Judges' Commentary: Refugee Immigration Policies

Chris Arney
david.arney@usma.edu
Yulia Tyshchuk
Dept. of Mathematical Sciences
U.S. Military Academy
West Point, NY 10996

Introduction

This year's ICM introduced the first problem that explicitly focused on policy modeling. Public policy is the system that produces laws, regulations, courses of action, policies, and funding priorities concerning governmental issues. Individuals and groups attempt to influence public policy. Therefore, policy modeling must take special efforts to overcome system and political biases to build fair and unbiased models to analyze complex situations and issues to ultimately make good recommendations.

It is often the dynamic and challenging human element that makes policy modeling so challenging. The ICM considers policy modeling as the process where, based on information and realistic assumptions, recommendations are made from the results of a model that can then be tested and/or validated, in order to advance understanding of an issue, build a new system, and/or recommend a policy decision. Policy issues often require the modeler to incorporate social and political science knowledge and perspectives to engage accurately with such a complex real-world issue. The culmination of the modeling process is usually a policy paper prepared by the modeler for the decision maker that contains the most cogent results of the policy model and explains and anticipates the model's implementation in the context of the human elements and the political situations.

We hope that by adding policy modeling to the ICM, we increase awareness about social science modeling that leads to more student experience in solving challenging social problems. The ICM policy modeling problem provides opportunity for students to experience interdisciplinary model-

The UMAP Journal 37 (2) (2016) 215–225.

ing (combining quantitative and qualitative perspectives) to solve some of society's most challenging and important social issues.

The problem statement is given in the contest report earlier in this issue.

Judges' Criteria

This year's problem involved modeling refugee immigration policies relevant to the on-going migration of people from Syria and the rest of Middle East to Europe. The problem statement is given in the contest report earlier in this issue. The judging goal of this ICM policy modeling problem is to evaluate teams' performance of good science that leads to viable policy recommendations. Getting good data to build and evaluate the models are challenges for this problem. Some of the issues the judges considered for the modeling team members are:

- Do they develop a means for producing a good policy recommendation?
- Do they find and use viable data and do they provide a visualization of their model and framework?
- Do they determine the specific factors which can enable or inhibit the safe and efficient movement of refugees? Do they develop a set of measures and parameters and justify why they should be included in the analysis of this crisis?
- Do they create a model of refugee movement that would incorporate projected flows of refugees across the six travel routes with consideration of transportation routes/accessibility, safety, and resource capacities?
- Do they identify the environmental factors that change over time, and show how these factors can be incorporated into the model to account for these dynamic elements? Do they determine how to incorporate resource availability and flow in their model?
- Do they prioritize the health and safety of refugees and of the local populations?
- Do they consider what parameters of the model would likely shift or change in a major exogenous event? What are the cascading effects on the movement of refugees in neighboring countries?
- Do they discuss the scaling of their model in an expanded crisis?
- Do they discuss what policies need to be in place to manage issues such as disease control, childbirth, and education?
- Do they discuss assumptions, strengths, weaknesses, and sensitivity of their models?
- Did they find and use good data to help their modeling and analysis?

- Is the Executive Summary clear and concise?
- Is the policy recommendation clear and concise?
- Is there good visualization of results?
- Do the models utilize policy science and immigration research factors?

Discussion of the Outstanding Papers

Renmin University of China: "Dual Goal Network Planning Model"

This team used a network optimization approach to develop a Dual Goal Network Planning Model. Their model attempts to optimize refugee movement along the routes with least difficulty and maximize living quality of the receiving country. The team chose 5 source nodes that represented the countries of emigration in Northern Africa and Middle East and 11 sink nodes that represented receiving countries in Europe (see **Figure 1**).

Figure 1. Map of the Renmin University team's source and sink nodes.

Then they abstracted the movement routes into a network where the length of the edges between the nodes represents transport accessibility of each route segment between any two nodes. The transport accessibility is developed from a compound measure of death rate, transport distance, and transport time. They develop a living quality index and use a minimum-cost network-flow model to develop a transport accessibility matrix.

Finally, the team uses goal programming to optimize the two objectives:

- maximize total living quality index, and
- minimize total accessibility index.

Assumptions made throughout their modeling are reasonable, and a number of them are relaxed to evaluate the effects.

The team's living quality index combines the receiving country's GDP, cereal production, pension spending, healthcare spending, and number of doctors per 1,000 inhabitants into one measure using principal components analysis. The index contains 80% of information of original five metrics. Additionally, they constrain refugee capacity of each country to be less than 0.5% of the country's population.

The dynamic component of their model allows the team to assess compounding effects of refugee influx on the living quality index. Their analysis of exogenous events is thorough, especially the mention of the cascading effects of the refugee movement. However, it would have been even better to discuss cascading effects at border closings.

Analysis of their model revealed that it is not quite scalable (at least, not out to an order of magnitude scale of $10\times$), due to the capacity constraints. Perhaps the team should have looked at other countries not utilized in the model as an option to receive the overflow of refugees. However, the team provides an insightful discussion on the change of the parameters and new challenges and constraints of their model due to a dramatic increase in the number of refugees. Moreover, the team provides insights on the role of NGOs in such a large-scale event.

The team's policy recommendations use findings from their modeling and transform the results into implementable strategies. Following are the policy suggestions advised by the team:

- Strengthen the construction of infrastructure and increase the supply of basic necessities and subsidies.
- Devote more efforts to the patrol and rescue of refugees in the Mediterranean area.
- Support countries on the front line and inhibit unilateral border-crossing.
- Make changes to the current Dublin system, and consider a fairly shared refugee intake plan.
- Embrace the multicultural aspects and emphasize considerations about the local people's welfare.

The final policy suggestion, however, would benefit from a direct support from the model. The team's argument rests on the effects of refugees through their living quality index, but religious and cultural differences were not directly included in it.

Shandong University: "Modeling to Refugee Policies"

The team optimized a control variable algorithm to build a model using factors such as psychological condition of refugees, resources, policies of the receiving countries, capacities of the receiving countries, and exogenous events such as natural disasters or terrorism. They further utilize a small-world network algorithm to analyze the flow of refugees into Europe. The team introduces a dynamic element to the problem by making resource factors, such as financial and material resources, become dynamic variables. The team expands on the role of NGOs in the crises as the primary providers of basic needs. The model's assumptions are to ignore countries with low volume of refugees as well as time delays associated with the movement of refugees.

An interesting component is the inclusion of religious beliefs and habits. The team stresses the importance of disparity between the receiving countries' religious beliefs and cultural habits and those of the refugees. They highlighted that this factor is particularly important in integrating the refugees into the local population.

The team report addresses the following exogenous events: border crossings, wars, and violence among refugee receiving and exporting countries, and natural disasters. The developed model is scalable and the team offers enhancements and new parameters to further strengthen the utility and scalability of the model. A strength of the report is the discussion on stability and sensitivity analysis of the model. The team assessed their model as low in sensitivity and high in stability.

The model uses the following influence factors:

- psychological condition of refugees;
- faith of the refugees;
- material and financial resources of the receiving country;
- refugee policy of the receiving country;
- refugee capacity of the receiving country;
- exogenous events: natural disasters and terrorist acts.

Finally, the team's policy recommendations are feasible and include three main suggestions:

- Give priority to cultural restraint and religion.
- Establish a "safe zone" for the refugees as a buffer in case of conflict between bordering countries.

- Provide more doctors and psychologists at border crossings and within the refugee receiving countries.

Sun Yat-Sen University, China: "Towards a Hopeful Journey"

This team uses network analysis and cellular automata to simulate refugee migration into Europe and then to build good management policies and a viable feedback system. The team establishes a set of metrics and indices to consider relevant factors in refugee migration. The six migration routes considered included 14 countries. Because they assume that refugees get limited information, they initially built a random migration model. However, using a Matlab-constructed simulation of this network flow, their initial results were inconsistent with data that they found to check their model.

As good modelers, they adjusted their assumptions and revised their model. Their new version was a gravity model that analyzes the factors affecting the migration of refugees. They integrate their factors into what they called the Attraction Index. Through statistical weighting, they produce a more accurate population distribution for the routes and used it to build and optimize a flow distribution model. Using their new model, they could expand the scale and capacities of nodes and edges. Their innovative modeling continued as they used a cellular automaton simulation of the migration progress of refugees to further refine the dynamics of the flow.

This team's policy discussion and recommendation try to play up the importance of the empathy that the receiving population of each country had to develop to accommodate the refugees and their impact on local living conditions. Unfortunately, this empathy element is not present or reinforced by their models. Additionally, the team noticed that they could not reliably scale up their model because of the fast saturation of the existing migration routes.

As part of their basic measures, they assemble a Safety Index, Environmental Acceptance Measure, and a Transportation Index, which take into account transportation cost, travel time, distance, and traffic conditions. Through the Environmental Acceptance Measure they could judge the danger of a route for groups and people, especially vulnerable ones, such as children, pregnant women, the elderly, and the disabled. Their measure of Environmental Acceptance consists of:

- resource abundance,
- economic condition, and
- religious and culture acceptance.

This team did a good job in identifying and describing the fundamental assumptions that they made. Some of the elements on this list were:

- Refugees migrate in groups

- The migration of refugees is irreversible and there will be no possibility of return to the home before arriving at their destinations.
- Refugees are sensible and can adjust their routes.

The dynamic simulation model of refugee migration based on a cellular automaton showed various elements of the migration. The results of their simulation are shown in **Figure 2**.

When the issues of scaling and sensitivity were addressed, the team realized that more countries were needed to accept refugees. So the team added Canada, the U.S., and China to expand the migration and checked the scalability of their work with more routes and locations. **Figure 3** shows the new results with Canada, the U.S., and China added to the destination list.

As part of the task on the effects of exogenous events, the team also considers the outbreak of the diseases and illness such as the newly-discovered Zika virus. If migration nodes and links are shut down from a disease outbreak, what will happen to people and places involved in the disease? The modelers also looked at the effects of a terrorist attack—especially the cascading effects of changes in refugee policy of a country where terrorism is blamed on refugees that then has the potential to cause attitude to change in neighboring countries as well.

This team also provides a good analysis of their effort. They list the strengths and weaknesses of their modeling and their results. They like how their models were verified by data that they found in the literature. One of the weaknesses discussed is that the distances in their models are approximated by straight lines, not real travel distances. They also ignore geological barriers on the routes, so they felt that there were errors in calculating the travel times and distances.

Overall, this was a strong modeling effort; and the team is congratulated on being selected as the INFORMS Prize winner for this problem.

North Carolina School of Science and Mathematics, NC: "ICM-RUN to Safe Countries"

This team models refugee immigration movements, policies, and issues of the current Syrian-European refugee crisis. They develop a creative measure for the capability of a country to host refugees by assessing economic and physical data (relative to other host countries). A resource distribution is also computed and analyzed using their measure. Their dynamic model simulates the flow of Syrian refugees to Europe using agent-based modeling (NetLogo). Using system dynamics and social constructs, the team also considers several countries' attitudes towards hosting refugees. Through the use of these general network structures, their model is able to simulate sudden influxes of refugees, the addition of host countries, changes in levels of support from countries, and the effects of an outbreak

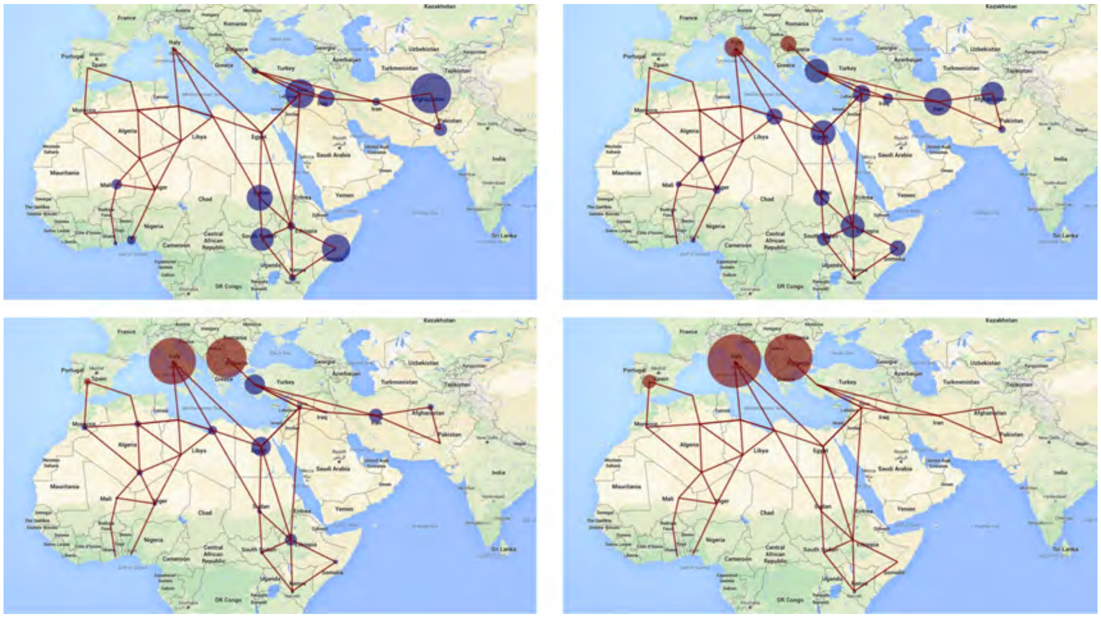

Figure 2. Refugee flow in the network model.

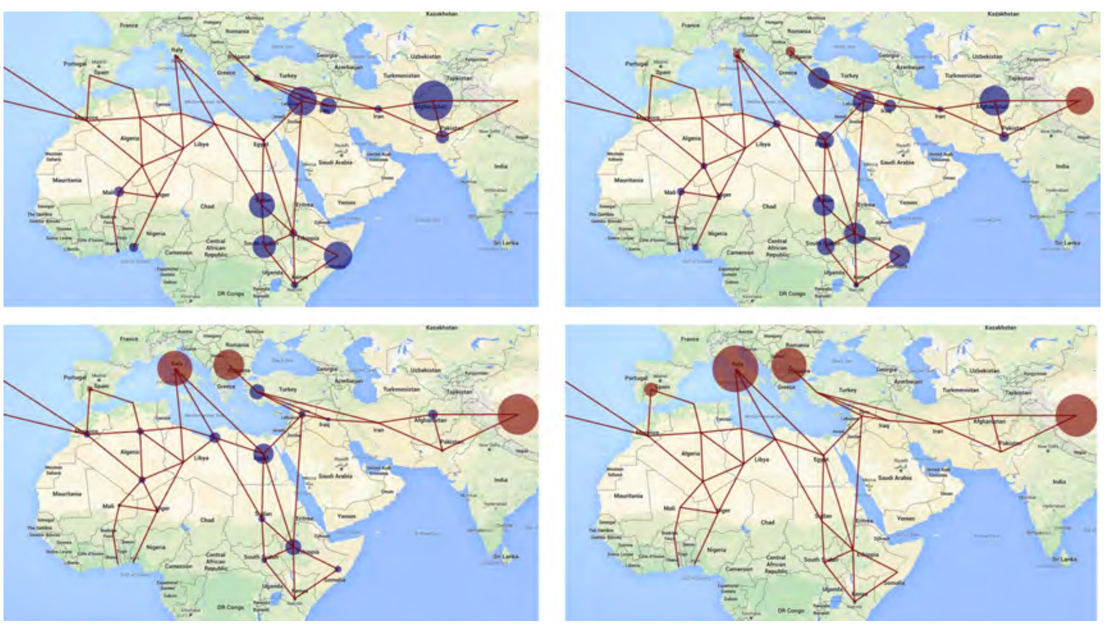

Figure 3. Refugee flow in the network model with the U.S., Canada, and China added as recipient countries.

of contagious disease. Their model is scalable, and therefore is useful in conducting policy planning. The dynamics of their NetLogo model help determine distribution of resources and optimization of refugee flow.

This team also develops a deterministic rate-based model to consider endogenous and exogenous events. They use a standard modeling structure of stock-and-flow with various feedback loops. Using their system dynamic model, they study both positive and negative events that could directly affect the rates of refugee entry into Europe. This was one of the few teams that studied the negative effects of delays and dynamic obstacles, such as the delays caused by the use of EURODAC, the fingerprinting identification system for processing asylum applicants. They also attempt to counter these negative effects by planning for positive events and implementing them in the simulation. In their simulation, they were able to take advantage of positive exogenous factors to achieve 95% of 1 million refugees being accepted in Europe within a specified time, even with endogenous delays continuously affecting the process.

Some of the most effective elements of this team's report are an extensive restatement of the problem in their own words; a very thorough itemization and analysis of assumptions, decisions, and findings; strong graphics of their network; solid analysis of their models strengths and weaknesses; and many pages with charts of various modeling results. The judges recognized the outstanding policy modeling and interdisciplinary problem solving performed by this team and awarded them the Rachel Carson Award, which honors an American conservationist whose book *Silent Spring* [Carson 1962] initiated the global environmental movement and whose work spanned many disciplines concerned with the local and global environments.

Future Trends in Interdisciplinary and Policy Modeling

The ICM tries to mimic some of the elements of real-life problem solving. Real-life problem solving is inherently interdisciplinary through its need to combine concepts, models, methods, knowledge, and perspectives of various disciplines in sciences, humanities, and arts. To develop students who are prepared to solve real world problems, disciplinary problem solving must be supplemented with broader, less restricted, more interdisciplinary and realistic problem solving. Real problems are often layered, multi-scaled, dynamic, and/or multi-dimensional. Policy modeling has become a popular way to inform decision makers of potential priorities and determine the what-if effects of different scenarios or decisions.

There is more to modeling than a templated structured mathematical process with quantitative measures and linear components. In particular, interdisciplinary modeling can include many types of knowledge and perspectives. Quite often the assembly and pathways from which the policy model is built or implemented are artistic and lead to qualitative models. Good problem solving thus involves making appropriate assumptions that lead to quantitative or qualitative models using scientific or artistic methods. Many viable models are hybrid—containing quantitative, qualitative, scientific, and artistic elements—and incorporate many different disciplinary and interdisciplinary structures and processes.

We have discovered many perspectives and terms being used in the area of interdisciplinarity. For instance, the term "antidisciplinary" is not just used to define a way that is opposite of the normal disciplinary approach. The MIT Media lab uses the term to indicate working in spaces that simply do not fit into any existing academic discipline or interdiscipline [Ito 2016].

Conclusion

As judges for this year's policy modeling problem, we hope that the teams that wrestled with the immigration problem experienced some of the policy modeling elements described in the previous paragraphs. Perhaps as they worked, questions such as these arose: Where should a qualitative structure or process enter in the modeling? What disciplines of study help with this model's context? What assumptions are necessary or appropriate? What data do we need to test the validity or verify the models utility?

The judges of this problem are excited about the future prospects of policy modeling in the ICM. Next year's ICM will continue to offer students an opportunity to perform policy modeling and analysis. The judges expect even better performance in this area as experiences with this type of problem increase.

Reference

Carson, Rachel. 1962. *Silent Spring*. Boston, MA: Houghton Mifflin.

Ito, Joichi. 2016. Design and science. *Journal of Design and Science*. `http://jods.mitpress.mit.edu/pub/designandscience`.

About the Authors

Chris Arney is a Professor of Mathematics at the United States Military Academy. His Ph.D. is in mathematics from Rensselaer Polytechnic Institute. He served as a Dean and acting Vice President for Academic Affairs at the College of Saint Rose in Albany and had various tenures as division chief and program manager at the Army Research Office in Research Triangle Park, NC, where he performed research in cooperative systems, information networks, and artificial intelligence. His current research and academic interest is cyberspace, social networks, philosophy of science, interdisciplinary modeling, and diversity. Chris is the founding Director of the ICM.

Yulia Tyshchuk graduated from Rensselaer Polytechnic Institute with a Ph.D. in Decisions Sciences and Engineering Systems. During her Ph.D. studies, she was a member of the Army-funded SCNARC (Social Cognitive Network Academic Research Center) research team and assisted in completion of successful grant proposals for National Science Foundation, Department of Homeland Security, and Army Research Laboratory. Her research interests include understanding, modeling, and predicting human behavior as expressed on electronic media as well as incorporating network models in the studies of team composition and performance. Her current research includes the study of the effects of simulations on learning, team performance, cyber team composition, and emergence of leadership.