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Problem Chosen

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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
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Summary

Our analysis and targets: In essence, this problem is kind of a case of maximum flow and minimum consumption with multiple sources and targets. "Multiple sources" refers to different original countries of refugees involved in the case, while "multiple targets" refers to different target countries where refugees arrive. It's our aim to rationalize the flows of refugees and to optimize the target country for each refugee, i.e. to optimize the choice of transmitting routes and the allocation of available resources with various condition factors.

The general idea and method: Set an indicator which consists of different parts of different factors. The indicator is designed to reflect the severity of both transportation and resources consumption. Every sub-factor should inflect the gap between theoretical value and actual conditions. For the actual conditions, we can get enough data to describe or estimate it. As for the theoretical value, we introduce the advanced Dijkstra algorithm inspired by Edmond-Karp algorithm. Besides, we proposed the conceptions: weighting factor matrix, resources factor matrix, a series sub factor matrices which is designed to describe the effect caused by different factors. The problem is quite similar to the model of water supply system. So we use the similar defining method to tackle the problems.

Main results and conclusions:

The model works well under dynamic conditions and the results fit the real situation well, while the factor of politics and the factor of adjustments can be changed thus it is able to assess the cascading effects. It is helpful when the population of refugees grows rapidly and is able to make prediction of the maximum capacity of European mainland to consume the flow of refugees.

Key points:

Maximum flow and minimum expense /Water supply network model
Dijkstra algorithm

Unstoppable Refugees

1 Introduction

1.1 Background

As a result of major political and social unrest and warfare, a massive surge of refugees emigrating from the Middle East to European countries. With hundreds of thousands of refugees moving across Europe and more arriving each day, much attention has been given to refugee integration policies and practices in many countries and regions. The challenges brought by the refugees must be managed carefully through effective policies.

1.2 An Over View of Tasks

- 1) Metrics of refugee crises. Develop a set of measures and parameters to for the refugee crises assessment.
- 2) Flow of refugees. Create a model of optimal refugee movement that would incorporate projected flows of refugees across six travel routes with consideration of several important factors, like transportations/accessibility, safety and countries capacities. Determine the number of refugees and the rate of points of entry. Justify the new elements added in the model and analyze the sensitivity.
- 3) Dynamics of the crisis. Refine the model to adapt the demand of changing environmental factors. Here we have to take the cascade effect of the resource consumption into consideration. What's more, a plan should be given to allocate the resource properly and rank the priority of different kind of resources. Analyze the effects of NGOs and the new destinations for refugees.
- 4) Policy to support refugee model. We are asked to write a report on our model and propose a set of policies that will support the optimal pattern. Consider and prioritize the health and safety of refugees and local populations. Take the laws and cultural constraints and role of NGOS into consideration.
- 5) Exogenous events. Analyze the exogenous events' influence on the situation parameters and the cascading effect of the refugee flows. How your plan is designed to be resilient to these events?
- 6) Scalability. Discuss the Scalability of your model when your model is applied for a much larger scale

1.3 Our General Analysis and Work

1.3.1 Analysis:

The index for the crisis assessment should be composed of two parts:

- 1) The burden of the refugee transition for the country on the path
- 2) The burden of the resource consumption for countries with refugees

Each part above should indicate the difference between ideal situations and practical ones.

The practical situation can be known or be estimated from statistic data, so our focus is the theoretic or ideal refugee flow pattern.

The essence of this problem is kind of a case of maximum flow (profit) and minimum consumption(cost) with multiple sources and targets. Here, it means multiple source of refugees a multiple destinations in Europe countries. This is similar to the pattern of city water supplement, so we call draw some conception of water supplement into this problem.

It's our aim to rationalize the flows of refugees and to optimize the target country for each refugee, i.e. to optimize the choice of transmitting routes and the allocation of available resources.

1.3.2 Our work

- 1) We build a basic refugee flow model based on the water supply pipe network model and Maximum flow and minimum expense model.
- 2) The basic algorithms are Dijkstra(optimal route for flow from a single origin) algorithm and Edmond-Karp(maximum flow with multiple origins) algorithm. We modified this two algorithms to adapt this multiple source and multiple targets problems.
- 3) The concepts of weighting factor matrix and available resource matrix are introduced into our model. Both matrices are composed of various factor matrices which represent different situation parameters.
- 4) We proposed a series of formulas to calculate different factors.
- 5) We extended and modified the model under different new conditions, and introduced corresponding factor matrix to measure the situation. For example, feedback factor matrix, cascading effect factor matrix.
- 6) Sensitivity of the model has been analyzed under different situations.
- 7) An optimal policy has been proposed according to the result of our model.
- 8) Scalability is discussed in different situations.

2 Assumption and Justification

2.1 Basic Assumptions

- 1) Terrain factor is out of other consideration.
Reason: The terrain of the most regions referenced in the problem is flat. So it can be taken as a plane problem.
- 2) Every refugee is regard as equivalent individuals except for their position and religion attributes.
Reason: Human nature is nearly all the same. The desire to high income and rest social environment and better welfare policy is similar to each other.
- 3) Not every country will be included in this model. Only typical and crucial countries are selected in our model.
Reason: There is nearly no refugees on certain routes out of position or other factors and the adjustment of policy won't change this situation which means it means nothing for our model.

2.2 Special Assumptions for different situations

- 1) At the beginning of modeling, apart from the six routes mentioned in the question, we do not consider other routes that refugees may choose and assume all the refugee we will concerning choose one of the six routes.
- 2) Second, at the beginning of modeling, we do not consider all the countries that have accepted the refugee, main countries producing refugees and main countries accepting refugees, such as
Germany, France, Spain, Sweden, Afghan, Iran, Iraq, Syria, Turkey, Greece, Albania, Macedonia , Bulgaria, Rumania, Serbia, Montenegro, Bosnia, Croatia, Hungary, Austria, Ukraine, Slovakia, Czechoslovakia, Poland, Germany, France, Spain, Morocco, Italy, Libya, United

Kingdom, Denmark, Norway, Sweden, Finland, Russia, Belgium, Holland and so on, other countries that the number of refugees produced or accepted is quite small are not being considered. Of course, there is no refugee who considers flowing to regions like America, Canada or China.

- 3) The means of transportation assumed in our model are by highway, by railway, by shipping and by walking. And we make a simplification to let these means of transportation run at a certain rate, for example the miles that railway run per day. Besides, at the beginning of the model, we assume that there is no sudden accident.
- 4) In our model, we assume that all refugees could reach the destination safe and sound.
- 5) Assume that countries accepting refugees don't change their refugee policy during the period of refugee crisis.
- 6) Assume every refugee move along the route straightly to reach the destination without detouring or changing the route.
- 7) Assume the resources that supplied by every country accepting refugees are stable in a period, these resources will not increase because of refugee crisis or decrease because of the number of accepted refugee less than budgeted.
- 8) Original model does not consider the influence of non-government agencies and only government takes the responsibility of accepting refugees.

3 notations

F	Indicator of the degree of refugee crisis	K_p	the actual number of refugees on such a certain route
F_T	factor of transportation pressure of refugees	K_t	the ideal number of refugees on such a certain route
F_C	the factor of resource consumption of refugees	n_{line}	the number of all routes
F_{C1}	factor of inequality	η	degree of danger
F_{C2}	factor of overload	K_d	number of death people on the routes
T_p	the practical number of people on the route	\bar{t}	time-consuming index
T_m	the allocation of refugees under the known condition without adjustment	\bar{e}	overloading index
T_i	the allocation of refugees with the reasonable adjustment	C_i	Total Capacity of i th country
n_{to}	The number of the countries receiving refugees	E_{mi}	Annual economy increment *100
S_i	the money each country could provide to refugees	Pl_i	Political factor
S	the money each country could provide to refugees	ρ_i	Welfare level

s	expense for each person.	G_i	gdp
T	the total number of refugees	n_t	Number of countries involved
T_c	the total reasonable number of refugees	n_{pi}	Population of i th country
a/b/x/y/z	Power index		

4 model overview

4.1 Basic idea:

A general indicator F is set up to indicate the degree of refugee crisis. The factor consists of two part: the transportation pressure indicator F_T and resource consumption of refugees indicator F_C . Each of the indicators above consists of more detailed factors which will be explained later. Both F_T and F_C represent the degree of deviation between actual and theoretical value. So when the F comes to a minimum, it means the most rational condition according to the policies and economic and other factors.

The actual conditions indicators can be calculated or estimated from the actual statistics, while the theoretical value can be solved according to the proceedings and formulas set up in the following sections.

We can achieve two level of optimization procedures.

4.1.1 The primary optimization: (without the adjustment of policies)

The factors which can influence the primary optimization:

- 1) Types of transportations, death rate of various routes, distance of various nodes of the simplified network, current nation policies and capacity, etc.
- 2) The result of the primary optimization procedure indicates the most rational distribution of refugees on the links and the nodes of the network according to the current policies.

4.1.2 The superior optimization:

The factors which can influence the superior optimization:

- 1) Types of transportations, death rate of various routes, distance of various nodes of the simplified network, the most rational nation policies and capacity after adjustment, etc.
- 2) The result of the superior optimization procedure indicates the most rational distribution of refugees on the links and the nodes of the network according to the most rational policies.

4.2 Introduction of advanced algorithm

4.2.1 Brief introduction

As for the theoretical value, we used special algorithm.

The main algorithm of us is the advanced Dijkstra algorithm. Dijkstra algorithm is designed for the single source problem. With the inspiration from Edmond-karp algorithm, we extended the Dijkstra algorithm to solve this multiple source and multiple targets.

4.2.2 matrix introduction

To apply this algorithm, we introduced two conceptions: weighting factor matrix and resource factor matrix.

The former matrix consists of different factors matrices and indicate the cost or degrees of difficulty of the various links on the network, while the resource matrix represents the resource of various nodes on the network for the consumption of transmission and settlement of refugees.

The weighting factor matrix consists of different factors matrices :

- 1) time-consuming (pressure attenuation)matrix
- 2) leakage ratio (death rate) matrix
- 3) the degree of social unrest (water pressure)matrix
- 4) economic attraction (water demanding)matrix
- 5) policy(node resistance)(number of entry points)matrix
- 6) overloading of routes(pipe resistance)matrix
- 7) Other special factor matrices

The resource factor matrix also consists of different factors matrices:

- 1) welfare factor(negative pressure)matrix
- 2) GDP factor(storage)matrix
- 3) Religious resistance (evaporation)matrix
- 4) Other special factor matrices

4.3 Special extending for various conditions

There are various extending parameters which will influence the final distribution of refugees. One of the most important advantages of our model is the excellent scalability of new parameters. As long as a proper parameter factor matrix is given and the rule to calculate every element of the matrix is rational, then, the result is rational. To adjust the importance and sensitivity of different factor matrices, we can use different power for different elements coming from different matrix.

5 The Model

5.1 The basic model

5.1.1 Assumptions and justification

Please refer the above assumptions

5.1.2 The process of model building

5.1.2.1 basic establishment

To evaluate the severity of refugee crisis, an indicator would be established:

$$F = F_T F_C$$

F_T is the factor of transportation pressure of refugees.

F_C is the factor of resource consumption of refugees.

$$F_C = F_{C1} F_{C2}$$

F_{C1} is the factor of inequality, which represents the difference between the actual number of refugees each country has accepted and the ideal number of refugees should be accommodated considering the general economical policy, region and even the resisting pressure from non-governmental aspects.

F_{C2} is the factor of overload, which represents the degree of deviation compared total number of refugees with the capacity to accommodate refugees of all the receiving countries.

$$F_{C1} = [1 + \frac{\sum_{n_{to}}^{n_{to}} (T_p - T_m)^2}{n_{to}}]^x [1 + \frac{\sum_{n_{to}}^{n_{to}} (T_m - T_t)^2}{n_{to}}]^x, T_t = \frac{S_i}{S} T$$

T_m is the allocation of refugees under the known condition without adjustment under the current policies (may not be reasonable enough).

T_t is the allocation of refugees with the reasonable adjustment of the policies. Before

the adjustment, $[1 + \frac{\sum_{n_{to}}^{n_{to}} (T_m - T_t)^2}{n_{to}}]^x$ equals 1, and x represents the undetermined weight index

$$C_i = \alpha \beta G_i, S = \sum_{i=1}^n C_i$$

C_i represents the money each country could provide to refugees

$\alpha \beta$ are relevant coefficient, such as the coefficient of economic trend and people's attitude on refugees

Suppose that the expenditure of each refugee in every receiving country is roughly equal and denoted as s. All the expense that all receiving countries could afford is denoted as S, while that of certain country C_i (i represents the i th country). As a

result, $T_t = \frac{C_i}{S}$

$$F_{C2} = (\frac{T}{T_c})^y, T_c = \frac{S}{s}$$

y represents the undetermined weight index

T_c represents the total reasonable number of refugees that all the receiving countries could accommodate.

S is all the expense that all receiving countries could afford while s is the expense for each person.

$$F_T = [1 + \frac{\sum_{i=1}^{n_{line}} (K_p - K_t)^2}{n_{line}}]^z,$$

K_p represents the actual number of refugees on such a certain route.

K_t represents the ideal number of refugees on such a certain route.

n_{line} represents the number of all routes.

z represents the undetermined weight index

5.1.2.2 the route network(water pipe networks)

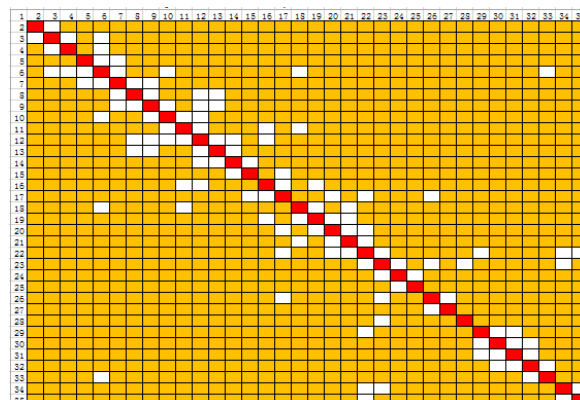
To build such a network, the first and most important work is to select some nodes which represent crucial countries according to the 3rd assumption mentioned above. The principle of selecting is that your selection will represent the structure of the problem, and the node is influential enough that it can't be ignored. By doing so, we get a pipe network where refugees can settle and transit.

1) Weighting factor matrix

a) Routes relationship(nodes and link)matrix

If there is n countries, then we can get a symmetric matrix $A(n*n)$. If there is a route between two countries, then the element of the corresponding position is 1, or it is 0. Like the figure below.

White means 1, other colors mean 0.



b) Leakage ratio (death rate or degree of danger) matrix

The death rate on the land is much smaller than on the sea and the total number of the refugees, so the death rate can be regarded as 0. When it comes to the sea, the death rate can't be ignored.

$$\eta = (1 + \frac{K_d}{K_p})^a$$

a represents the undetermined weight index

K_d represents number of death people on the routes

K_p represents number of people on the routes

c) Time-consuming (pressure attenuation)matrix

Firstly, identify the percentage, m_w for the percent of walk, m_b for the percent of bus,

m_r for the percent of rail way, m_s for the percent of sea. Use the formula

$$v = \frac{\sum m_i v_i}{1}$$

Then we get the average speed of European refugees on the land v_{land} and on the sea

v_{sea} .

Identify the specific distance of each route (to gain the data, we use the google earth to measure the distance).Then we know the average time of each route t .

The index we use here is \bar{t} .

$$\bar{t} = t^b$$

Here, b represents the undetermined weight index

d) Overloading of routes(pipe resistance)matrix

The number of refugees in Europe has gone over 1 million , so here we take 10 thousand of people as 0.01 unit. We set a base constant e , e should be selected properly to adjust the sensitivity.

$$\bar{e} = e + \frac{K}{10000}$$

e) Policy factor(node resistance)(number of entry points)matrix

This is the most important factor and also the hardest to define. So to give a practical criterion, we adopt a Fuzzy Synthetic Evaluation model. we define the indicator p.

We select 0.5 as a standard number, the assessment level ranges from 0 to 1.

The evaluation system involves the number of entry points and the open degree of government for refugees.

The indicator p is largest value 1 means absolute open while 0 means totally refuse.

f) Degree of social unrest (water pressure)matrix

We define r as an indicator of the degree of social unrest

Like the procedure above, we adopt a Fuzzy Synthetic Evaluation model.

The lager the gap between the degree of social unrest of two countries, the smaller the r is.

So r ranges from 0 to 1.

g) Economic attraction (water demanding)matrix

We define u as an indicator for economic attraction between two countries.

The lager the gap between the degree of economic states of two countries, the smaller the u is. So u ranges from 0 to 1.

2) the resource array

Make a list of the GDP of the countries involved in the problem.

Set a series of factors to represent different influence factors, like economic state, religious factor. To identify them, we also use a Fuzzy Synthetic Evaluation model. And will be discussed during the algorithm explanation.

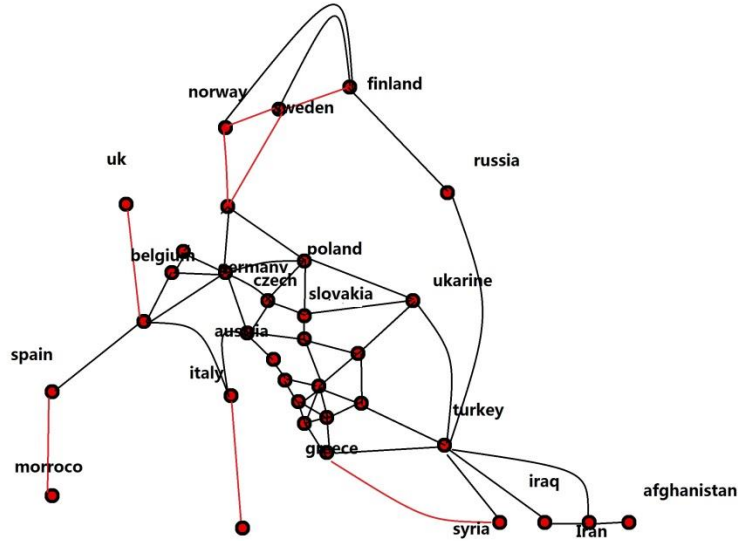
$$C_i = k_i P_i G_i$$

6 The Unstoppable Refugee Algorithm

6.1 The background introduction

As we concentrate on the main map of Europe relative to the route of refugee flow, we can figure out the major and minor nations that re directly infected by methods of both taking settlement and passing-by. So we regard them as the nations that re “on the way”, as for those not directly infected, such as Iceland, we made the assumption that they re not on the way.

Abstractly we build a network of this relationship, just as the following diagram presented, each country were regarded as one single point and the connection, or saying ,the traffic path between two different lands were summarized as one line in the networking, and each path were confirmed no ignorance---that means where there lies a common boundary between two countries ,there should be one path. The only difference is that the difficulties of travelling on that path, which varies under condition of the nature or mathematical distance, dangerous rankings, traffic system, etc. There’s no need to discuss every detail about the route but we can provide a single factor that can inflect and summarize the difficulty of one single route.



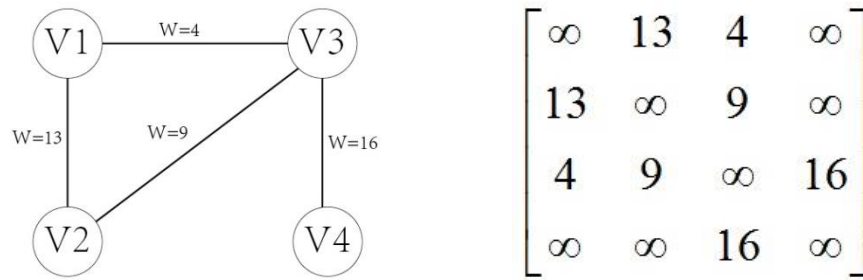
Under the specific situation and assumption we made, we can build a explicit network of Europe expressing the relationship and the condition of all the possible routes and destinations refugees may take.

6.2 Graphing the Europe

We define that there is the Graph $G(V, E)$, and each country should be regarded as one Vertex $v_i \in V$, the connection from country 1 to country 2 $\langle v_{i1}, v_{i2} \rangle \in E$, to simplify the model, the Graph should be the Undigraph, that means if $\langle v_{i1}, v_{i2} \rangle \in E$, $\langle v_{i2}, v_{i1} \rangle \in E$ and furthermore, we made the assumption that the difficulties between the two way path were of the same size. The difficulty of the single path between country i_1, i_2 should be expressed $W_{1,2} = W_{2,1}$ by the weight of the specific path.

For the total explanation of the geographical relationship as well as the path between countries, we summarize the matrix we discussed before and then store the result of each path into one adjacency matrix, if there is a path between, we store the weight of path into the matrix, the less difficulty of the path, the lower value it should be. And if there is no direct path or not accessible (like from Russia to Spain we must take the way of Poland, France), the value of the path should be regarded as 0 for no relationship, but stored as INFINITY for most difficult.

For example, if there're 4 countries $D_v = \sum W$, the difficulty of the path between v_1, v_2 is $W_{1,2} = 13$, and $W_{2,3} = 9, W_{1,3} = 4, W_{3,4} = 16$, while there is no direct path from 1 and 4, 2 and 4, we can draw the diagram and the matrix below.

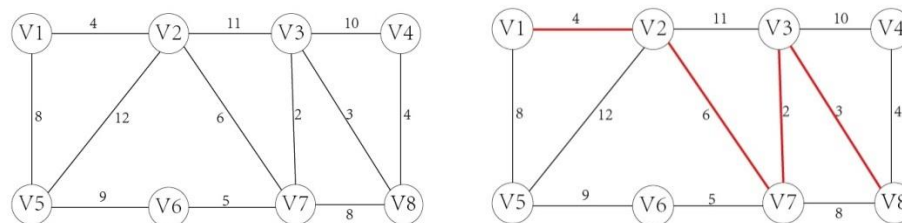


And that for the program language (c++ for example) we store them into a dyadic array $\text{arrayarc}[i][j]$.

So for single refugee, the initial task for him should be finding a way leaving the battlefield as soon as possible and settle down at the peaceful place. And the best way to do that is to find a quickest way to other country. Let's assume that there is recently a battle taken place at country v_1 and one homeless refugee was searching for the

way to the peace country v_8 , and the difficulties of the travel route are explained in the following graph. so what will that refugee do? He will probably find the way of least difficulty and get rid of the disaster as soon as possible, because it is not the trekking but fleeing. So every refugee are at the same dilemma, that he should find a quickest way of the network. The following shows that the best way from v_1 to v_8 is $v_1, v_2,$

v_7, v_3, v_8 .



So if v_1 states for Syria and v_8 states for Germany, the refugee find a most efficient way from Syria to Germany, experiencing less difficulties.

6.3 Basic path finding algorithm

Then the problem comes out that how to find the most efficient way? It is simplified to the model that in Graph $G(V, E)$ we should find a shortest way from $v \in V$ to $v' \in V$ and make sure $\langle v = v_{i,0}, v_{i,1}, \dots, v_{i,m} = v' \rangle \in E$. And there is the famous algorithm called Dijkstra, or the Shortest Path Algorithm, fitting the condition of finding a shortest way from single start vertex to ending vertex in the graph stored in the adjacency matrix. So after the calculation before, here comes the 32*32 matrix stored with information of 32

relative countries on the 6 major routes with the weight explaining the difficulties of each path, but the Dijkstra algorithm can only find the single short way from one start point. The disadvantage of the original algorithm is explicit:

- 1) Dijkstra can only find the shortest way once.
- 2) Dijkstra algorithm can only define the start point , and the system tends to find all the shortest path to the remaining points.
- 3) Dijkstra is the algorithm mainly deal with the weight of each arc in the Graph.

For detailed explanation, if we use the original algorithm of Dijkstra, we will face much dilemma.

Let's suppose there's a refugee, he will find a shortest way, he knows the shortest walk to every other country, but he don't know the destination of his trip. So he will take the risk of shortest walking from Syria to Iraq, even worse situation.

Even if the shortest way is determined once ,that one guy says that from Turkey we take a train, then we take a Greek bus... at last the refugees all take the way to Germany, one million departure from Syria and one million land at Germany, it is ridiculous to see they just change their base.

Furthermore, is there any reason why the refugees choose Germany than other places? Is that because German is fine? But will it be fine after the flood of massive refugees? That's all what algorithm Dijkstra never told us, and we should form a better solution

6.4 The Unstoppable Refugee Algorithm

6.4.1 Factor introduction

So if we are to deal with the refugee problem , we should advance the algorithm based on the actual condition, including the refugee individuals, the countries situation, the current policy or other details. Then we summarize the following factors:

- 1) The total resource capacity: C_i

It is the single measurement of the capacity of the nation.

$$C_i = k_i Pl_i G_i$$

- 2) The political factor Pl_i , related to the economy increment/decrement percentage

factor E_{mi} and the government attitude factor ρ_i , basic attitude factor ρ_i , and

control factor k_{mi}, k_p matching the realtime database.

$$Pl_i = \left(\frac{\sum E_{mi}}{n_i} + k_{mi} E_{mi} \right) (B_p + \rho_i) k_p$$

- 3) The staying cost st_i , for the settlement cost of the refugee and the resource

consummation of the country. Related to the total GDP G_i , population n_p , and

inflation rate factor η_p

$$st_i = \frac{G_i}{n_{pi}} \times (1 - \eta_p) k_{g1} + \frac{\sum \frac{G_i}{n_p}}{n_t} k_{g2}$$

4) The passing cost pt_i , for the temporary stay cost in the nation, related to daily

supplement cost c_i and average retention days $\overline{d_i}$,

$$pt_i = c_i \overline{d_i}$$

6.4.2 Detailed description of URA

Then we can summarize the array list of 32 countries by the Total Capacity, and give each vertex in Graph G their weight, so we upgrade the simplified network into a double-weight Graph $G(V, E)$, in which the weight $W_{i,j}$ of arc $\langle v_i, v_j \rangle \in E$

explains the difficulty level of the path while the weight C_i of vertex $v_i \in V$ explains the total capacity of this country.

And of course we know that the refugee can either stay in the country or just take the country as the transit station for other destination. But both the permanent settlement of the refugees and the temporary few-days stay will cause problems and will consume the limited resources in the country, and the difference is the degree of resource decreasing and potential disturbance.

So what we need to do is to determine a plan of refugee administration by which we can arrange most efficient refugees movement while settle more population, with reasonable utilization of the limited resource and tend to reduce the unfair of refugee assignment.

Under that condition, we discussed and give an advanced algorithm for the typical situation:

Take an assumption that there's one refugee individual were ready for departure, and he have the variety choices of destination, and he choose the country which owned the most total capacity value, and find the shortest path to the country, during his trip, he will travel through several other countries, and cause minor resource decrement to those countries, and finally he arrived to destination, which will pay a huge budget to support his living, and result in a major resource decrement to that country. Then the value of total capacity of the countries on his route decreased.

And for second, third, or the 10000th, they will do the same thing, the difference lies that if the most popular country's total capacity fell so fast that it owns no more the most capacity, it will not be chosen, but still has the possibility to be the 'service station' in which refugees may go through.

If one country's max capacity reached, the country will not support any more refugees

and will shut down the boundary. So the path through the country will not be available any more.

For thousands of thousands of choice done, until there is no path to go, there will be one talented custom officer—of course the computer will suit that job—who will report a huge statistic list of how many refugees settled and how many just travel through in specific country. And that should be the most reasonable and efficient route choice.

So we summarized the algorithm in the followings:

- 1) Define a Graph $G(V, E)$, with the weighted adjacency matrix of paths named $\text{arc}[i][j]$ stands for all paths information between 32 countries and valued vertex array list $\text{max}[i]$ stands for capacity initialized. In this condition, $i=j=32$.
- 2) Define the start vertex and set the value of vertex to 0, means no capacity in the country, they are the refugee source—Syria, Iraq, Morocco, Lybia, etc.
- 3) Choose the start point v_0 based on the population percentage of refugees in route start position, according to 2015 statistic database. Choose the vertex that has the most capacity value to be the end point v'
- 4) Find a shortest path from v_0 to v' , the path should have several mid points $v = v_i, \dots \in V$, or no mid points. For the mid points, the capacity value subtract the cost of pass-by: $C_{\text{new}} = C_i - pt_i, C_i = C_{\text{new}}$. For the final point $v = v'$, $C_{\text{new}} = C_i - st_i, C_i = C_{\text{new}}$, in which st_i stands for stay cost. And $D_v = \sum W$, recording the total path length. Record the settlement and passenger-by number.
- 5) If $C_i \leq 0$, $\text{arc}[i][x] = \text{arc}[x][i] = \infty$, means the max capacity of country(i) reached, and the country must shut down the boundary.
- 6) Redo process(2),(3), (4), (5), if $D_v = \infty$ or for all possible integer i , $C_i \leq 0$, break and print all static. Means the model reached its maximum capacity.

7 Result and Dynamics Assessment

7.1 The dynamic URA

The algorithm is based on dynamic situation, and the destination will change based on the remaining capacity of the specific nation, so the result is dynamic when the population and the destination changes

If we take the test of 500,000 refugees under the condition of 2015 economy situation and suppose that no special government action were to take due to the accidents, we can see that the refugees tends to choose the developed western European countries when the resources are abundant and the population are not too large to cause crisis.

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The Visa Officer give out the report:
on condition of : 500000 refugees flood into Europe
Afghanistan : refugee pass-hy: 0 refugee settlement: 0
Syria : refugee pass-hy: 0 refugee settlement: 0
Turkey : refugee pass-hy: 0 refugee settlement: 0
Greece : refugee pass-hy: 0 refugee settlement: 0
Albania : refugee pass-hy: 0 refugee settlement: 0
Macedon : refugee pass-hy: 0 refugee settlement: 0
Bulgalia : refugee pass-hy: 0 refugee settlement: 0
Romania : refugee pass-hy: 0 refugee settlement: 0
Serbia : refugee pass-hy: 0 refugee settlement: 0
Hessen : refugee pass-hy: 0 refugee settlement: 0
Posenia : refugee pass-hy: 500000 refugee settlement: 0
Croatia : refugee pass-hy: 500000 refugee settlement: 0
Hungary : refugee pass-hy: 0 refugee settlement: 0
Austria : refugee pass-hy: 500000 refugee settlement: 0
Ukraine : refugee pass-hy: 0 refugee settlement: 0
Slovakia : refugee pass-hy: 0 refugee settlement: 0
Czech : refugee pass-hy: 0 refugee settlement: 0
Poland : refugee pass-hy: 0 refugee settlement: 0
Germany : refugee pass-hy: 250707 refugee settlement: 206562
France : refugee pass-hy: 73248 refugee settlement: 192593
Spain : refugee pass-hy: 0 refugee settlement: 36704
Morroco : refugee pass-hy: 0 refugee settlement: 0
Italy : refugee pass-hy: 0 refugee settlement: 42731
Libya : refugee pass-hy: 0 refugee settlement: 0
England : refugee pass-hy: 0 refugee settlement: 36544
Denmark : refugee pass-hy: 4709 refugee settlement: 0
Norway : refugee pass-hy: 0 refugee settlement: 0
Sweden : refugee pass-hy: 0 refugee settlement: 4709
Finland : refugee pass-hy: 0 refugee settlement: 0
Russia : refugee pass-hy: 0 refugee settlement: 0
Belgium : refugee pass-hy: 202041 refugee settlement: 1634
Netherland : refugee pass-hy: 0 refugee settlement: 41523
total refugees : 500000

Process returned 0 (0x0) execution time : 15.082 s
Press any key to continue.

```

When the population grows to 1,000,000, the Developed countries, like Germany, France, were too crowded to live, and the resource, described as the factor of “Total Capacity” were reduced sharply, and the refugees turned to seek fortune in north Europe—where the distance, or saying, the weight of path leads to difficulties but the optimistic policies still cause addition to the total capacity of nation, we can see from the result that the population settled in Germany rise a bit from 206,562 to 250,333, but those in the three northern kingdom—Norway, Sweden and Denmark take a sharp rise from 0 0 4,789 to 16,573 33,972 and 47,055

So we can see the dynamic fitness is to our content.

```

The Visa Officer give out the report:
on condition of : 1000000 refugees flood into Europe
Afghanistan : refugee pass-hy: 0 refugee settlement: 0
Syria : refugee pass-hy: 0 refugee settlement: 0
Turkey : refugee pass-hy: 13078 refugee settlement: 15001
Greece : refugee pass-hy: 28079 refugee settlement: 0
Albania : refugee pass-hy: 28079 refugee settlement: 0
Macedon : refugee pass-hy: 0 refugee settlement: 0
Bulgalia : refugee pass-hy: 0 refugee settlement: 0
Romania : refugee pass-hy: 0 refugee settlement: 0
Serbia : refugee pass-hy: 0 refugee settlement: 0
Hessen : refugee pass-hy: 28079 refugee settlement: 0
Croatia : refugee pass-hy: 971921 refugee settlement: 0
Hungary : refugee pass-hy: 0 refugee settlement: 0
Austria : refugee pass-hy: 953200 refugee settlement: 18721
Ukraine : refugee pass-hy: 0 refugee settlement: 0
Slovakia : refugee pass-hy: 0 refugee settlement: 0
Czech : refugee pass-hy: 0 refugee settlement: 0
Poland : refugee pass-hy: 0 refugee settlement: 34559
Germany : refugee pass-hy: 613495 refugee settlement: 250333
France : refugee pass-hy: 165520 refugee settlement: 174648
Spain : refugee pass-hy: 0 refugee settlement: 84454
Morroco : refugee pass-hy: 0 refugee settlement: 0
Italy : refugee pass-hy: 0 refugee settlement: 89772
Libya : refugee pass-hy: 0 refugee settlement: 0
England : refugee pass-hy: 0 refugee settlement: 81066
Denmark : refugee pass-hy: 91453 refugee settlement: 16573
Norway : refugee pass-hy: 10426 refugee settlement: 33972
Sweden : refugee pass-hy: 0 refugee settlement: 47055
Finland : refugee pass-hy: 0 refugee settlement: 10426
Russia : refugee pass-hy: 0 refugee settlement: 13078
Belgium : refugee pass-hy: 340168 refugee settlement: 45732
Netherland : refugee pass-hy: 0 refugee settlement: 85010
total refugees : 1000000

Process returned 0 (0x0) execution time : 26.888 s
Press any key to continue.

```

7.2 NGO effects

7.2.1 The positive NGO provocation

We suppose that there is an association of charity in Poland, according to the equation

$C_i = k_i P_i G_i$ provided before, the factor $k_{i\text{new}} = k_i \times (1 - \alpha)$ changed due to the

additional social welfare provided by individuals and thus led to the growing C_i , let's see

the result and we can notice that the population in Poland grow from 34,559 to 75637

7.2.2 The negative NGO provocation

Let's assume there is a group of new nationalism in Germany that take extreme actions towards people from middle east, and therefore the factor $k_{inew} = k_i \times (1 - \alpha)$, the same way we notice that the population settled in Germany drop from 250,333 to 162,088 and cause even more pressure in the neighboring countries

```

The Visa Officer give out the report:
on condition of : 1000000 refugees flood into Europe
Afghanistan : refugee pass-hy: 0 refugee settlement: 0
Syria : refugee pass-hy: 0 refugee settlement: 0
Turkey : refugee pass-hy: 9706 refugee settlement: 11633
Greece : refugee pass-hy: 21339 refugee settlement: 0
Albania : refugee pass-hy: 21339 refugee settlement: 0
Macedon : refugee pass-hy: 0 refugee settlement: 0
Bulgaria : refugee pass-hy: 0 refugee settlement: 0
Romania : refugee pass-hy: 0 refugee settlement: 0
Serbia : refugee pass-hy: 0 refugee settlement: 0
Hessen : refugee pass-hy: 21339 refugee settlement: 0
Posenia : refugee pass-hy: 97861 refugee settlement: 0
Croatia : refugee pass-hy: 97861 refugee settlement: 0
Hungary : refugee pass-hy: 0 refugee settlement: 0
Austria : refugee pass-hy: 962810 refugee settlement: 15851
Ukraine : refugee pass-hy: 0 refugee settlement: 0
Slovakia : refugee pass-hy: 0 refugee settlement: 0
Czech : refugee pass-hy: 0 refugee settlement: 0
Poland : refugee pass-hy: 0 refugee settlement: 75637
Germany : refugee pass-hy: 629073 refugee settlement: 247416
France : refugee pass-hy: 159483 refugee settlement: 171700
Spain : refugee pass-hy: 0 refugee settlement: 81330
Morocco : refugee pass-hy: 0 refugee settlement: 0
Italy : refugee pass-hy: 0 refugee settlement: 0
Libya : refugee pass-hy: 0 refugee settlement: 0
Denmark : refugee pass-hy: 83404 refugee settlement: 13838
Norway : refugee pass-hy: 7555 refugee settlement: 31565
Sweden : refugee pass-hy: 0 refugee settlement: 44284
Finland : refugee pass-hy: 0 refugee settlement: 7555
Russia : refugee pass-hy: 0 refugee settlement: 9706
Belgium : refugee pass-hy: 331183 refugee settlement: 42847
Netherlands : refugee pass-hy: 0 refugee settlement: 82164
total refugees : 1000000
Process returned 0 (0x0) execution time : 27.548 s

```

```

The Visa Officer give out the report:
on condition of : 1000000 refugees flood into Europe
Afghanistan : refugee pass-hy: 0 refugee settlement: 0
Syria : refugee pass-hy: 0 refugee settlement: 0
Turkey : refugee pass-hy: 19284 refugee settlement: 21282
Greece : refugee pass-hy: 40485 refugee settlement: 1477
Albania : refugee pass-hy: 41963 refugee settlement: 0
Macedon : refugee pass-hy: 0 refugee settlement: 0
Bulgaria : refugee pass-hy: 0 refugee settlement: 0
Romania : refugee pass-hy: 0 refugee settlement: 4715
Serbia : refugee pass-hy: 0 refugee settlement: 0
Hessen : refugee pass-hy: 41963 refugee settlement: 0
Posenia : refugee pass-hy: 952891 refugee settlement: 0
Croatia : refugee pass-hy: 952891 refugee settlement: 0
Hungary : refugee pass-hy: 4715 refugee settlement: 431
Austria : refugee pass-hy: 928878 refugee settlement: 24013
Ukraine : refugee pass-hy: 0 refugee settlement: 0
Slovakia : refugee pass-hy: 0 refugee settlement: 0
Czech : refugee pass-hy: 0 refugee settlement: 4681
Poland : refugee pass-hy: 0 refugee settlement: 48728
Germany : refugee pass-hy: 666400 refugee settlement: 162688
France : refugee pass-hy: 176633 refugee settlement: 180074
Spain : refugee pass-hy: 0 refugee settlement: 90205
Morocco : refugee pass-hy: 0 refugee settlement: 0
Italy : refugee pass-hy: 0 refugee settlement: 94989
Libya : refugee pass-hy: 0 refugee settlement: 0
Denmark : refugee pass-hy: 0 refugee settlement: 86428
Norway : refugee pass-hy: 106268 refugee settlement: 21607
Sweden : refugee pass-hy: 15711 refugee settlement: 38482
Finland : refugee pass-hy: 0 refugee settlement: 52155
Russia : refugee pass-hy: 0 refugee settlement: 15711
Belgium : refugee pass-hy: 0 refugee settlement: 19284
Netherlands : refugee pass-hy: 356707 refugee settlement: 51043
total refugees : 1000000

```

Positive NGO provocation

Negative NGO provocation

7.3 the Exogenous events

Let's assume that there is a terrorist attack in Madrid, and the France government was forced to shut down the boundary so the access to Spain was no more.

```

on condition of : 1000000 refugees flood into Europe
Afghanistan : refugee pass-hy: 0 refugee settlement: 0
Syria : refugee pass-hy: 0 refugee settlement: 0
Turkey : refugee pass-hy: 19094 refugee settlement: 21013
Greece : refugee pass-hy: 40107 refugee settlement: 1296
Albania : refugee pass-hy: 41403 refugee settlement: 0
Macedon : refugee pass-hy: 0 refugee settlement: 0
Bulgaria : refugee pass-hy: 0 refugee settlement: 0
Romania : refugee pass-hy: 0 refugee settlement: 4523
Serbia : refugee pass-hy: 0 refugee settlement: 0
Hessen : refugee pass-hy: 41403 refugee settlement: 0
Posenia : refugee pass-hy: 953831 refugee settlement: 0
Croatia : refugee pass-hy: 953831 refugee settlement: 0
Hungary : refugee pass-hy: 4523 refugee settlement: 243
Austria : refugee pass-hy: 929980 refugee settlement: 23851
Ukraine : refugee pass-hy: 0 refugee settlement: 0
Slovakia : refugee pass-hy: 0 refugee settlement: 0
Czech : refugee pass-hy: 0 refugee settlement: 4417
Poland : refugee pass-hy: 0 refugee settlement: 40540
Germany : refugee pass-hy: 575193 refugee settlement: 255552
France : refugee pass-hy: 86264 refugee settlement: 180032
Spain : refugee pass-hy: 0 refugee settlement: 0
Morocco : refugee pass-hy: 0 refugee settlement: 0
Italy : refugee pass-hy: 0 refugee settlement: 94818
Libya : refugee pass-hy: 0 refugee settlement: 0
Denmark : refugee pass-hy: 105815 refugee settlement: 21453
Norway : refugee pass-hy: 15549 refugee settlement: 38267
Sweden : refugee pass-hy: 0 refugee settlement: 51999
Finland : refugee pass-hy: 0 refugee settlement: 15549
Russia : refugee pass-hy: 0 refugee settlement: 19094
Belgium : refugee pass-hy: 266296 refugee settlement: 51002
Netherlands : refugee pass-hy: 0 refugee settlement: 90087
total refugees : 1000000

```

According to the given function before, and the relatively total political factor PI_i will

take a sharp shift due to the change of ρ_i , also, the difficulty level of path connected to Spain were turned into infinity.

$$Pl_i = \left(\frac{\sum E_{mi}}{n_i} + k_{mi} E_{mi} \right) (B_p + \rho_i) k_p$$

And let's see what if the terrorist attack Roma, and forced Italy to close the boundary:

Afghanistan	: refugee pass-by: 0	refugee settlement: 0
Syria	: refugee pass-by: 0	refugee settlement: 0
Turkey	: refugee pass-by: 19413	refugee settlement: 21330
Greece	: refugee pass-by: 40743	refugee settlement: 1601
Albania	: refugee pass-by: 42344	refugee settlement: 0
Macedon	: refugee pass-by: 0	refugee settlement: 0
Bulgaria	: refugee pass-by: 0	refugee settlement: 0
Romania	: refugee pass-by: 0	refugee settlement: 4846
Serbia	: refugee pass-by: 0	refugee settlement: 0
Hessen	: refugee pass-by: 42344	refugee settlement: 0
Posenia	: refugee pass-by: 952251	refugee settlement: 0
Crotia	: refugee pass-by: 952251	refugee settlement: 0
Hungary	: refugee pass-by: 4846	refugee settlement: 559
Austria	: refugee pass-by: 928128	refugee settlement: 24123
Ukraine	: refugee pass-by: 0	refugee settlement: 0
Slovakia	: refugee pass-by: 0	refugee settlement: 0
Czech	: refugee pass-by: 0	refugee settlement: 4726
Poland	: refugee pass-by: 0	refugee settlement: 40856
Germany	: refugee pass-by: 667701	refugee settlement: 255701
France	: refugee pass-by: 176863	refugee settlement: 180187
Spain	: refugee pass-by: 0	refugee settlement: 90324
Morocco	: refugee pass-by: 0	refugee settlement: 0
Italy	: refugee pass-by: 0	refugee settlement: 0
Libya	: refugee pass-by: 0	refugee settlement: 0
England	: refugee pass-by: 0	refugee settlement: 86539
Denmark	: refugee pass-by: 106575	refugee settlement: 21711
Norway	: refugee pass-by: 15820	refugee settlement: 38494
Sweden	: refugee pass-by: 0	refugee settlement: 52261
Finland	: refugee pass-by: 0	refugee settlement: 15820
Russia	: refugee pass-by: 0	refugee settlement: 19413
Belgium	: refugee pass-by: 357050	refugee settlement: 51153
Netherlands	: refugee pass-by: 0	refugee settlement: 90356
total refugees : 1000000		

So we may see, the final settlement of the refugees were effected but not so severe, but the flood of pass-by refugees grows sharply in neighboring countries.

7.4 Result and assessment

From the result we can see that this model works well in dynamic situation, and fits the real situation well, thus we can provide normal policies to the refugees.

8 Policies

8.1 Custom In-and-Out Controls

According to the model result, the country of Greece, Albania, Hessen, Posenia, Crotia, Hungary, Austria will face a potential crisis of refugee temporary stay-in, and the country of Germany, France, Italy, Belgium and Netherlands will face a potential crisis of refugee settlement, so the best custom in-and-out policy should be:

- 1) Greece, Albania, Hessen, Posenia, Crotia, Hungary, Austria should set more entries nationwide to prevent the country from mass population retention.
- 2) Germany, France, Italy, Belgium and Netherlands should turn down the budget of refugee settlement to prevent the country from exogenous events.

8.2 Normal Policies

8.2.1 Total Introduction

As for policy: Social welfare system, analyzing principles of economics, can lead to instability in national political circumstance and make the far-right who oppose to immigration and accepting refugees rise suddenly in European countries. This is a good chance for them to delude the lower class people. Once they win the victory, it will be more difficult for refugees to flow to Europe. And the corresponding parameter will change and we will add new parameters to evaluate the influence that immigration policy has on the index of refugee crisis. If European countries make the refugee policy tighter, the refugee crisis will become more severe.

Environmental factors change with time, the environmental factors that we consider most are government's continuously change refugee policy, foundation, terroristic organization, and whether residents ostracize refugees or not.

8.2.2 Resource arrangement in advance

- 1) Transportation equipment, because countries should move refugees who meet the requirements of applying to shelter, it needs to prepare transportation equipment in advance. Transportation equipment should be allocated dynamically and flexibly according to these.
- 2) Daily necessities, these elementary daily necessities should be prepared in advance to guarantee that refugees could live a normal life in initial stage.
- 3) Refugee accommodation, there should be houses prepared in advance for refugee accommodation, complete infrastructure and corresponding plan in the area that government plot out for refugees' living; these accommodation resources cannot be allocated dynamically according to the dynamic elements mentioned before.
- 4) Administrators. To guarantee that refugee area could operate normally, corresponding administrators should be prepared in advance; administrators can be allocated dynamically according to the dynamic elements mentioned before.
- 5) Medical treatment. Health care system for refugees includes medical equipment, medical staff; to a certain extent, some aspects like medical equipment and medical staff can be allocated dynamically according to the dynamic elements mentioned before.
- 6) Security measures. Deploying the police in advance to guarantee refugees' normal life and try to have little influence on residents' life; the police and corresponding security equipment can be allocated dynamically according to the dynamic elements mentioned before.
- 7) Educational resources. The corresponding educational resources for refugees can be deployed in advance; educators and educational facilities can be allocated dynamically according to the dynamic elements mentioned before.

8.2.3 Resources that should be given top priority

Daily necessities, refugees' living area, and then medical treatment, security measures and administrators.

8.3 Government and NGO

Government organization should take the responsibility of helping refugees. Every aspect of resources should be undertaken mainly by government. Government should also guarantee that the refugee have the basic life security. And every aspect of administrators' deploying should be undertaken by government.

Non-government agencies mainly consider some foundations in society, such as European refugee fund, this kind of organizations can help government organizations ease refugee crisis. And some bad organizations, such as terrorist organizations, this kind of organizations can make refugee crisis more severe. The role that non-government agencies should play is warming refugees' heart, let refugees feel the warmth given by the world, and mend refugees' broken heart. These organizations can elevate refugees' living standards, but the resources brought by these organizations are limited, they could only assist the government. Other malevolent non-government agencies may do harm to the refugee and influence local policy, for example, terrorists mingle in the refugee, and then malevolently cause damage to local society, and it can make local government reduce the number of accepted refugees and other measures like this.

Because we only think about the six routes that given in the question originally, we do not consider other destinations, if original model do not work in these regions, our model also can work in these regions when the situation is simple and satisfies our requirements after slightly changing some corresponding parameters and these countries' refugee policy. But factors like the routes' changing, the distance's extending and these regions' refugee policy, social welfare, non-government agencies all could lower refugees' desire of integration. Besides, long distance, various means of transportation and variety of routes, our model need further improvement, and it will be more complicate. Our model could only consider some relevant unitary circumstances, so it can have slight effect. We hope this model could give some inspiration and help to other scholars who want to make a further investigation in this field.

8.4 Policy to support refugee model and integration pattern

- 1) According to past annual average cost of the refugee, every country makes a new budget of annual average cost of one refugee, and takes account of each country's actual financial situation to make corresponding budget. Let x denote the number of euro each country provides to each refugee, let w denote the number of euro that budget containing, then the number of accepted refugees is $n = \lfloor w/x \rfloor$, this is Gauss integral, and then provide refugees the money. This is the basic cost to resettle refugees and it is also refugees' survival guarantee.
- 2) Six airlines still work as their former model to achieve optimum integration pattern; besides, pick up the speed of handling refugee affairs, simplify procedures, remind those refugees who will be repatriated in time, so that they can migrate to other country that still accept refugees.
- 3) Establish a sound system of refugee asylum applications to maintain countries' security system and public order. And each country should send enough means of transportation corresponding to the number of refugees accepted to guarantee the efficiency of integration.
- 4) Government should plot out the area that refugees could live, and refugee should live in the refugee shelter established by government. And it is suggested that refugee shelter has models divided by family and gender, if the quantities of refugee are too large, it also can form a supply system and manage system.

- 5) Establish a health care system for refugees. Since most refugees come from North Africa or West Asia, it is necessary to do health examination for refugees to prevent from bringing infectious diseases to its country.
- 6) As to religion, if refugees' religion conflicts with residents', those refugees should be repatriated to avoid unnecessary conflict, loss and injury.
- 7) To help refugees integrate into local society, it is necessary to set up corresponding and different levels of education and other training. Since having the ability of doing normal language communication is the first need for individuals to integrate into local society, local language is the most important. And it needs policy to let refugees make a living after a certain period of time. Immigration policy is corresponding to this, improving and completing corresponding immigration policy, making refugees acquire the requisite living skills after training. And let refugees who have the ability and satisfy its immigration requirements migrate, transforming refugees into member of nation, it not only can enhance the comprehensive national strength, perfuse vitality to the nation, but also accept new refugees to ease refugee crisis.
- 8) Country should recruit more people for those departments dealing with refugee crisis to guarantee the operation efficiency.
- 9) Establish refugee fingerprint identification system, establish common information retrieval system for information transmission and sharing and agree to manage refugees' application. It can be convenient to compare the number of refugees' application.
- 10) Launch a refugee fund and call on caring community to help refugees. Form a refugee assistance system to reduce national fiscal spending.
- 11) Let EU countries make relative unified primary refugee policy.
- 12) Use consistent ways and methods inspect the common borders of member states to maintain the security and stability of borders. Meanwhile, every country's police cooperate closely to combat illegal immigration.
- 13) Provide measures and methods to prevent crimes for each other, enhance propaganda, and educate refugees about this. Generally, refugees will appreciate it, and crime rates and success rates of crime will reduce greatly with effective preventive measures and sound security system.

9 References

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10 Appendix



Figure 1

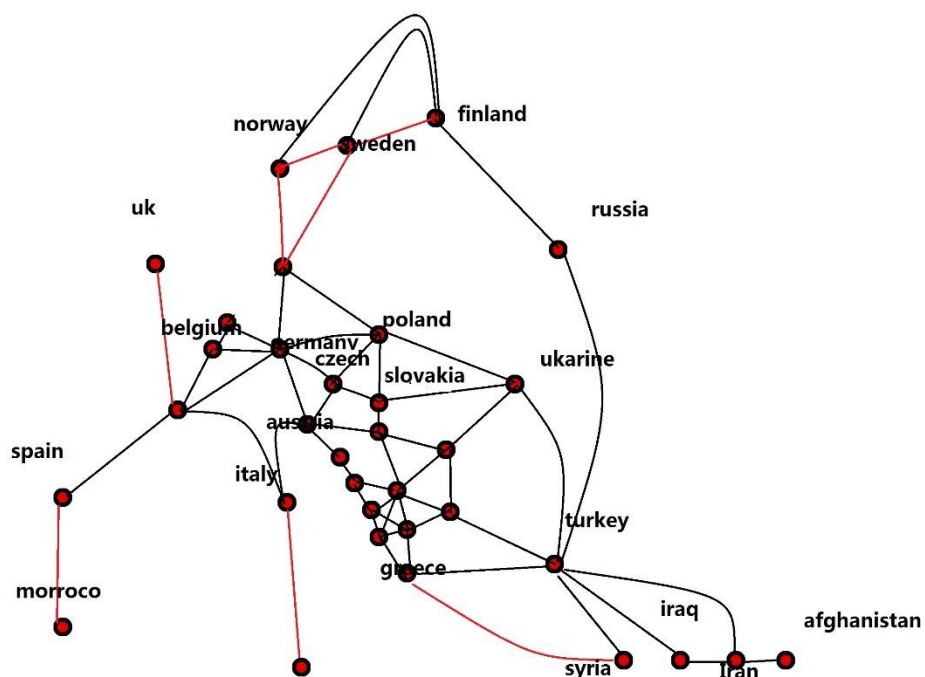
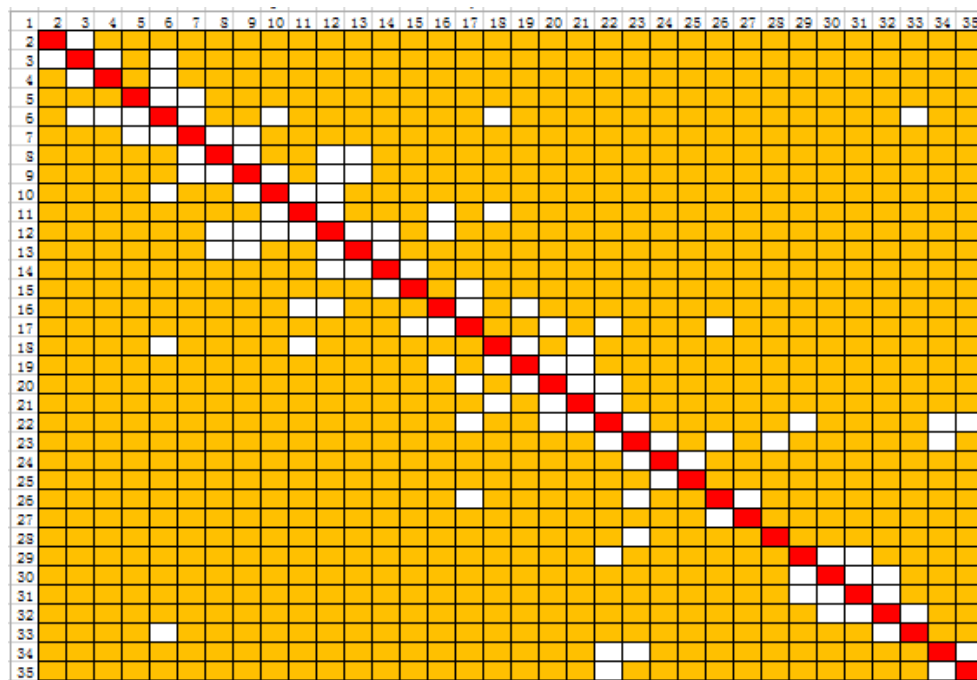


Figure2



Figure 3

**Figure 4**