Catch Them Coming and Going: Probabilistic Pathway Projection to Counter Foreign Fighters

Final Research Report

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About This Report

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About START

The National Consortium for the Study of Terrorism and Responses to Terrorism (START) is supported in part by the Science and Technology Directorate of the U.S. Department of Homeland Security through a Center of Excellence program led by the University of Maryland. START uses state-of-the-art theories, methods and data from the social and behavioral sciences to improve understanding of the origins, dynamics and social and psychological impacts of terrorism. For more information, contact START at infostart@start.umd.edu or visit www.start.umd.edu.

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Project Background and Introduction

The Analysis and Production (A) Division of the National Geospatial Intelligence Agency (NGA) identified a requirement for an assessment of the possible transportation corridors used by foreign fighters when traveling to and from Islamic State of Iraq and Levant (ISIL), specifically focusing on transportation networks in Europe, North Africa, and the Levant. As part of this effort, START completed qualitative and quantitative research to assess the risk and the threats posed by foreign fighters in regards to international violence and influence. START also conducted geospatial transportation analyses to identify possible and most probable routes that could potentially support both licit and illicit movement of foreign fighters as well as modes of transport that could be used in such activities.

START used methods and analysis from the Transnational Illicit Trafficking (TransIT) tool[1] to create a subset of the larger model for the specific purpose of developing a scientifically grounded methodology for identifying the most likely routes of foreign fighters into and out of conflict zones. The complexity of the multi-modal network is specifically designed to model all likely modalities used by a foreign fighter. The tool includes detailed modeling of illicit pathways known to be used by foreign fighters as well as a traditional licit means of routing. START's analysis used Dijkstra's algorithm in ArcGIS's Network Analyst to determine optimal routes for traveling throughout the study area.

The unexpected flood of refugees and economic migrants into Europe and the subsequent introduction of security measures created a significant alteration to our initial analysis plan. This has been accounted for in START's analysis by running a baseline analysis prior to the introduction of border measures as a control test and running analysis with these measures in place to show potential deviation in route planning. The analysis incorporates the added complexity of increased security measures in Europe and integrates the rampant human trafficking between Turkey and Greek islands in the Aegean.

The following report provides a methodology and analysis of transit between Europe and ISIL-held territory. START examines modeled routes originating in Europe and ending in Syria and Iraq and vice versa. Assessing the likelihood of a chosen route requires a consideration of the interaction between time, speed, and choice of modality. The selection of specific routes by the potential foreign fighters is a product of both the shortest path distance between two nodes and a number of potential costs and benefits associated with a traversed route.

This report begins with an analytic methodology describing the methods used to compile, construct, and run the model. The Data section describes the data sources, various networks, and weights in detail. The

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[1] The TransIT Tool was originally designed for the TCOTRN Project, a similar study to the current study conducted in the Central and South American regions, in 2012. Please refer to Behlendorf, Brandon. *Geospatial Modeling of Potential Routes for RN Trafficking: Central America and the Caribbean Basin.* Interim Report to the Domestic Nuclear Detection Office. College Park, MD: START, 2012, for more detail on the origin of the TransIT Tool and TCOTRN specific route analysis.

Analysis and Results section provides a comprehensive investigation of the model's results under differing parameters. The section on Research Opportunities provides an overview of potential growth of the project.

Analytical Methodology

In order to analyze probable routes for foreign fighters entering ISIL-controlled territory, we use an algorithm originally developed by Dijkstra[2] with custom parameters. This algorithm is applied to a multi-modal transportation network to generate probable routes to and from ISIL-controlled territory. The integrated multi-modal transportation network across the study region is a bidirectional graph that consists of a set of vertices and edges. The total network consists of over 1.4 million edges, 100 points in Europe and North Africa, and 100 points located near or within ISIL-controlled areas. The points in Europe and North Africa consist of major cities such as Brussels, Berlin, Copenhagen, Paris, London, Budapest, Milan, Casablanca, Stockholm, and Tunis. Of the 100 points located near or in ISIL-controlled area, 52 of them were randomly generated, while the other 48 were cities of interest such as Ramadi, Tikrit, Al Fallujah, Kirkuk, Mosul, Ar Raqqah, Tamdur, Abu Kamal, Aleppo, and Damascus.

If foreign fighters want to minimize risk when traveling to or from ISIL-controlled areas, the baseline assumption of this model is that they will choose the least cost path from an origin point in Europe to an ISIL-controlled destination (or vice versa). The unweighted cost variable, speed, is applied to the edges in order to weight the graph. The weighted cost variable is a function of time (derived from distance and speed) and risk. A potential foreign fighter will prefer to take the shortest pathway with the lowest amount of risk. To this end, the model is a simple function of distance (measured in time to traverse a segment) weighted by the costs and incentives discussed below.

Data

START began by creating a conventional licit transportation network for the Europe, North Africa, and Levant regions. The licit network includes primary modes of transportation used by individuals when travelling domestically or internationally across the study region. These modes of transportation include roadways, rail lines, air lines, and maritime ferry routes. The network then adds on an illicit mode of transportation that individuals could exploit to avoid detection when travelling to or from the Islamic State operational areas. This primarily focuses on maritime routes used by both migrants and foreign fighters exiting the Turkish mainland via the Aegean Sea in hopes of seeking asylum in the European Union.

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[2] Dijkstra, E.W. "A Note on Two Problems in Connexion with Graphs." Numerische Mathematik http://www-m3.ma.tum.de/foswiki/pub/MN0506/WebHome/dijkstra.pdf (accessed November 19, 2014)

Building Transportation Networks

Aerial Network

START collected the flight information from the Federal Aviation Administration's (FAA) Flight Database.[3] The data includes all flights for a single month as START recognizes that commercial airline carriers fly on regular schedules that repeat daily, weekly, and monthly. This data is not comprehensive but represents a substantial number of routes (fig. 1) providing an acceptable representative model for both commercial and civil (corporate jets) aviation. In addition to the airline flight data, the origin and destination airport locations were also derived from the FAA dataset.

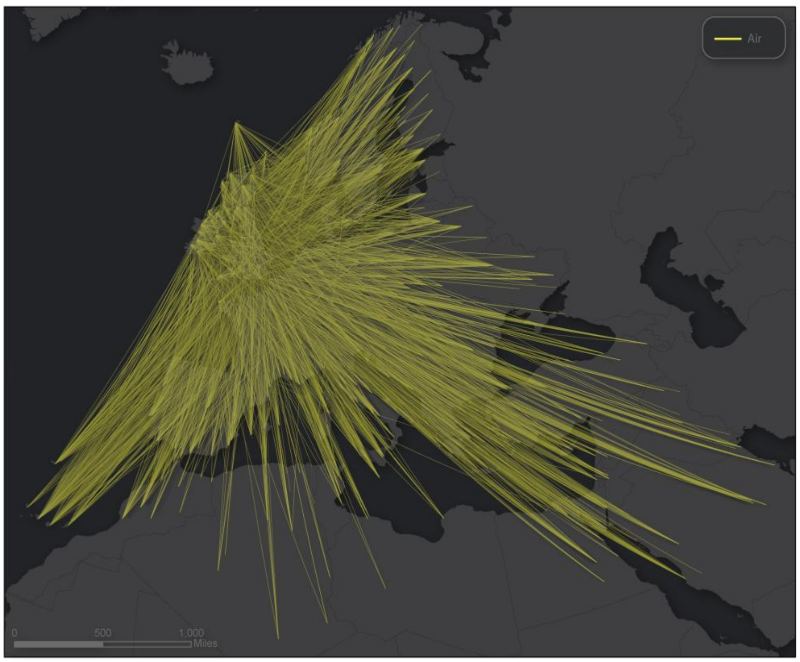

Fig. 1 Aerial Network

Land Network

Roadways

The road network (fig. 2) is comprised of highway, primary, secondary, tertiary, local/urban, trail, and unspecified roads derived from an open source global roads file provided by the National Aeronautics and Space Administration (NASA) Socioeconomic Data and Applications Center (SEDAC).[4] Although this dataset lacks directional attributes and Z elevation usually found in the network models of city-level transportation planning, considering the regional-level focus of the model, the absence of these elements

[3] National Transportation Atlas Database 2011, Bureau of Transportation Statistics, Office of the Assistant Secretary for Research and Technology.

[4] Center for International Earth Science Information Network - CIESIN - Columbia University, United Nations Food and Agriculture Programme - FAO, and Centro Internacional de Agricultura Tropical - CIAT. 2005. Gridded Population of the World, Version 3 (GPWv3): Population Count Grid. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://dx.doi.org/10.7927/H4639MPP.

did not alter the final results of the model.[5] Lastly, roads classified as "unspecified," "local/urban," and "trail" were reclassified and weighted as tertiary road segments, because the speed limit of these roads normally correlates to tertiary roads.

Fig. 2 Roadway Network

Rail Network

The rail network (fig. 3) is a composite of two data sources. There are no comprehensive datasets of railways throughout the world or the study area. As such, START utilized both OpenStreepMap[6] and EuroGraphics[7] datasets to create a model of rail travel in the study area. Due to differences in gauge, exposure to conflict, lack of funding, age of rail lines, and consistent loss of valuable construction materials to thieves, large swaths of the study region in northern Africa lack integrated rail infrastructure.[8]

[5] This model serves as a proof of concept that it is possible to create a multimodal network to investigate flows of people over vast distances. The lack topological accuracy is an issue at the local level, particularly in Europe where overpasses, underpasses, and unidirectional streets are common.
[6] OpenStreetMap contributors. Openstreetmap.org
[7] EuroRegionalMap v.8. EuroGraphics. http://www.eurogeographics.org/products-and-services/euroregionalmap
[8] Collier, Paul, and James Cust. "Investing in Africa's infrastructure: Financing and policy options." Annu. Rev. Resour. Econ. 7, no. 1 (2015): 473-493.

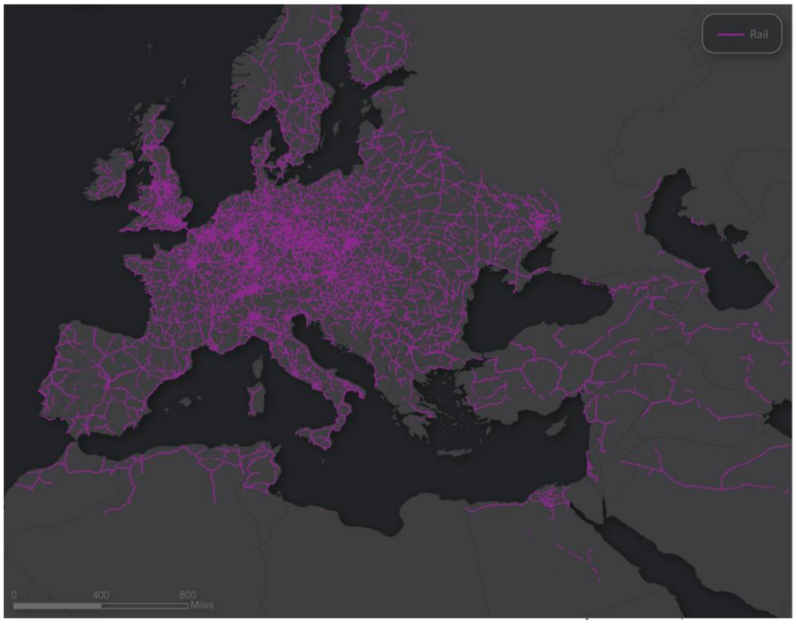

Fig. 3 Rail Network

Maritime Network

The ferry network (fig. 4) is a composite of two data sources. START utilized both EuroGraphics[9] and hand-digitized ferry routes derived from GoogleMaps. EuroGraphics data provides extensive routes for ferry traffic between various European, North Africa, and Levant countries. Any routes that were missing from this dataset were supplemented with the Google Maps digitized routes in order to create a robust, comprehensive ferry network of the study region.

[9] EuroRegionalMap v.8. EuroGraphics. http://www.eurogeographics.org/products-and-services/euroregionalmap

Fig. 4 Ferry Network

Illicit Maritime

The illicit maritime network (fig. 5) is comprised of hand-digitized lines from Turkey to Greek islands known to be transited by migrants and foreign fighters entering Greece via Aegean Sea routes. Based off of UNHCR reports, these Greek islands are not recognized as official reception centers for migrants but have encountered a high volume of human traffic in 2015.[10] Once in the European Union, illicit transit routes (i.e., human trafficking) highly correlate to licit modes of transit.[11]

[10] UNHCR. Greece- Sea Arrivals 2015. Jan. 1, 2016. The UN Refugee Agency. http://data.unhcr.org/mediterranean/download.php?id=442

[11] Ruggiero, V. (2015). Organised crime in Europe and the mafia method. European Police Science and Research Bulletin, (13), 15-21. Harrison, David (2015). "Britain's modern slave trade," *Al Jazeera*.

Fig. 5 Illicit Maritime Network

Network Speeds

While obstacles to efficient transit across a transportation network can slow down travel, the transportation modes have inherent speeds governed by the capabilities and limitations of that particular mode. For the entire transportation network, speed in miles per hour (MPH) was calculated based on a review of available speeds for the various modes of transit used (table 1).[12] Once the speed is attributed to each mode of transportation, time is calculated in minutes for specific segments.

Mode of Transportation	*Speed (Mph)*
Highway Road	60
Primary Road	50
Secondary Road	40
Tertiary Road	20
Railroad	30
Airline	450
Ferry	25
Illicit Maritime	25

[12] Roads classified as Local/Urban, Trail, or Unspecified were all considered Tertiary for our purpose.

Intermodal Network Transitions

The NASA global roads dataset represents a highly accurate major roads dataset; however, it lacks the spatial accuracy to enable direct connection to other transportation networks. In order to account for this, connection lines were created using a nearest-distance function to ensure connectivity between roadways, rail stations, airports, ferry ports, and illicit maritime exit/entry points.

One important component of transition networks relevant to a network-based transportation model is the consideration of waiting times while transferring from one modality to another. Every transition between networks requires at least some period of time to adjust equipment, transfer to a new vehicle, or load/unload material. Each transition also increases the total time required to complete a route segment, providing important delays that could shift the selection of routes from one method of transportation to another. As not all waiting times between two modes of transit are equivalent, START constructed a table of stopping times between one mode and another based on a review of known waiting periods for various transition points (table 2). In essence, these periods act as a delayed barrier to a route, encouraging the selection of other routes that may have a longer distance but a shorter transition time. So, each connection line is attributed with a waiting time that represents the reality of the time it takes to transfer from one specific modality to the next.

Network Transition Connections	*Waiting Period*
Roads to International Airports	150 Minutes
Roads to Ferry Ports	30 Minutes
Roads to Rail Stations	30 Minutes
Roads to Illicit Maritime	0 Minutes

Table 2: Waiting periods between nodes

The network model was built with a compilation of segments from the aforementioned transportation networks and designed using endpoint connectivity to only allow transitions at the appropriate network nodes. Both roadways and railroad lines were planarized to ensure complete and comprehensive connectivity, and produce a thoroughly traversable network dataset.

Transportation Network Summary

The multiple modes of transportation, each with individual transit speeds and specific transition waiting periods, complete a substantial network model of the possible and most probable routes an individual would take when travelling to, or from, ISIL operational areas. The total network contains 1,488,582 line segments, 1,195,537 junction points between line segments, and millions of possible routes connecting origin points to destination points in the study area. Given the relative size of the network, one of the key considerations of this report is the identification of several "chokepoints" within the network dataset, for which the flow of potential foreign fighter routes is constrained to a small number of transportation hubs and corridors. As a result, investment of interdiction efforts or intelligence gathering at these locations could provide targeted gains in the ability to interdict foreign fighters travelling to and from the ISIL operational areas.

Areas of Operation

Modeling Group-Specific Route Preferences

With the completion of both the network of possible routes and the specific travel time costs or incentives to transport individuals via specific routes, the third component of this project focused on modeling the route preferences of ISIL fighters travelling throughout the study region. A number of factors were implemented into the model to serve as weights specific to ISIL foreign fighters that modify the route selection preferences of the algorithm. The possible effects of these factors are dichotomous – they either incentivize or discourage foreign fighters from taking certain routes or modalities.

Areas of Operation

One of the core influences in the selection of routes by foreign fighters traveling to ISIL-controlled territory is the operational area of ISIL itself and the operational areas of opposition forces in the region. Contests for control over specific routes suggest that the area where a group operates is directly tied to its use of that area's transportation infrastructure for transporting goods and/or people. A potential foreign fighter traveling to ISIL controlled area is going to avoid areas controlled by Kurdish or Iraqi Security Forces, and instead prefer to use areas directly controlled by ISIL to utilize existing transportation corridors and smuggling networks. To capture this dynamic, operational areas for the three main forces in the study region – ISIL, Kurdish, and Iraqi Security Forces – were digitized using data collected from the Institute for the Study of War.[13]

ISIL Area of Operation

Individuals attempting to travel to destinations within ISIL-controlled territory will prefer to travel through ISIL-controlled area (fig. 6), rather than areas controlled by opposition forces. This decreases their risk of capture. Drawing from both the operational area digitization and the network data, potential routes in ISIL controlled territory will be traversed twice as fast to simulate route preference.

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[13] Martin, Patrick, Emily Anagnostos, and Rachel Bessette. *Iraq Control of Terrain Map: February 9, 2016*. Feb. 9, 2016. Institute for the Study of War. http://iswresearch.blogspot.com/2016/02/iraq-control-of-terrain-map-february-9.html; Unknown Author. ISIS Sanctuary: January 29, 2016. Jan. 29, 2016. Institute for the Study of War. http://www.understandingwar.org/backgrounder/isis-sanctuary-january-29-2016

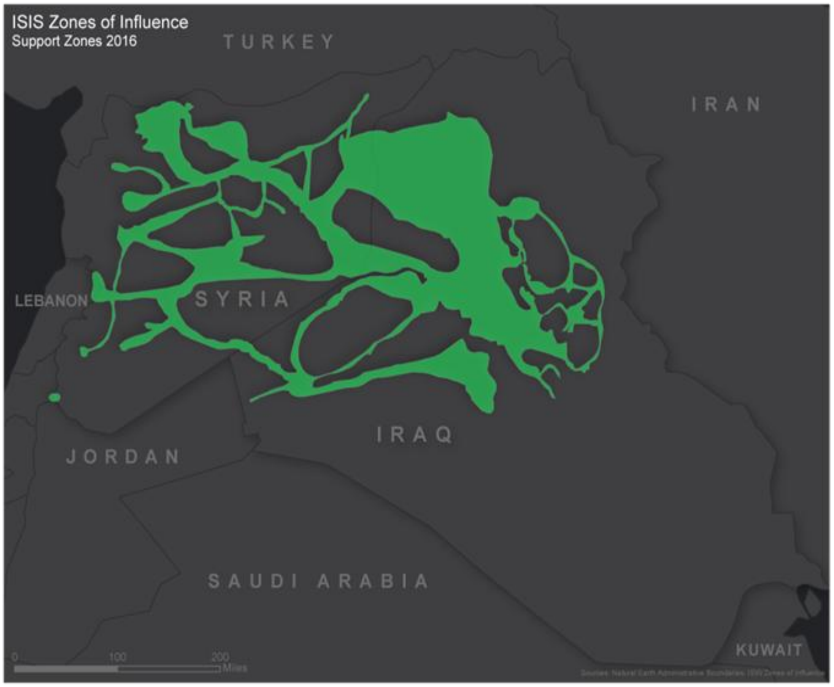

Fig. 6 ISIL Operational Areas

Opposition Force Area of Operation[14]

As ISIL territory is hypothesized to facilitate the transit of individuals to ISIL-controlled destinations, areas where opposition forces operate (fig. 7, fig. 8) would most likely increase the transit risk. To simulate this increased risk, routes traveling through opposition force controlled territory will be traversed at half the speed of an unbiased route.

[14] START did not include areas of operation for the Free Syrian Army or al-Nusra Front to simplify the model and show proof of concept.

Fig. 7 Kurdish Area of Operation

Fig. 8 ISF Area of Operation

Country Corruption

START hypothesizes that an ISIL foreign fighter would choose a route that has the highest combination of efficiency and likelihood of success. Efficiency of the route – the speed at which one can transit between the start and end point – is critical in regards to the route selection preferences, with the other critical criteria affecting route selection preference being likelihood of success. Like route efficiency, likelihood of success has an inverse relationship with likelihood of interdiction.

To accurately reflect a preference to select routes with highest efficiency as well as highest likelihood of success, the research team incorporated the *ControlofCorruption* variable from the Worldwide Governance Indicators (WGI) dataset[15] into the transportation model (fig. 9). The *ControlofCorruption* variable reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. The variable is coded as a categorical variable ranging from *low, moderately low, moderately high, high, and neutral* for 215 economies worldwide from 1996-2013. In incorporating the *ControlofCorruption* variable into the routing algorithm as the proxy for likelihood of success, the research team hypothesized that individuals avoiding apprehension or detection would prefer to select those routes that traverse through countries with higher levels of corruption since it will lessen the likelihood of interdiction due to the potential for bribes and other corrupt activities, thus increasing the likelihood of success.

In the model, the edges of the network transiting through a corrupt country received a decrease of time by a factor of two. For example, an individual would be able to traverse through a country with the *ControlofCorruption* value of *high or moderately high* two times faster than it could through a country with the *ControlofCorruption* value of *neutral.* For countries with *low* or *moderately low* values travel time takes two times as long to traverse the country.

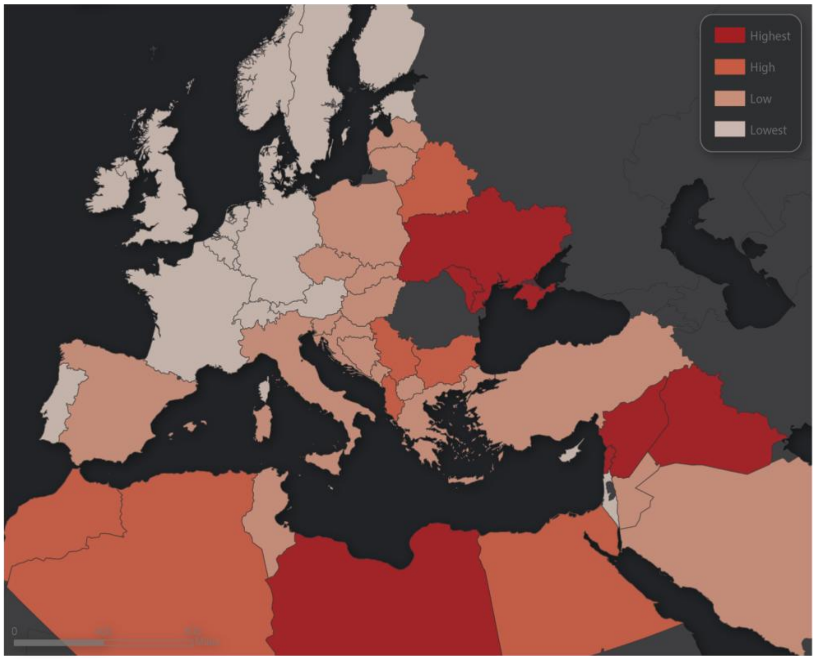

Fig. 9 Levels of State Corruption

[15] The World Bank Group. "Worldwide Governance Indicators." 2014. http://info.worldbank.org/governance/wgi/index.aspx#home.

ISIL Smuggling Districts

It's widely accepted that ISIL engages in the smuggling of both licit and illicit material across the Iraq, Syria, and Turkish borders. To identify these areas, START geocoded the locations of news reports and interviews regarding the smuggling of goods, materials, or people contributing to ISIL operations. After collecting the point locations of where these reports and interviews took place, the administrative districts that these points fall in are then selected and implemented into the model (fig. 10) as a preference weight. The network edges that fall within these areas received a decrease of time by a factor of two. For example, an individual traversing a network segment that falls within a smuggling district will travel that segment twice as fast compared to a segment that does not fall within a smuggling district.

Fig. 10 ISIL Smuggling Districts

Refugee Camps

The model assumes that ISIL will use the flow of economic migrants and asylum-seekers as a way of obscuring the movement of militants into the European Union. Blending in with the mass movement of refugees/migrants into and throughout Europe likely decreases an individual's likelihood of being detected.[16] To account for this in the model, any network segment that falls within five miles of a known

[16] Some of the assailants involved in the November 2015 terrorist attack on Paris successfully used fake Syrian passports to hide amongst the flow of refugees. http://www.wsj.com/articles/paris-stadium-attacker-entered-europe-via-greece-1447698583

migrant camp (fig. 11) received a decrease in time by a factor of two. Data on migrant camps was culled from an open-source database run by a European migrant rights group.[17] For example, an individual traversing a segment that falls within a refugee buffer zone can travel twice as fast compared to a segment that does not fall within the buffer zone.

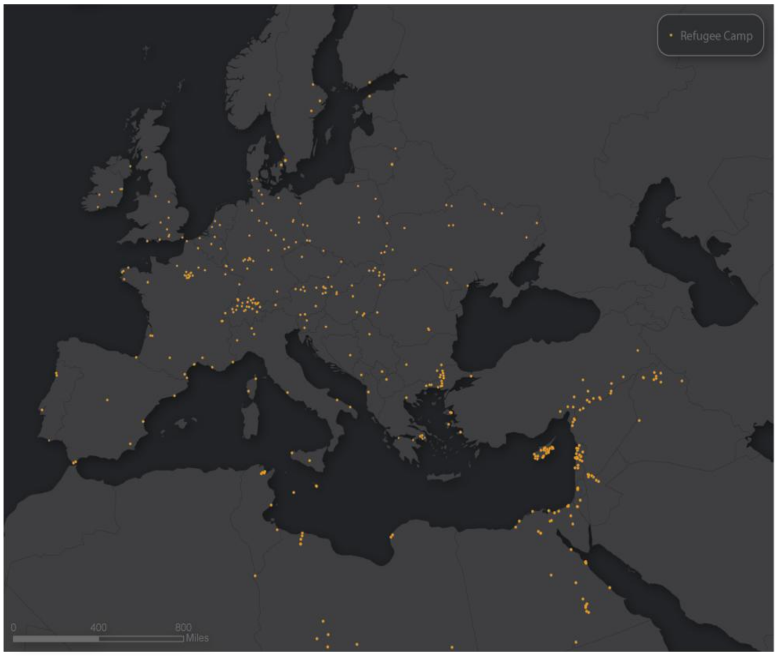

Fig. 11 Known Refugee Camps in the Study Area

Unofficial Border Crossings

The unofficial border crossings were determined by a UNHCR report citing locations where significant numbers of migrants are choosing to use unofficial locations to cross country borders. Although these locations are primarily located on the Bulgarian border with Turkey, the report also suggests other unofficial crossings throughout Greece, Syria, Iran, and Iraq. These unofficial border locations are referred to as green borders.[18] After identifying the known green border locations (fig. 12), START generated border crossing points where roads intersected with that country's border and deemed that location as an unofficial border crossing. A weight is then applied to any network edges that intersect with that administrative area to reduce the time by a factor of two. For example, an individual traversing a network segment that falls within an unofficial border crossing district will traverse that segment twice as fast.

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[17] Close the Camps. Mapping the Migrant Camps. Migreurope. Closethecamps.org.
[18] UNHCR, Mixed Migration Flows in the Mediterranean and Beyond, January 2016, http://data.unhcr.org/mediterranean/download.php?id=442

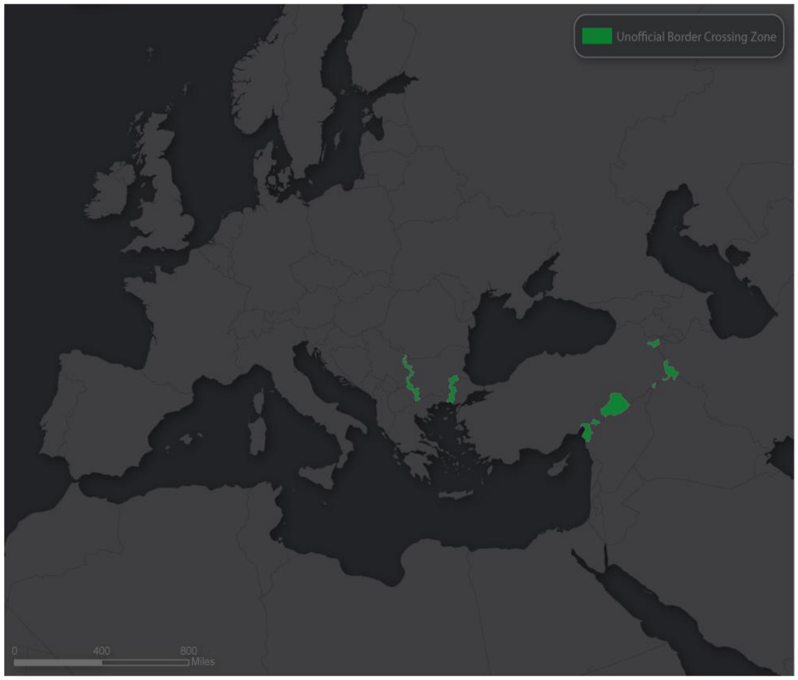

Fig. 12 Known Unofficial Border Crossings

Illicit Greek Island Crossings

Illicit Greek island crossings were determined from a UNHCR report of landing areas on Greek isles that are not official reception areas.[19] These isles were used as a preference weight in the routing algorithm to represent the mass flux of migrants traveling through the Aegean Sea to seek asylum in Greece (fig. 13). As with the other weights, any network segment traveling through these islands will be traversed twice as fast compared to a segment that does not fall within one of these isles.

[19] UNHCR. Greece- Sea Arrivals 2015. Jan. 1, 2016. The UN Refugee Agency. http://data.unhcr.org/mediterranean/download.php?id=442

Fig. 13 Greek Islands Known for Illicit Traffic

Border Barriers

The border barriers file was digitized using data collected from *The Economist*.[20] The available information includes whether the status of the border barrier is proposed, under construction, or completed (fig. 14). For the purpose of our model, all the barriers, no matter what the current status, were implemented as restrictions in the model to represent how an individual would travel throughout the region when avoiding all highly monitored border crossings. However, to enable an individual to still exploit land routes on the Turkish, Iraq, and Syria borders where a border barrier is located, START eliminated border barrier lines if the barrier was located adjacent to previously determined unofficial border crossing or known smuggling districts. This aims to simulate how an ISIL foreign fighter would exploit established smuggling networks and controlled territories when attempting to emigrate from the region undetected.

[20] Élisabeth Vallet, Josselyn Guillarmou, and Zoé Barry, Raoul-Dandurand Chair, University of Quebec in Montreal (2016) Boundary Walls and Fences Worldwide. *The Economist.*

Fig. 14 Known Border Control Locations

Analysis and Results

START's analysis began with baseline assessments of the multi-modal network model. These baseline assessments consisted of runs of the unweighted multi-modal network. Under these conditions, the algorithm found the unweighted optimal solution. Due to the speeds of different segments (e.g., using airlines versus trains or automobiles), it was necessary to test the model with the air network turned on and turned off. Likewise, the baseline model tested origin points in Europe with destinations in Syria and Iraq and origin points in Syria and Iraq with destination in Europe. The baseline results show a proof of concept and serve as a null hypothesis for the weighted analysis. START expects that the weighted results will differ considerably from the unweighted baseline network.

In total, START ran 14 specific scenarios (table 3 and 4) of modeling movement between Europe and regions in Iraq and Syria.

Scenario 1 serves as a baseline, unweighted model of routes originating in 10 Iraq and Syrian cities of interest to 100 destination cities of interest in Europe. This first model includes the air network. Scenario 2 is identical to scenario 1 except the air network has been excluded from the model. This scenario serves as a baseline, fastest route between Syrian and European cities. Scenario 3 is a gradual progression from the second scenario. The air network is excluded, but weights are turned on to determine how routes shift based on the inclusion of intervening variables. Scenario 4 shows a continued shift by excluding the air network, including weights, and including border checkpoints and closings that various European countries installed as the flow of immigrants/refugees increased.

Scenario 5 is the baseline, unweighted model originating in the selected European cities to 100 random points in ISIL-controlled territories. START used random points because specific information related to training camps and/or safe havens within ISIL territory is unknown. Scenario 6 is identical to scenario 1 except the air network has been excluded from the model. Scenario 7 models travel from the selected European cities to 100 random points in Iraq and Syria, introduces weights, and provides no access to the air network. Scenario 8 is complex in that it models from European cities to random points in Iraq and Syria with weights, but it provides limited access to the air network. Open source sources suggest that foreign fighters have commonly made use of commercial airlines to Turkey, and then used other modes to enter ISIL territory; scenario 8 attempts to model this.

Scenarios 9 and 10 examine a very specific micro-section of START's multi-modal network to test for illicit entry into Greece from Turkey. Scenario 9 is an unweighted model, and scenario 10 is weighted to show differences when intervening variables are introduced. Scenarios 9 and 10 are specifically meant to model the proliferation of illicit maritime crossings between Turkey and Greece through the Aegean Sea. Scenarios 13 and 14 are also focused on a micro-section of the multi-modal network. The specific purpose of these runs are to route, unweighted baseline (13) and weighted (14), from Turkey to official border crossings on the border between Greece and its European neighbors. Scenarios 13 and 14 are designed to show land-based migration that excludes illicit island hopping in the Aegean Sea.

Scenarios 11 and 12 are designed to show how routes might shift if a foreign fighter returning from ISIL territories originate their trip in Turkey with destinations in European cities. Scenario 11 serves as an unweighted baseline while scenario 12 includes weights.

Scenario	Start	End	Networks	Weights	Barriers
Scenario 1	Syria 10	Europe 100	All	No	No
Scenario 2	Syria 10	Europe 100	No Air	No	No
Scenario 3	Syria 10	Europe 100	No Air	Yes	No
Scenario 4	Syria 10	Europe 100	No Air	Yes	Yes
Scenario 5	Europe 10	Syria 100	No Air	No	No
Scenario 6	Europe 10	Syria 100	All	No	No
Scenario 7	Europe 10	Syria 100	No Air	Yes	No
Scenario 8	Europe 10	Syria 100	Limited Air	Yes	No
Scenario 9	Turkey 12	Greece 13	All	No	No
Scenario 10	Turkey 12	Greece 13	All	Yes	No
Scenario 11	Turkey 20	Europe 100	All	No	No
Scenario 12	Turkey 20	Europe 100	All	Yes	No
Scenario 13	Turkey 20	Greece Official Exit	All	No	No
Scenario 14	Turkey 20	Greece Official Exit	All	Yes	No

Table 3: Specific route scenarios

Points	Description
ISIL 10	10 Highly Populated Cities in ISIL Region
ISIL 100	48 Highly Populated Cities & 52 Random Points in ISIL Region
Europe 10	8 Highly Populated Cities in Europe + Tunis and Casablanca
Europe 100	98 Highly Populated Cities in Europe + Tunis and Casablanca
Turkey 12	12 Turkey Exit Locations Based on UNHCR Report
Turkey 20	20 Turkey Entry Locations Based on UNHCR Report
Greece 13	13 Greek Entry Ports Based on UNHCR Report
Balkan Official Exit	Official Greek and Bulgarian Exits Based on UNHCR Reports

Table 4: Start and End Points

Scenario 1:

In this unweighted baseline model from Iraq and Syria to European cities, START observes that the model and algorithm function properly. Air routes are the least cost path. The model (fig. 15) finds the most efficient route from the origin point to the nearest airport, flies to a European destination nearest to the final destination and then the most efficient road route to final destination. Roadways are used only as a means of arriving at, or departing, airports. The edge bundling visualization (fig. 16) shows that most routes converge on London, as the airports around London are a major hub for European air traffic.

Fig. 15

Fig. 16

Scenario 2:

In the unweighted baseline model from Iraq and Syria to European cities, with airlines removed from the model, START observes wide-scale usage of major roadways throughout Europe. The chokepoints with the highest density are located in and around the Aegean (fig. 17), due to the model's speed preference; the least cost path is via the Aegean or Mediterranean into Europe. Once in Europe, the model quickly switches to roadways. Likewise, from the edge bundling visualization (fig. 18), the vast majority of routes traverse maritime routes. As this is an unweighted model, it behaves exactly as expected.

Fig. 17

Fig. 18

Scenario 3:

Once intervening variables are introduced, routes become less diverse, and the distribution tightens. This scenario builds on the previous scenario by incorporating various intervening variables. The scenario has the same number of origin and destination points, but the model's decisions are more constrained. Routes begin to resemble actual migrant/refugee pathways (fig. 19) with routes running through Bulgaria and Serbia; when the present wave of migration started last summer, this was the pathway that received the most attention until Bulgaria altered its policies and took a more hardline stance.[21] Due to constraints, the model constrains to fewer roadways in Europe compared to the unweighted model (fig. 17). The edge bundling visualization clearly shows (fig. 20) the extent of the shift once weights are introduced. Most routes travel across the Bosporus Strait, through Greece, and then through Bulgaria and Serbia. START observed a new preference for a land route across North Africa.

Fig. 19

Fig. 20

Scenario 4:

The introduction of physical barriers (border checkpoints, border fences, etc.) in Europe causes the weighted baseline model to shift to the least cost path around those barriers. The border policies Croatia and Hungary enacted had the most significant effect on route selection (fig. 21). It is here that START observes the Balkan Route that has now become a popular pathway for migrants/refugees. The edge bundling visualization does not show the significance of the emergence of the Balkan Route; most routes shift to Mediterranean and/or Aegean crossings before taking pathways through the Adriatic (fig. 22).

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[21] Frontex, European Agency for the Management of Operational Cooperation at the External Borders of the Member States of the European Union. (2016). "Trends and Routes," Accessed 16 January 2016 from http://frontex.europa.eu/trends-and-routes/migratory-routes-map/. Ágh, A. (2016). The Decline of Democracy in East-Central Europe: Hungary as the Worst-Case Scenario. *Problems of Post-Communism*, 1-11.

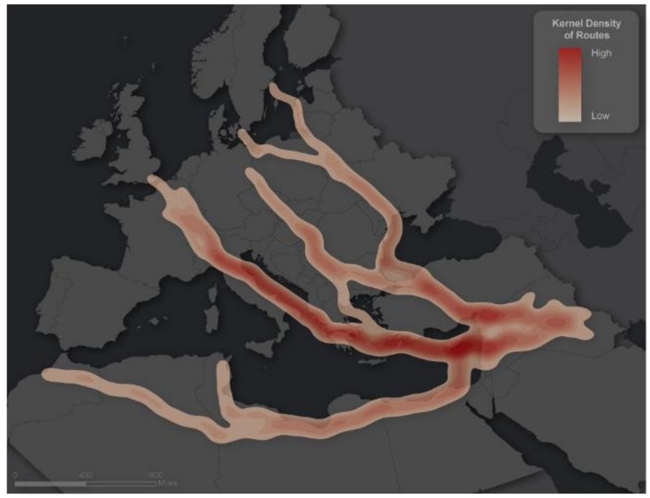

Fig. 21 **Fig. 22**

Scenario 5:

The unweighted baseline model without airport access predicts that foreign fighters moving into Iraq and Syria will have a least cost preference for travel through the Adriatic and Aegean Seas (fig. 23). The edge bundling visualization shows the narrow distribution of route choices (fig. 24) with two main routes out of Europe.

Fig. 23 **Fig. 24**

Scenario 6:

As with scenario 1, when air routes are available, START observes that the most efficient pathways for entry into ISIL territory is via commercial airlines. Airports in England serve as the hub of chokepoints (fig. 25). The edge bundling visualization shows the most commonly used routes run between England and points in Iraq and Syria. (fig. 26).

Fig. 25

Fig. 26

Scenario 7:

Once weights are introduced, routes distribute further and chokepoints change significantly (fig. 27). However, START observes a more realistic representation of the routes recruits have taken from Western Europe to Iraq and Syria (fig. 28). The edge bundling visualization makes clear that despite the wide distribution of individual routes, these routes converge in Central Europe, crossing from Greece into Turkey via the Bosporus Strait. START also observes significant land routes across North Africa that show likely pathways into ISIL territory.

Fig. 27

Fig. 28

Scenario 8:

The "limited air" scenario is designed to show how recruited foreign fighters without access to airports in Syria or Iraq, would transit toward their goal. There are some locations where the most expeditious route remains via maritime pathways (fig. 29), however the edge bundling visualization (fig. 30) shows the bulk of the routes converge on Istanbul and take land routes from there into ISIL territory.

Fig. 29 **Fig. 30**

Scenario 9:

Scenario 9 routes an unweighted baseline of illicit pathways between Turkey and Greece. This baseline analysis of a subsection of the network specifically tests the potential of START's illicit network infrastructure. The results (fig. 31) shows how illicit maritime and ferry routes network through the Aegean to form viable, probable routes for persons attempting to cross from Turkey to the European Union. START observed the greatest density (fig. 32) of routes around the Greek islands of Lesvos and Tinos.

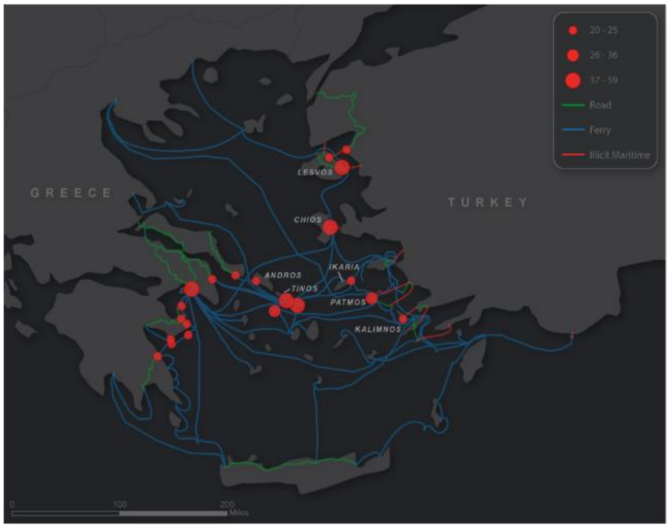

Fig. 31

Fig. 32

Scenario 10:

The weighted, illicit network scenario (fig. 33) is visually similar to the unweighted baseline in scenario 9, but the edge bundling (fig. 34) shows vast differences in the dispersion of routes from the previous scenario. While the general route selection is similar we can observe that, when compared to the unweighted model (fig. 31), the weighted model routes on the northern Aegean and southern Greek mainland disappear while new central Aegean routes appear. In the edge bundling image (fig. 34) START observes a higher concentration of overlapping routes illustrated in the concentration of routes intensifying in the central region indicating a higher likelihood traffic through the central Aegean region. Reinforcing indications of route selection through the central Aegean region is the decline in number and intensity of chokepoints south of Athens. Instead, START notes an upswing in the number of routes going through central Aegean island chokepoints. Tinos and Mikonos are particularly prominent as we can see their chokepoint count ranks (app. #9 and #10) increase from 5 and 4 to 2 and 3 respectively when comparing the unweighted to weighted models.

Fig. 33

Fig. 34

Scenario 11:

This unweighted baseline model examines route selection of returning foreign fighters who have successfully entered Turkey and are attempting to gain access to the European Union. START observes that routes diverge widely across the continent (fig. 35). The routes mainly converge in the Aegean and Adriatic, but also along the Turkey/Greece border and in Serbia (fig. 36).

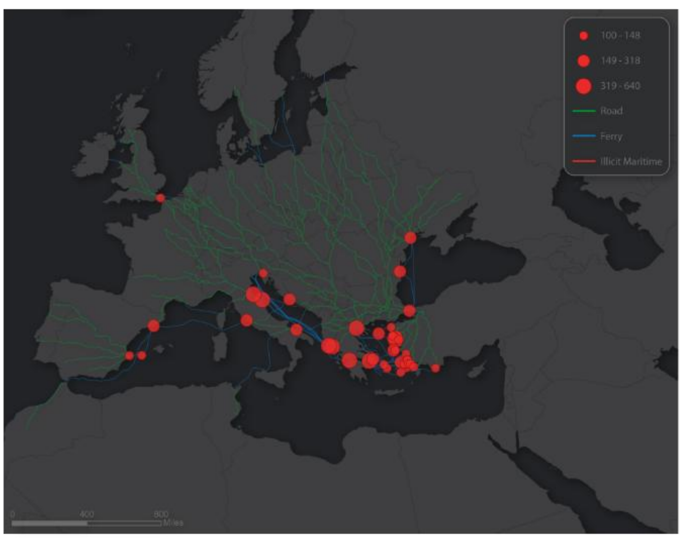

Fig. 35

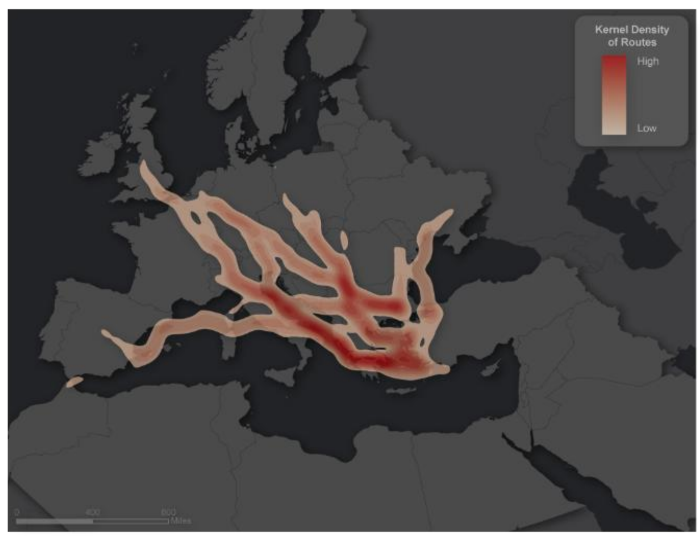

Fig. 36

Scenario 12:

The weighted model (fig. 37) of routes from Turkey to European cities is very similar to the unweighted model; however, there are significant changes to route choices due to intervening variables (fig. 38). Weighting the model causes the algorithm to make different decisions to achieve a least cost path. While

START observes similar route selection, densities change. While routes through the Aegean Sea are still preferred by the model, traversing the Adriatic is less pronounced. Land-based routes through Greece, Serbia, and the Balkans are more prominent.

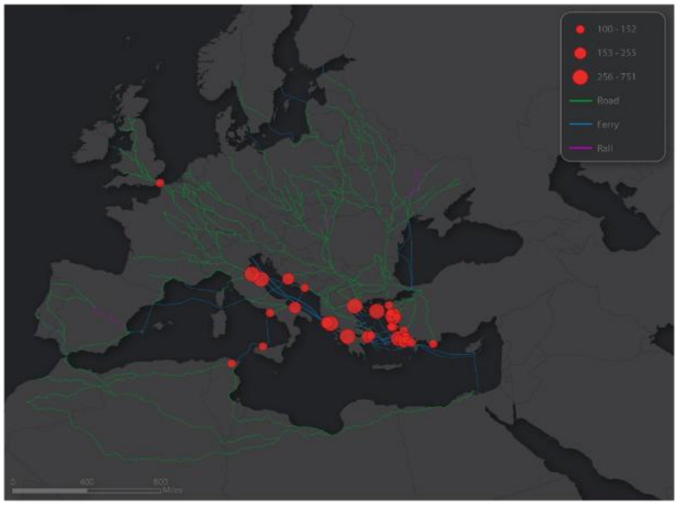

Fig. 37

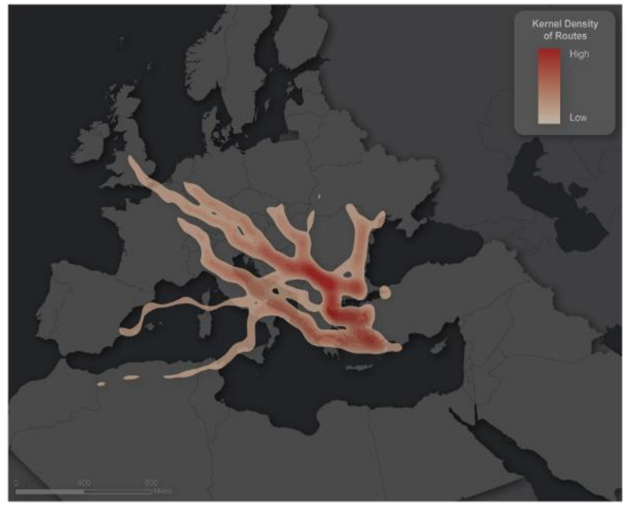

Fig. 38

Scenario 13:

From the previous models START observed that there are general routes diverting through the Aegean towards mainland Europe via Greek islands within close proximity to the Turkish coast. In order to fully explore the tendencies of route selection, a higher level analysis focusing specifically on Aegean routes has been conducted. However, modelling Aegean routes proves to be difficult because of the fluid nature of maritime routes. Using the unweighted model parameters, routes are created using known unofficial exit locations from Turkey which are connected to known entry locations on Greek islands. The starting locations are points within Turkey, while end locations are known official exit locations in Greece and Bulgaria that lead to the interior of Europe. In the unweighted model (fig. 39), START observed that there are few chokepoints concentrated on mainland Greek ports and beyond. The edge bundling visualization shows a slight preferences for maritime routes (fig. 40).

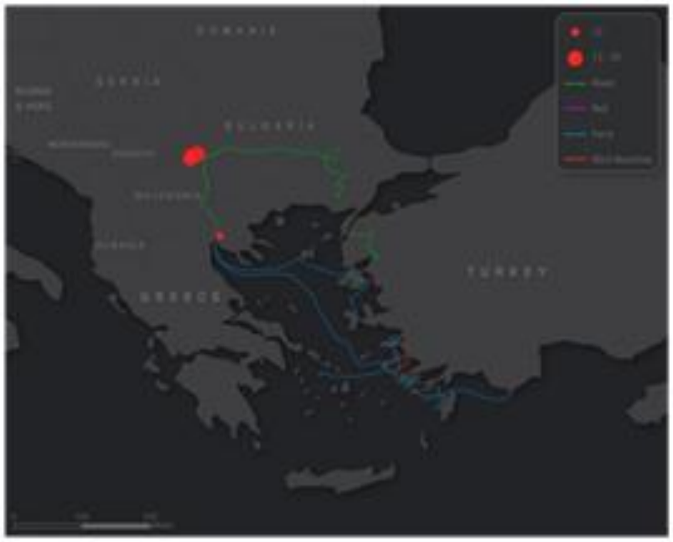

Fig. 39

Fig. 40

Scenario 14:

When weights are applied, START observed generally similar routes (fig. 41) to the unweighted model above, but routes become more concentrated (fig. 42). Previously, no Greek islands had remarkable choke points, whereas the weighted model indicates that the islands of Patmos, Lesvos, and Limnos become waypoints in trans-Aegean routes.

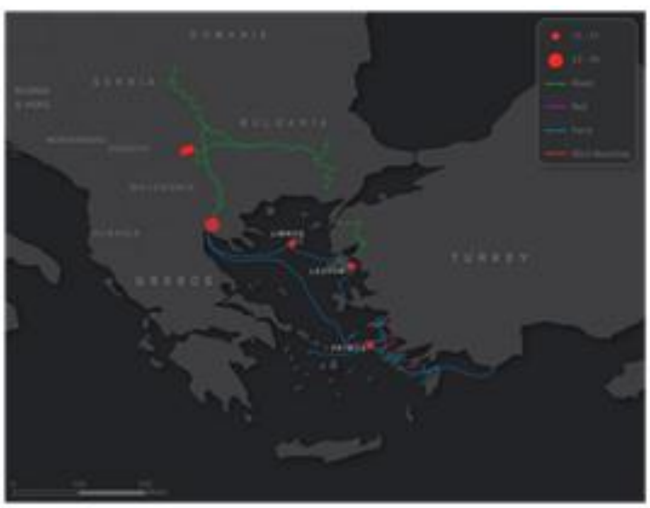

Fig. 41

Fig. 42

Research Opportunity

The threat of foreign fighters fueling conflict is real. The historical idea of external fighters joining a battle for ideological reasons goes back for centuries. The influence of foreign fighters fuels ideological campaigns by inflating troop numbers and acumen in battle. While in the past, particularly in Africa in the 1960s and 1970s, "soldiers of fortune" were common, now it seems that has shifted to "soldiers of ideology." As new battlefronts take shape, it will become increasingly necessary to stem the tide of trained, and untrained, foreign fighters seeking to give root to their ideological causes.

As ISIL moves into other territory, it is possible to use the TransIT tool as a way to forecast potential realities. For this project, START's TransIT tool was successfully adapted to show flows of people and, as variables were introduced, it showed how routes shifted with a good degree of accuracy. START has become adept at uncovering illicit modes of transit and modeling them to create plausible representations of illicit travel networks. With a new target, START could forecast flows of foreign fighters or other trafficked material before large numbers of fighters/goods arrive.

Conclusions

Overall, the model succeeds in producing variations between baseline and weighted analyses, indicating that the model is sensitive to intervening variables (i.e., different costs, incentives, and preferences). The ability to replicate changes in real world conditions shows that the tool has the potential to inform decision-making if given relevant variables. The analysis generated numerous routes for general scenarios, both baseline and weighted, and produced other scenarios which had the explicit—and additional—purpose of accounting for changes in real world conditions (e.g., the dramatic increase in the flow of refugees and migrants).

As U.S. government agencies attempt to prioritize their strategies to prevent trained foreign fighters from entering the United States, the results of these analyses provide valuable insights on locations that need close monitoring and/or engagement to prevent/reduce the potential for human trafficking in the future.