Session 9: Network Modeling: Merging the social and physical

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• Collaborative Modeling and Integrative Education
• Overview of Modeling and Networks
• Network Modeling of Teams: Linking layers of cooperation
• Geographical factors driving Household Vulnerability in Four East African countries
• Modeling World Trade: Land and Sea
• Unification of models toward MegaCity models
Why Collaboration/Integration are important

Modern Society’s Global Issues and Needs

Complex Environment

Modern Perspective

Breadth and Depth of Thought
Inter- and Multi-Disciplinary Problem Solving

Embrace Complexity

Diversity of Thought

Within Self Development:
- Competent Problem Solver
- Wise Decision Maker
- Deep Thinker

Part of Team

Development:
- Leader
- Collaborative Team Member
Modeling as an enabler of problem solving.
What Is Happening?
What Happened?
What Happens?
What May Happen?

Data
Information
Knowledge
Wisdom

Organize
Understand
Apply
Society’s Needs: Perspectives & Opportunities in Modeling

Physical view (quest to understand & model complexity)
reality → assumptions → model → solution → verification → algorithm → tool (product) (Reductionist)

Social/Informational view (quest to understand basic principles & develop constitutive equations): 
reality → sensor → data → information → intelligence → knowledge → wisdom → decision (Non-reductionist)

The world is complex! We have to embrace the complexity, instead of assuming it away.
Network Science

... examines the interconnections among physical entities for communication, sharing information, collaborating; network science seeks to discover common principles, algorithms and tools that govern network behavior & allow for prediction of performance & utility.
dynamic networks with central control
Some of the Flights
What is a Network?

- **Social/Cognitive Information**
  - Dynamic Communities of Interest
  - Distributed Planning
  - Trust
  - Synchronization

- **Information**
  - Secure Information Flows
  - Distributed Self-Organizing Services
  - Knowledge Management

- **Communication Networks**
  - Dynamic Interoperability
  - Medium Access Control
  - Self-Configuring Networking
  - Routing

- **Physical (Radios/Sensors)**
  - Radios
  - Spectrum Agility
  - Sensors
  - Propagation
Network Modeling of Teams: Linking Layers of Cooperation

Kathryn Coronges
Currently moving to Northeastern Network Science Institute
Boston, MA

Chris Arney
United States Military Academy, West Point, NY
Network Models used to understand and predict *relationships* in terms of influence, tipping points, feedback and emergence.

Models to capture processes that lead to emergent phenomena in teams, organizations, communities and populations

Use network analysis to explain phenomena that
• generate or spread information,
• initiate or prepare for state shifts,
• build or disrupt collaborative alliances.
Approach:
Integrate
a) organizational and cognitive sciences into group dynamics, linguistic processes, &
collective intelligence,
b) modeling of multi and interdependent systems,
c) social complexity theories to understand emergent capabilities of teams.
Team Science

• Increased reliance on small teams

• Teams define objectives, develop and implement strategies, evaluate and adjust together

  --- Humanitarian aid, disaster relief, security, community coalitions, technological infrastructure, education, public opinion campaigns

• Develop theories and models to predict, evaluate, & measure how teams organize, exchange information, build knowledge, influence, adapt, learn, and build consensus.
Household Vulnerability Mapping in Africa’s Rift Valley

Amy Richmond Krakowka, PhD
An Interdisciplinary Study of Household Vulnerability and Wellbeing

**Vulnerability** model

**Interdisciplinary** framework

Relationship between **environmental processes and human wellbeing**.

**Household-level drivers of vulnerability** that are rarely accounted for in regional and global indices.
Definitions and Methodology

**Vulnerability** inability to withstand the effects of social or environmental changes.

**Wellbeing** state of being content, healthy and prosperous.

**Current State of Vulnerability Analysis**
- Scale (national vs. local data)
- No localized variables
- Data availability & reliability

**Our Methodology**
- Household data
- Expert interviews
- Rich data from a variety of sources.
Case Study: Ethiopia, Basic Facts
Terrain and Population Density
Pushing towards a middle-income country
Household Security
Near Connections
Distant Connections
Household Vulnerability

Water
- Water Access
- Water Quality
- Water Insecurity

Health
- Sanitation
- Wellbeing
- Mortality
- Poverty

Livelihood
- Access
- Assets
- Education
- Natural Resources

Environment
- Climate
- Change
- Hazards
- Electricity

Energy
- Food
- Livestock
- Arable Land
- Under-nutrition Malnutrition

Vulnerability

Environmental Degradation
Ethiopia

TYPE OF TOILET

Map by Krakowka et al. (2015)
United States Military Academy
Demographic and Health Survey Uganda, 2011
Administrative Boundaries (GADM.org)

African Environmental Stability Project
United States Military Academy, West Point
Ethiopia

Source of Water

Map by Krakowka et al. (2015)
United States Military Academy
Demographic and Health Survey Uganda, 2011
Administrative Boundaries (GADM.org)

African Environmental Stability Project
United States Military Academy, West Point

15,952 Households
652 DHS Clusters

Surface Water
Piped Water into dwelling
Ethiopia

Time to Water

Map by Krakowka et al. (2015)
United States Military Academy
Demographic and Health Survey Uganda, 2011
Administrative Boundaries (GADM.org)
Preliminary Conclusions

• Least vulnerable areas are generally alike. The most vulnerable areas are vulnerable because of their own unique set of circumstances.

• A scalar analysis of vulnerability is crucial to understanding processes that occur at multiple socio-environmental
Modeling World Trade: Land & Sea

Chris Arney
USMA
West Point, NY
Outline

1. **Modeling Global Health (prosperity & harmony) by measuring the World’s Trade networks**
   - Transportation network evolution (global trade) as a proxy

2. **Flow of goods over intercontinental transport networks**
   - On land, revitalization of Old Silk Roads (OSR) through trade routes -- Northern Distribution Network (NDN) or New Silk Road (NSR).
   - Effectiveness & impact of trade networks. Trade moves goods, cultures, technology, knowledge, disease (Marco Polo’s day).
   - At sea, effects as canals & port channels get deeper and wider & companies are larger & fewer.
   - Global Supply Chain: Network measurements guide policies for producing better trade flow.

3. **How to use social networks to measure global prosperity and harmony?**
Earth: How healthy is it? Is it getting healthier or sicker?

A Proxy: Measure the changing health of its transportation-trade networks
Announcement: Interdisciplinary Contest in Modeling (ICM) --- help your students compete

2012
• 1337 three-undergraduate teams worked 4 days in Feb 2012 to solve a criminal conspiracy problem
• 83 people in the company
  (8 known conspirators, 7 known non-conspirators)
• 600 messages

2014
• 1028 teams
• Erdos collaboration network (510 coauthors, 1400 papers)
• Which papers are the most influential in network science?
• Which individual network researcher is most influential?

2015
• 1496 teams confronted a challenge to measure sustainability for low development countries
• 641 teams took on Measuring churn and other human capital properties in an organization
• ICM is in conjunction with 3 problems in the mathematical contest in modeling

See Comap.com and sign up a team or two from your school for 2016’s contest (in February) involving interdisciplinary problems in network, environmental, and policy issues.
Lay of the Land & Sea Transport & Trade Networks

• Goal: Understand effects of new trade networks & how they affect society
• Build the networks (geographic constraints, structure, attributes, process -- flow)
• Compare to existing networks
• Determine flow mechanisms & usage rates - size, shapes, speeds, hubs, interoperability
• Infrastructure costs
• Maintenance & movement
• Trade volume and revenue
• Effect on Society
The Social Aspects & Impacts

- Spatial Cohesion & Social Contagion
- Vulnerability & Security factors
- Human elements -- political, diplomatic, gov’t
- National Measures, Regional Measures, Global Measures
- Goals: Economic (prosperity) vs Social (Human Rights)
- Policy Decisions (questions: to participate, to develop systems, which modes, where, tipping points)
Philosophy of the Health Model

• Health comes from prosperity (network functionality & harmony) and its equality.
• Isolation or low trade adversely affects a nation’s prosperity.
• Extreme inequality undermines world harmony -- unequal opportunity and access to global influence.
• In Network Science terms: Measures of global health are **high density** and **low centralization** in the world trade network -- less variance in centrality and data.
Land Transportation & Trade --- The Asia-Europe (and now Africa) Corridor

• Old Silk Road (OSR) (100BC-1400) (5,000 miles)
• No Road --- Central Asia Land-bridge closed (1450-1960)
• New Silk Road

• Speed factors:
  Time vs distance
  (road, rail, sea)
The New Era in Central Asia

- Kazakhstan (16.6 m), Kyrgyzstan (5.5 m), Tajikistan (7.6 m), Turkmenistan (5.1 m), & Uzbekistan (29.5 m), the region’s potential is finally realized by other nations.

- US resupply in Afghanistan developed the NDN.

- China, Russia, Iran, and US have strong competing and cooperative reasons for developing the NSR (roadways, railways, pipelines)

- Ultimate Multi-modal transport network
One View: A Giant (8,000 mile) Land Bridge through Central Asia
Another view: The Transit Map of OSR

Old Silk Road

Northern Route

Southern Route

Europe/Rome

Damascus

Persia

Merv

Kashgar

Hami

India

Khmer

China/Fujian

Peking

Water Route

Alexandria
The Transit Map of NDN

NDN (mainlines)
There is more, much more

NDN (main & subs)
Much More to do
Flow & Usage rates and costs

Cooperation drives down prices & builds efficiencies

Rail Link or Sea Lane --- 36 day container ship trip reduced to several 13 day freight train (China-Europe)

Multimodal (diversity always helps)

Rail link Problems (differing rail gauges)

Border Crossing Issues (tariffs, fees)

Social and Political issues abound
Status Report

NSR produces a large central trader --- China gaining more centralization along with US domination (not good for global health)

Social factors are unsettled and unresolved – potential for advances in societal health as the islets become more central

Multi-modal trade is good for economy & control & influence (less centralization --- more places for the smaller nations)

New players (like Iran) can emerge and gain stature in the network (less centralization)
# Sea Lane Evolution/Revolution

<table>
<thead>
<tr>
<th>Before Canals</th>
<th>Modern Shipping</th>
<th>Mega Shipping</th>
</tr>
</thead>
<tbody>
<tr>
<td>No containers</td>
<td>5,000 container ships</td>
<td>18,000 container ships</td>
</tr>
<tr>
<td>Suez --- 1870</td>
<td>Efficient-designed ports</td>
<td>600–ship companies</td>
</tr>
<tr>
<td>Panama -- 1914</td>
<td>Suez (26 ft depth, 16 hrs for 120 miles)</td>
<td>New Panama Canal</td>
</tr>
<tr>
<td></td>
<td>Panama (40 ft depth, 20 hrs for 48 miles)</td>
<td>(25% longer, 50% wider, 25% deeper)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Net Suez facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(79 ft depth)</td>
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<tr>
<td></td>
<td></td>
<td>North Passage studies</td>
</tr>
</tbody>
</table>
• International Maritime Organization -- UN agency responsible for shipping and prevention of marine pollution.

• Value of TEU container lies in how it is used.

• **Container** -- basic entity of flow networks for moving goods from anywhere to anywhere.

• 30 million containers in the world. Each of them with 60,000 pounds of something. Doesn’t matter what you’re shipping – the price is the same.

“The Box, How the Shipping Container Made the World Smaller and the World Economy Bigger,” by Marc Levinson.
The Good, Bad, and Cold (the north is open for business)

9,321 miles
Shorter voyage, saves on fuel, but fewer ports for shelter and must hire icebreakers

14,000 miles
Traditional shipping route, open year-round but threatened by regional instability
The Transit Map of Sea-lanes (Atlantic-centered)
The Transit Map of Sea-lanes (Pacific Centered)
A Transit Map of Sea-lanes (Arctic-Centered)
Sea-Lane Flow Summary

• US gains from Panama Improvement (more centrality)
• China gains from Suez Improvement (more centrality)
• Russia gains from Northern Passage opening (more centrality)
• Rest of the world loses if big companies/nations (the Big 3) get bigger (more centralization), or gains if everyone gains from these changes (less centralization).
Still much to do

• Human-based measures for prosperity and harmony from multi-modal trade/diplomacy networks.

• What is the impact of greater trade density. Everyone can’t be central but can be equal (less centralization in trade). The Silk Road’s Bigger, Stronger, Fewer, does not help.

• Probability for 50% increase in trade in less than 10 years?
Africa Megacity Vulnerability Network

Rapidly evolving social, economic, and physical structures throughout the world suggest that future operations will involve complex systems, unexpected scenarios, and nonlinear processes. These systems have been described as having four components: volatility, uncertainty, complexity, and ambiguity (VUCA) (Kail, 2010).

The following questions will guide our research:
• Who are the key actors and what are the main supply-chains and core processes? How do these develop and change?
• Who is vulnerable? Why are they vulnerable? How do we mitigate risk and vulnerability?
• How are Infrastructure/Resource/Logistic networks sustained when growth outpaces capacity?
• How does environmental stress, to include resource demand and pollution, exacerbate vulnerability and strain networks?

This research will use our vulnerability framework and social network models to reveal the dynamics in urban and peri-urban spaces to expose critical elements and vulnerable populations.