for routes with high throughput for a given route.

We choose a monotonically increasing density function that models the risk of not completing the route. Higher population densities along a route result in a higher risk than lower densities. We assume that low densities have low risk and that high densities have high risk, so density may have an exponential, sigmoidal or linear relationship to risk. If we assume that once a threshold density is reached, risk increases at a slower rate then, a sigmoidal curve may approximate the relationship between density and risk more accurately than an exponential or linear relationshp. However, since we have decided to use a linear programming model If data becomes available, then a more realistic density-risk function may be substituted into the model.

Calculation of risk must also relate the length of the route to the density, perhaps with a linear relationship.

Efficiency - With high numbers of migrants, where do bottlenecks occur? Why do bottlenecks occur, and What measure may be used to evaluate the efficiency of a system? Penalty for slower travel and for long waits in camps before reaching the end destination and exiting the system. Policy that prevents a high number of individuals existing without citizenship to a country should be preferred.

Assumptions: All migrants who make it to their destination travel at the average rate. Due to our choice of a linear programming model, all relationships are linear.

2. **How do we gain a better understanding of the factors?**

   Create a model of optimal refugee movement, considering accessibility of transport, safety of route, and resource capacities of countries. Use metrics considered to predict the number of refugees that are to be moved, as well as the rate and point of entry necessary to accomodate their movement. Explain new elements you have incorporated into the migration process.

   It should be noted that we must account for dynamically changing environmental factors. Our model should exhibit a use of endogenous change (prepositioning and allocating resources) to form the best route planning approach. Exogenous parameters (unavoidable, unpredictable events, like the terrorist attack in France) must also be considered.

   Graph with connected nodes. Known number of people at a number of entry points. Need to optimize distribution.

   Modelling methods considered: Stochastic Differential Equations are used in the stock market because individual factors cannot be influenced. This may be a way to realistically model the randomness of individual refugee movement. However, this type of model is difficult to optimize, which may make it difficult to meet our objective to optimize refugee movement. The use of stochastic programming may allow for optimization of the

model. Stochastic effects are generally more important when you are dealing with small population sizes[5]. Since stochastic effects will likely have little impact on the overall movement of large groups of refugees along major migration routes, it is reasonable to model this situation using deterministic models.

Propogater models

Modelling refugee movement may be treated as a social network problem, with multiple sources and sinks. Travel through the system may be described using fluid dynamics with partial differential equations describing each time step. One way to model exogenous events would be to

Create a graph where edges describe travel routes and vertices represent various locations that refugees may travel through and to.

What do we know about our system? How much feedback exists in our system? Is it a closed system? Let us consider a model that describes refugees that are not settled. This includes migrants who are residing in refugee camps in Northern Africa, migrants who are in transit, and migrants who have reached a destination, but do not have accepted migrant status (?) and have not been officially settled in the country. If a migrant becomes officialty settled then they have left the system.

Starting with a basic model, each possible country near Europe where there may be a substantial refugee population is represented as a vertex on a graph. The edges between vertices represent the connectivity between locations for refugees. Rates of travel along edges may vary based on qualities of the travel route including capacity, distance, modes of transportation available and risk to migrants. Once these variables and parameters are related on a graph, we need to learn about the dynamics of the system.

One way to inform the movement of refugees from their country of origin into safe haven countries is to learn about how our system behaves when safety and efficiency are optimized. Safety and efficiency are optimized when risk is minimized and ___, respectively. Risk and ___ can be combined linearly, resulting in an overall measure that determines We chose to use linear programming to optimize our system because it can always be solved.

Question?

3. **Propose a set of policies to the UN**

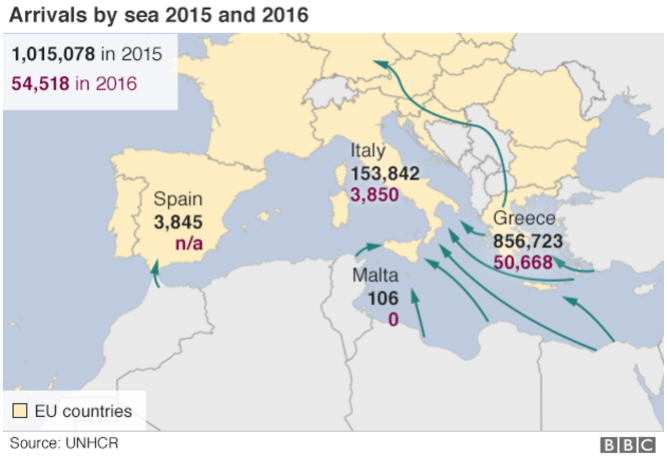
   Write a report to the UN, proposing a set of policies to enact which will support the conditions for optimal migration (optimal to the UN's views).

The 1951 refugee convention defines a refugee to be "owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his

[5] Vries *et al.* 2006

nationality, and is unable to, or owing to such fear, is unwilling to avail himself of the protection of that country"[6], rather than a migrant, who is just someone moving from one country to another.

Immigrants travel multiple routes – beginning at the middle east, and travelling through the West, East, and Central Mediterranean, the West Balkans, the Eastern Borders, and from Albania to Greece.



1. The majority of refugees resettle in the middle eastern countries of Jordan, Lebanon, and Turkey.

2. 1,015,078 refugees arrived by sea in 2015.

3. 942,000 refugees sought asylum in the European Union in 2015[7].

4. 315,000 have sought asylum in Germany, yet more than 1 million have been counted in Germany's EASY system[8].

5. 174,055 applied in Hungary.

Illegal immigration is dangerous, both for political relationships ensuring sustained immigration, and the danger to the immigrants of crossing the border. Poorly managed camps in Hungary damaged migrants reputation, leading to a surge in the popularity of the radical nationalist Jobbik party[9]. It is difficult to control the way countries will handle the immigration crises, so this is an exogenous factor. In other countries, such as Germany, strong moral foundations protect the influx of immigration[10], with little (and strongly opposed) backlash at the new immigration policies. The Paris attacks threatened relations about

[6] http://www.unhcr.org/pages/49da0e466.html
[7] Eurostat
[8] http://www.bbc.com/news/world-europe-34131911
[9] http://www.bbc.com/news/world-europe-34280460
[10] http://www.bbc.com/news/world-europe-33700624

refugees. A Polish minister stated that "we were too idealistic" [11]. The attack deepened the level of insecurity across Europe, since it was believed that the terrorists snuck into the country with refugees. Regardless of the truth of these facts (the only known attackers are French and Belgian residents), the coinciding events were treated as such, and has lead to border problems in the country.

The difference in each country's utility to hold refugees is integral to how important it is to uphold their immigration policy. Economically, immigration should be beneficial to host countries in the long term. A well defined immigration policy, distributed across the continent, should not be a problem

1. Our best evidence suggests that immigration is usually economically beneficial for host countries. The majority of refugees arriving on European shores are able-bodied and unlikely to be an exception to this general rule. So the best way for Europe to help would be to offer immediate legal residency and access to labour markets. It might be politically expedient to restrict access to some welfare benefits but most migrants will be keen to work regardless[12].

Note that our proposal is a short term proposal. The only way to permanantly ease the migrant situation in Europe is to end the conflicts that make people flee their countries in the first place. Therefore, we should only project our models into short time periods in the future (5 years?). How much do refugees move once they enter countries? Evidence to suggest immigrants attempt to flee Hungary and enter Germany.

Things to research for tomorrow:

1. History, pertaining to dangers and effects of certain decisions on immigration policy.

2. The UN's framework and objectives for the goals of refugee immigration.

   Under the general UN assembly, a refugee has the unconditional right to return home.

3. How NGOs fit into the immigration picture.

   s

4. How much does immigration cost?

   Typically, the total cost for processing and accommodating asylum seekers can be in the range of 8 000 and 12 0000 per application for the first year, although the figure may be much lower for fast track processing[13]. 4 years after social assistance, 75% of immigrants moved out of social assistance.

[11] http://www.bbc.com/news/world-europe-34826438

[12] http://www.telegraph.co.uk/news/worldnews/europe/11845205/Why-do-refugees-and-migrants-come-to-Europe-and-what-must-be-done-to-ease-the-crisis.html

[13] http://www.oecd.org/migration/How-will-the-refugee-surge-affect-the-European-economy.pdf – GOOD ECONOMIC PAPER

5. Look up the application for official refugee status.

   Look in paper[14] and also[15].

   The first step for a refugee is to arrive and register in a UNHCR refugee camp outside of Syria. The UNHCR then refers those who pass the first stage of vetting to the U.S. government refugee process (as described above). The National Counterterrorism Center, the Terrorist Screening Center, the Department of Defense, the FBI, Department of Homeland Security, and the State Department use biometrics and biographical information gleaned through several interviews of the refugee and third-party persons who know him or could know him to make sure applicants really are who they claim to be, to evaluate their security risk, and to investigate whether they are suspected of criminal activity or terrorism. Numerous medical checks are also performed. During this entire screening process, which takes about three years for Syrians, the refugee has to wait in the camp. If there is any evidence that the refugee is a security threat, he or she is not allowed to come to the United States[16].

6. How many immigrants do we need to accomodate?

   3 Million refugees to enter the EU by the end of 2016[17].

7. What Routes do immigrants take - what type of transportation are they taking?

8. Where are immigrants trying to go?

9. Quotas for countries.

$http://www.pewresearch.org/fact-tank/2015/04/24/refugees-stream-into-europe-where-they-are-not-welcomed-with-open-arms/ft_15-04-22_eu-immigration/$

1 Linear Programming

We wish to find the optimal travel routes for refugees emmigrating for asylum. The vast majority of these countries are found in the Middle East through to Western Europe, and it would be economically unfeasible to pay to emmigrate a large portion of refugees across the ocean, so we shall focus only on emmigration to these states.

We must optimize the travel routes of refugees, under realistic constraints which prevent a utopian immigration process. This is most naturally formed as

[14] $http://fra.europa.eu/sites/default/files/fra-focus_02-2015_legal-entry-to-the-eu.pdf$

[15] $https://www.hrw.org/report/2015/11/16/europes-refugee-crisis/agenda-action$

[16] http://www.cato.org/blog/syrian-refugees-dont-pose-serious-security-threat

[17] http://www.independent.co.uk/news/world/europe/eu-expecting-another-3-million-refugees-migrants-before-end-of-2016-a6722096.html

a linear program. For each route that refugees could travel, we allocate a certain number of refugees. We wish to prevent overcrowding routes, and sending refugees down dangerous routes – these concerns will be summarized by a risk metric. We cannot settle down more refugees in a country then that country can handle. Furthermore, we cannot leave any refugee who wants to leave behind – as we have seen in recent years, refugees will attempt any desparate means to escape their home country. An unorganized approach will likely result in more damage than is desired.

We begin by forming a directed graph, summarizing the routes that refugees can take. For each simple path $(v_1, \ldots, v_n)$ in the graph (for refugees are unlikely to take cyclic routes) we allocate a certain number $x_{(v_1,\ldots,v_n)} \in \mathbf{R}$, which represents the number of refugees allocated to that route. Our prior constraints can be summarized by the following equations

1. (No Refugee Left Behind) For every source node v, we have

$$\sum_{\substack{(v_1,\ldots,v_n) \\ v_1=v}} x_{(v_1,\ldots,v_n)} = R_v$$

   Where R_v is the number of refugees exiting the node v.

2. (Every Country is Bounded by its Capacity) For each possible country w in which a refugee may take asylum, we have

$$\sum_{\substack{(v_1,\ldots,v_n) \\ v_n=w}} x_{(v_1,\ldots,v_n)} \leq C_w$$

   Where C_w is the capacity of the node w.

We formulate risk as a quadratic constraint with multiple factors. First, we take the risk of a route into account. We associate a certain 'risk constant' $K_{(v,w)}$ to each edge (v, w) in the graph, which represents the probability of death of a single refugee travelling along that edge. Of course, if n refugees travel along this path, then the expected number of death is $nK_{(v,w)}$. The risk of death travelling along a certain path $(v_1, \ldots, v_n)$ is then compounded. By basic laws of probability, we have

$$\mathbf{P}(\text{immigrant dies on } (v_1, \ldots, v_n)) = \sum_{i=1}^{n-1} \mathbf{P}(\text{immigrant dies on } (v_i, v_{i+1}))$$

Since the event of dying on a certain interval is obviously independant of dying on a disjoint interval, we have an analogous equation for the constant,

$$K_{(v_1,\ldots,v_n)} = \sum_{i=1}^{n} \left(\prod_{j=1}^{i-1} \left(1 - K_{(v_j,v_{j+1})}\right) \right) K_{(v_i,v_{i+1})}$$

This shall form our first linear constraint on the system.

Our second concern is overcrowding. In an overcrowded group, disease, fighting and ___ are likely to cause harm to travelling refugees. This is a rather simple constant to form. In a group of n people, the number of interactions is approximately quadratic, and thus the chance of disease or other factor if quadratic. We assume (or approximate) that there exists a constant B such that the change of death of x people on a route is Bx^2.

One final concern is that refugees do not wish to travel paths which are too long and arduous for them to travel. Therefore, if we have a distance function d on the vertices, giving us the length of a route to travel from one vertex to another, then refugees will travel a distance proportional to the sum of the distances of the edges they travel along. Thus we add another constant C relative to the distance traveled by refugees which causes a route to be dangerous.

We have thus formulated enough constraints and costs to form a quadratic program. The standard form of the optimization problem is detailed below:

$$\min \left(\sum_{(v_1,\ldots,v_n)} K_{(v_1,\ldots,v_n)} x_{(v_1,\ldots,v_n)} + Cnx_{(v_1,\ldots,v_n)} + Bx^2_{(v_1,\ldots,v_n)} \right)$$

such that, for each source v and sink w,

$$\sum_{\substack{(v_1,\ldots,v_n) \\ v_1=v}} x_{(v_1,\ldots,v_n)} = R_v$$

$$\sum_{\substack{(v_1,\ldots,v_n) \\ v_n=w}} x_{(v_1,\ldots,v_n)} \leq C_w$$

This may be solved via any of your favourite quadratic optimization methods.

2 Deriving the Path Correlation Coefficient

Currently, our linear program does not take into account the intersection of paths formed by travelling refugees. Furthermore, it assumes that refugees travel deterministically, not dispersing in response to extraneous events. This obviously does not hold. No two refugees are completely alike, and react differently in response to different events.

The reason why this problem arises when studying the correlation between two different paths arises when two paths intersect. Consider the diagram below, consisting of two curves, with unit speed parameterizations c and c'. Suppose that we model the movement of refugees as a single point moving along the line. Then the movement of two groups of refugees coincides when $c(t) = c'(t)$. If the traces of c and c' intersect, but hit the point at different times, then our model would determine that these groups never meet each other. On the other hand, if $c(t) = c(t')$ where t and t' are two time points very far apart, then we would like to consider these two intersections less important than when t and t' are

very close. We solve this problem by taking a stochastic movement along these curves.

INSERT IMAGE OF CURVES c AND c' HERE

To accomodate the random motion of immigrating populations along a specific route, we apply the theory of stochastic processes. Begin by making the following assumptions TO DO: ADD MORE JUSTIFICATION FOR ASSUMPTIONS

1. Every immigrant starts the route at the start point.
2. The movement of immigrants, as a function of time, is continuous.
3. The average position of immigrants is linearly proportional to the time elapsed since immigration.
4. Past movement of a certain immigrant cannot predict future movement. That is, the process of immigration is Markovian.
5. Relative to the 'center of mass' of the population, an immigrants movement is normally distributed, whose standard deviation is linearly proportional to time. This represents a 'diffusion' of immigrants over time as they travel to their destination, which converges to the final destination asymptotically.

First, we pull back the curve c to its domain $[0, A]$, and extending the definition of c to $[0, \infty)$, by definining $c(A+t) = c(A)$ for $t \geq 0$. We shall place a stochastic process on the interval. With the assumptions above, since c has unit velocity at all time points, we can describe the process X_t which models the movement of immigrants via the stochastic equation

$$X_t = \varepsilon W_t + t$$

where ε is a small constant, and W_t is standard brownian motion. We perform this task for each path, represented by a curve c, we construct a process following the equation above. If X_t is such an equation, then $c(X_t)$ gives us a stochastic process on the path in the graph. We wish to measure, in some capacity, the 'population correlation' between the stochastic processes $c(X_t)$ and $c'(Y_t)$. We cannot use the probability that two particular instances of the motion meet at a certain time point, since, because continuous processes are nasty – $\mathbf{P}(c(X_t) = c'(Y_t)) = 0$ for all values. The best we can do is to approximate two populations coinciding; fixing a small ε', and consider the quantity

$$D_{c,c'} = \int_0^\infty \int_0^1 \mathbf{P}(c'(Y_t) - \varepsilon' < c(X_t) < c'(Y_t) + \varepsilon') \; dY_t \; dt$$

Though theoretically an approximation, practically, this method should model situations well in practice. Really, two people can never be in the *exact* same location at a particular time, so our model really does model the correct situation, provided we pick ε' so that 'vicinity' is both small enough for two populations

to affect one another, and big enough so that the quantity above does not converge to zero. In a particular application of this derivation, we can take two independant motions X_t and Y_t for the same curve c, to obtain better density constants for the linear programming formulation.

3 Metrics of Refugee Crisis