

# **Session 9: Network Modeling: Merging the social and physical**

Amy Krakowka, Kate Coronges, and Chris Arney  
United States Military Academy, West Point, NY

- **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

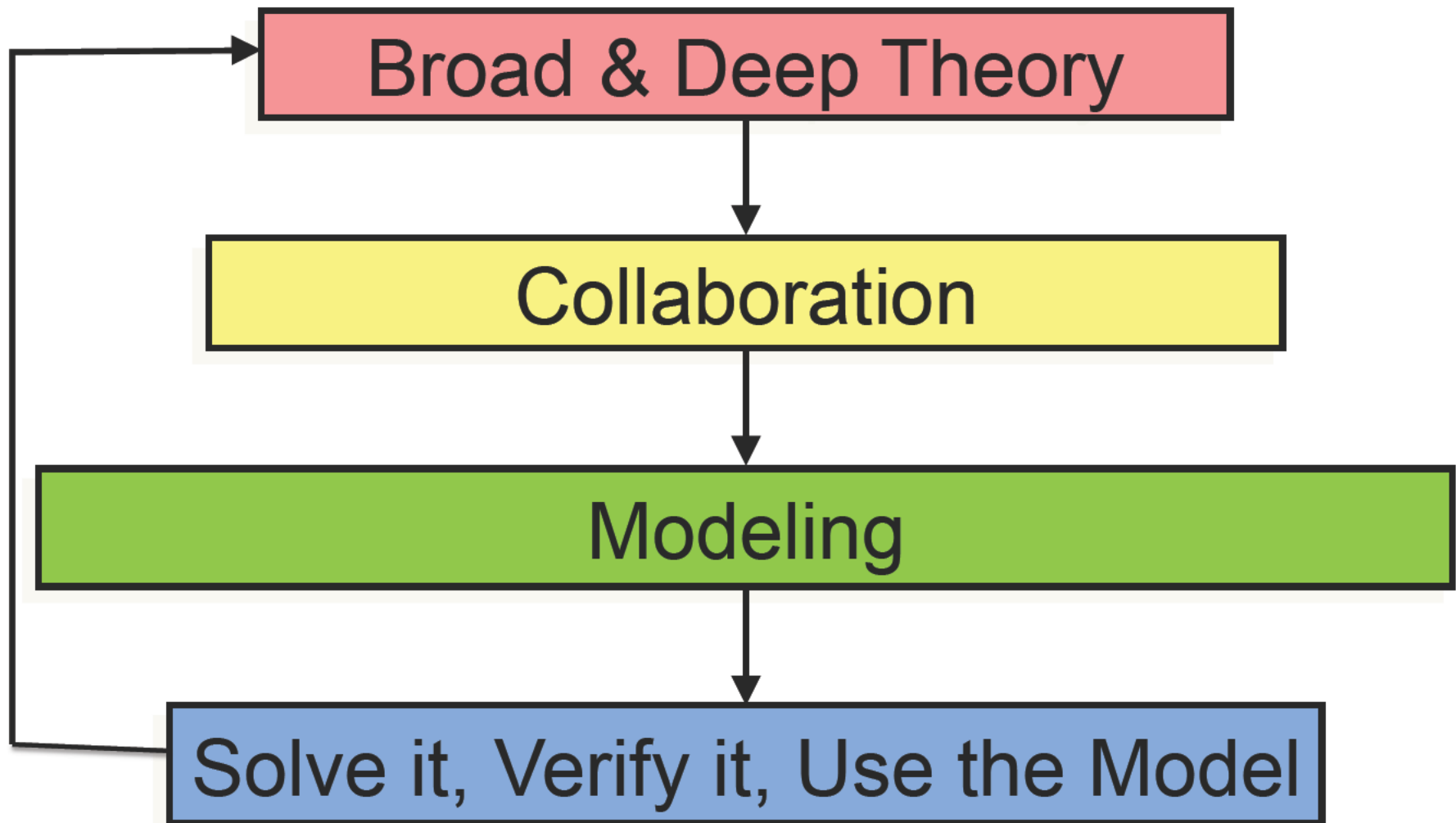
Part of Team Development:

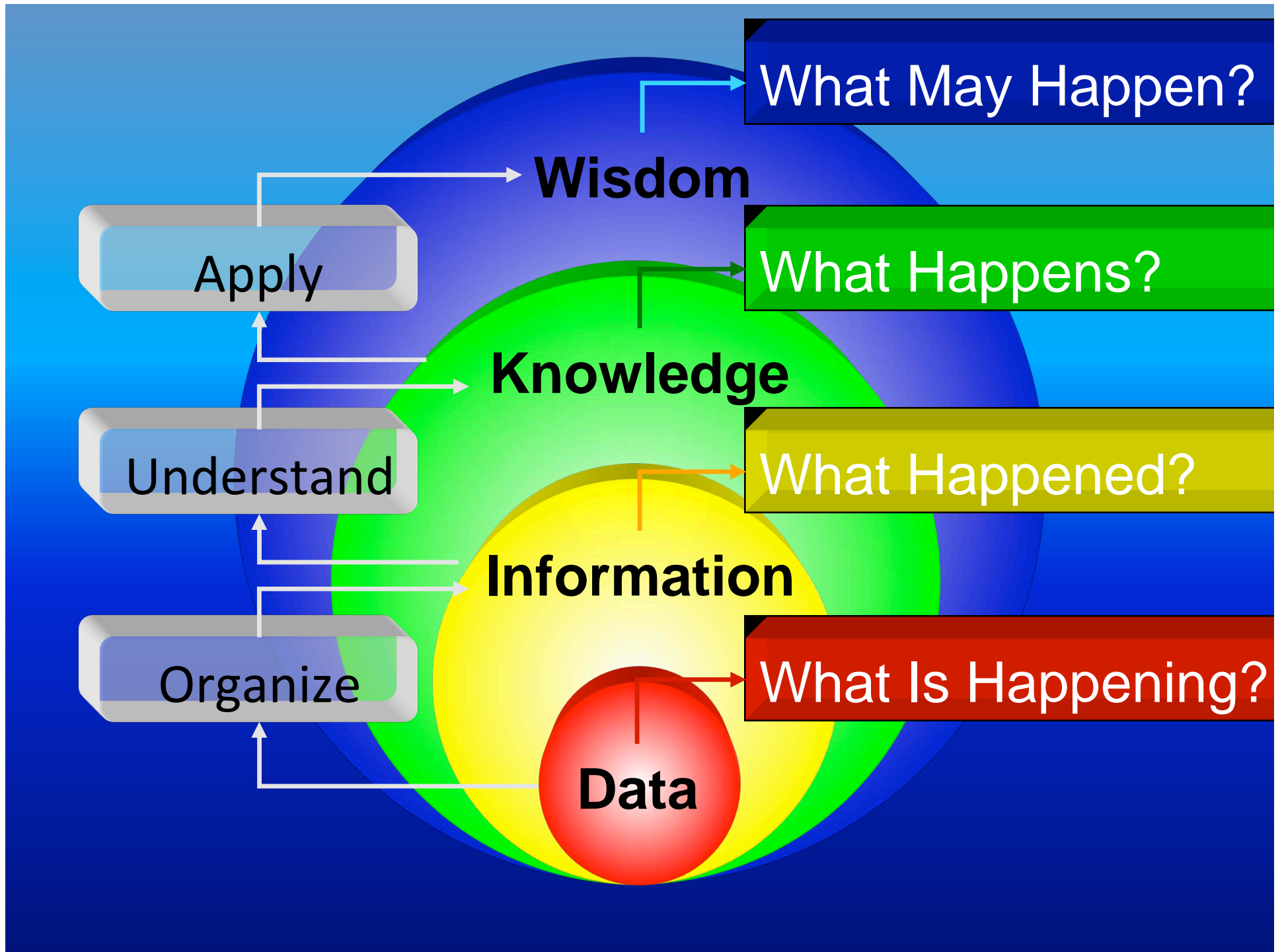
- Leader
- Collaborative Team Member

# Modeling as an enabler of problem solving.



# Modeling and Problem Solving





# 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

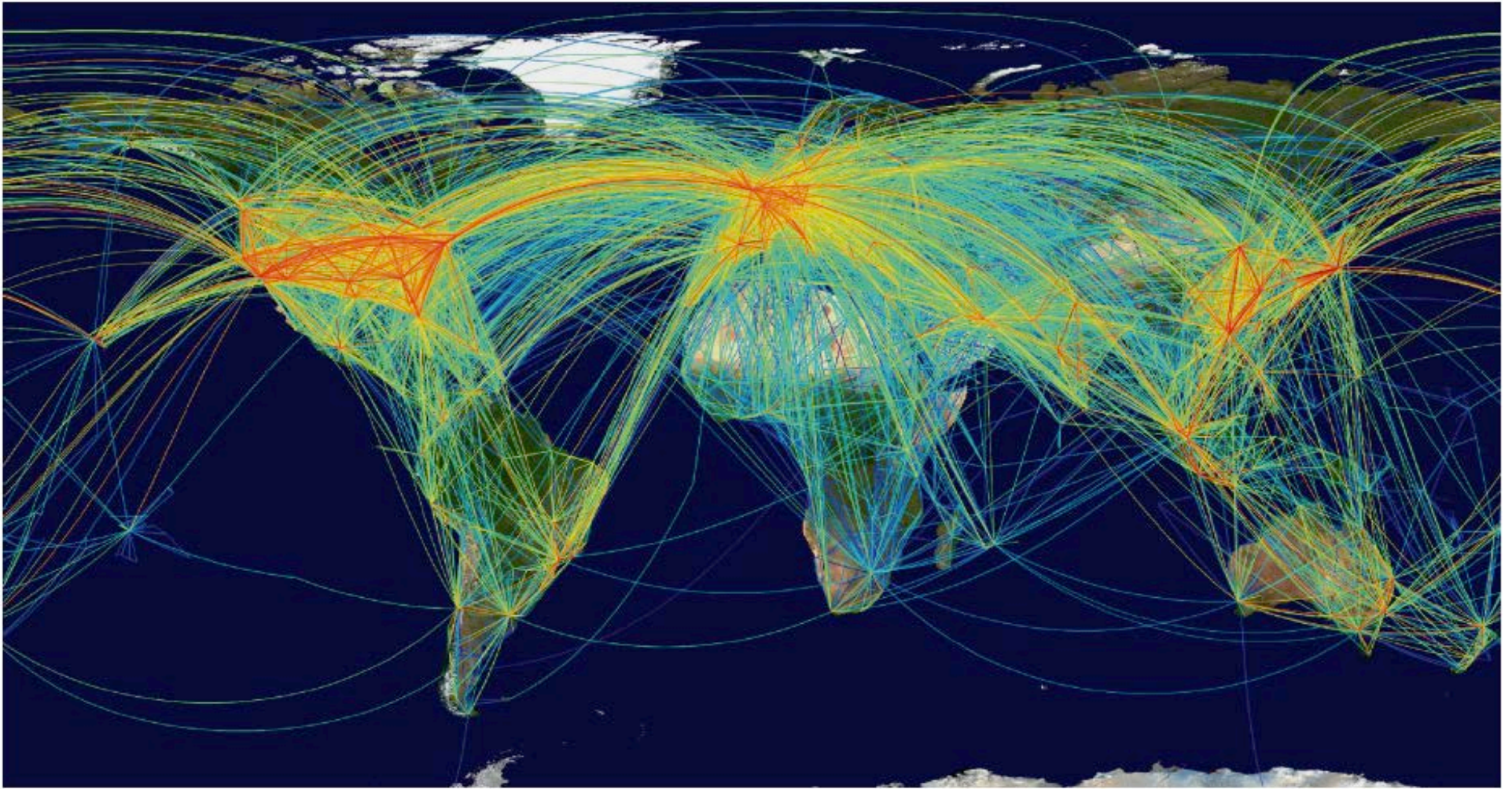




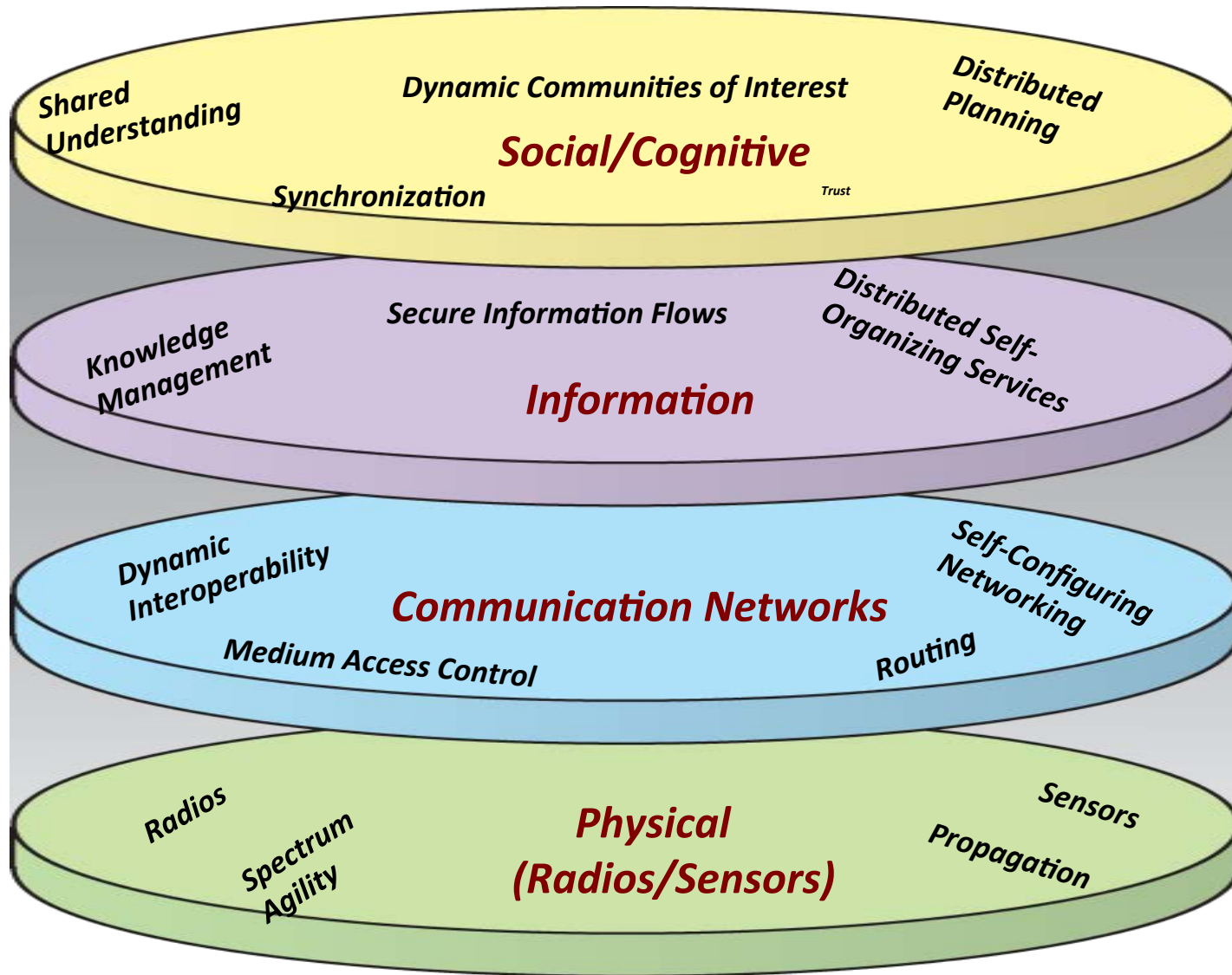
# London



# Some of the Flights



# What is a Network?





UNITED STATES MILITARY ACADEMY  
**WEST POINT**

# **Network Modeling of Teams: Linking Layers of Cooperation**

**Kathryn Coronges**

Currently moving to Northeastern Network Science Institute

Boston, MA

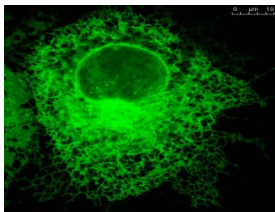
**Chris Arney**

United States Military Academy, West Point, NY

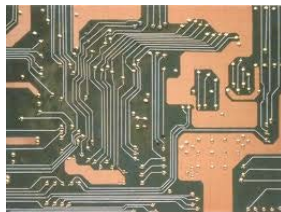
# Network Models used to understand and predict *relationships* in terms of influence, tipping points, feedback and emergence.

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

**Biological**



**Physical**



**Geo-spatial**



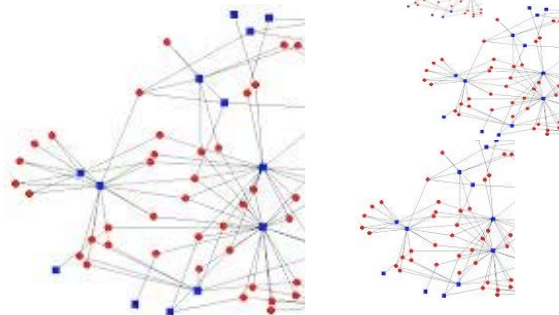
**Social**



**Attributes**

- Demographics
- Affiliations
- Knowledge Beliefs
- Resources

**Evolve**



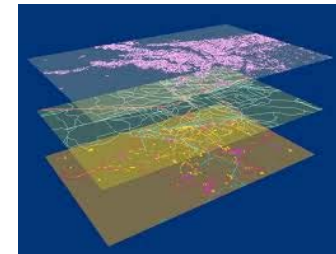
**Multi-modal**

- Biological
- Physical
- Social



- Location
- Political
- Hashtags
- Skills
- Knowledge
- Terrorist group

**Multi-dimensional**



Information, Cognition Social,  
Physical, Biological

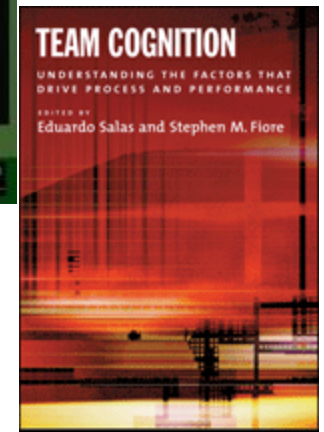
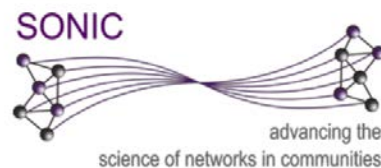
**Use network analysis to explain phenomena that**

- 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.



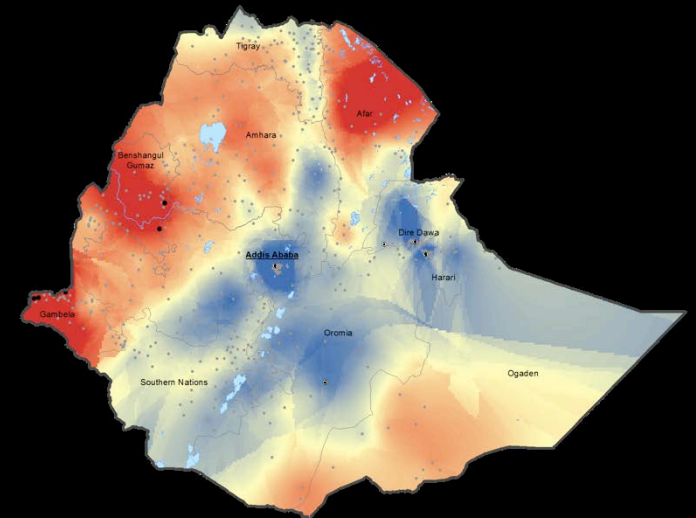
# Team Science



- 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*



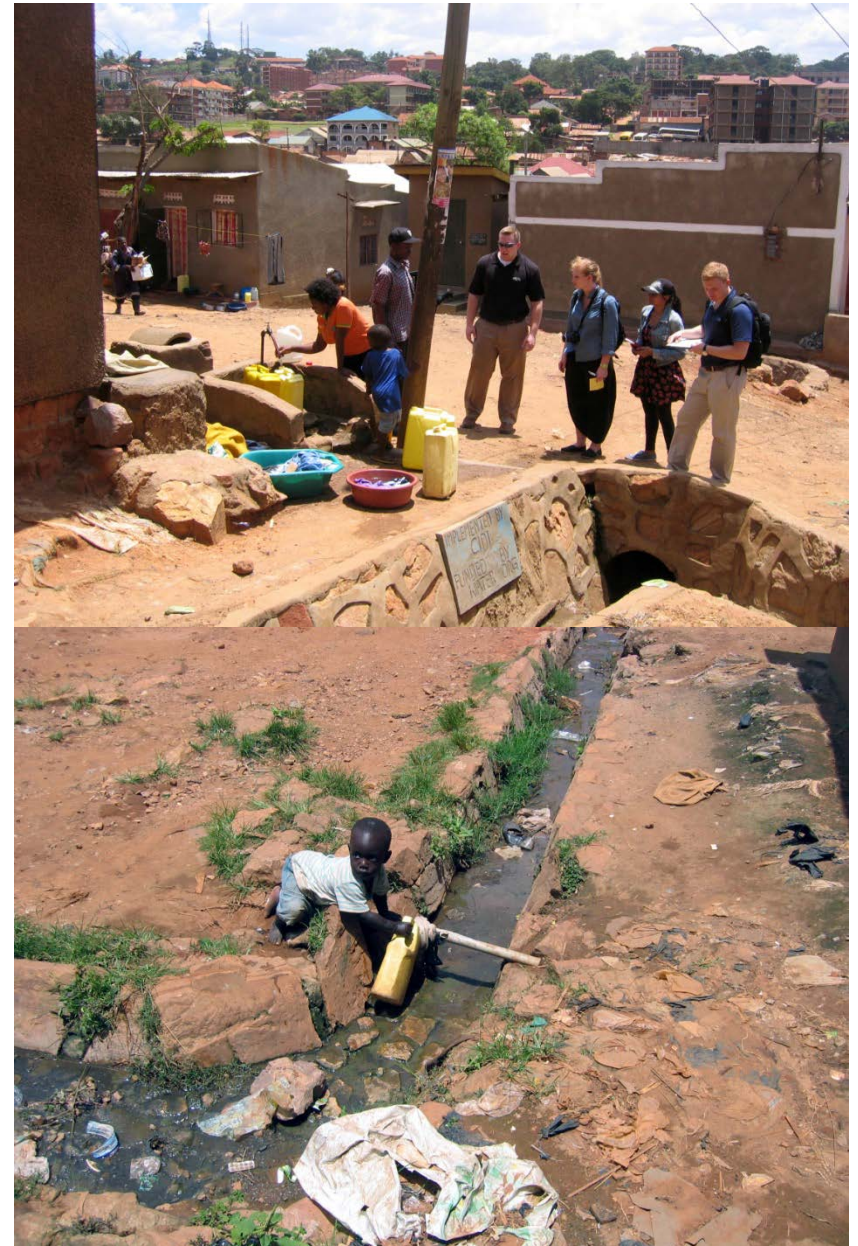
# An Interdisciplinary Study of Household Vulnerability and Wellbeing

**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.

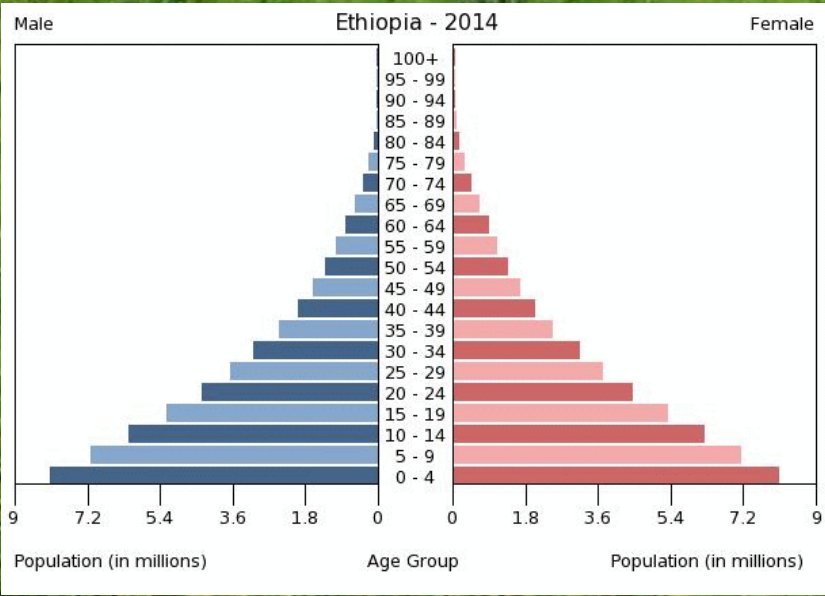
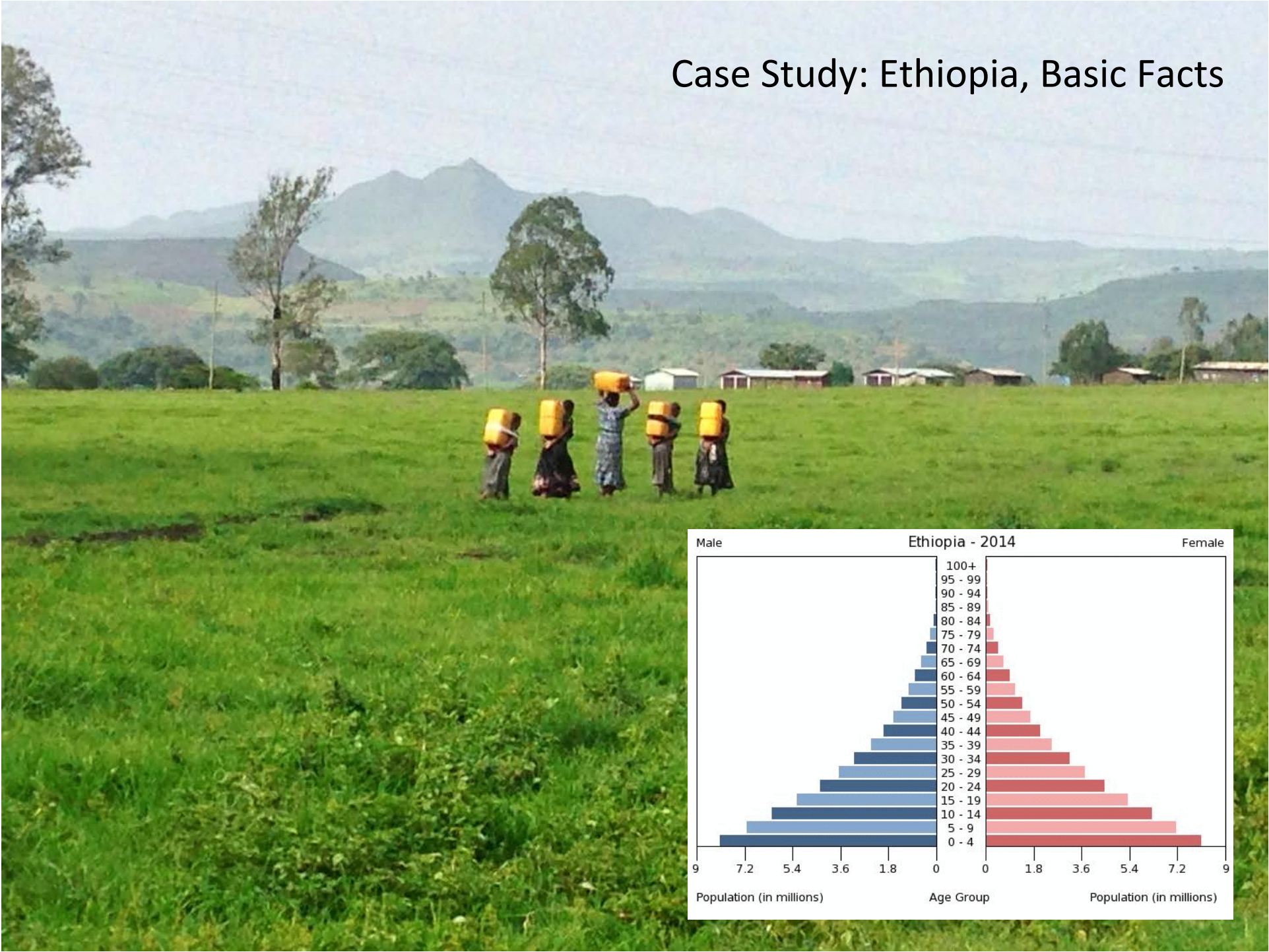
## *Current State of Vulnerability Analysis*

- Scale (national vs. local data)
- No localized variables
- Data availability & reliability

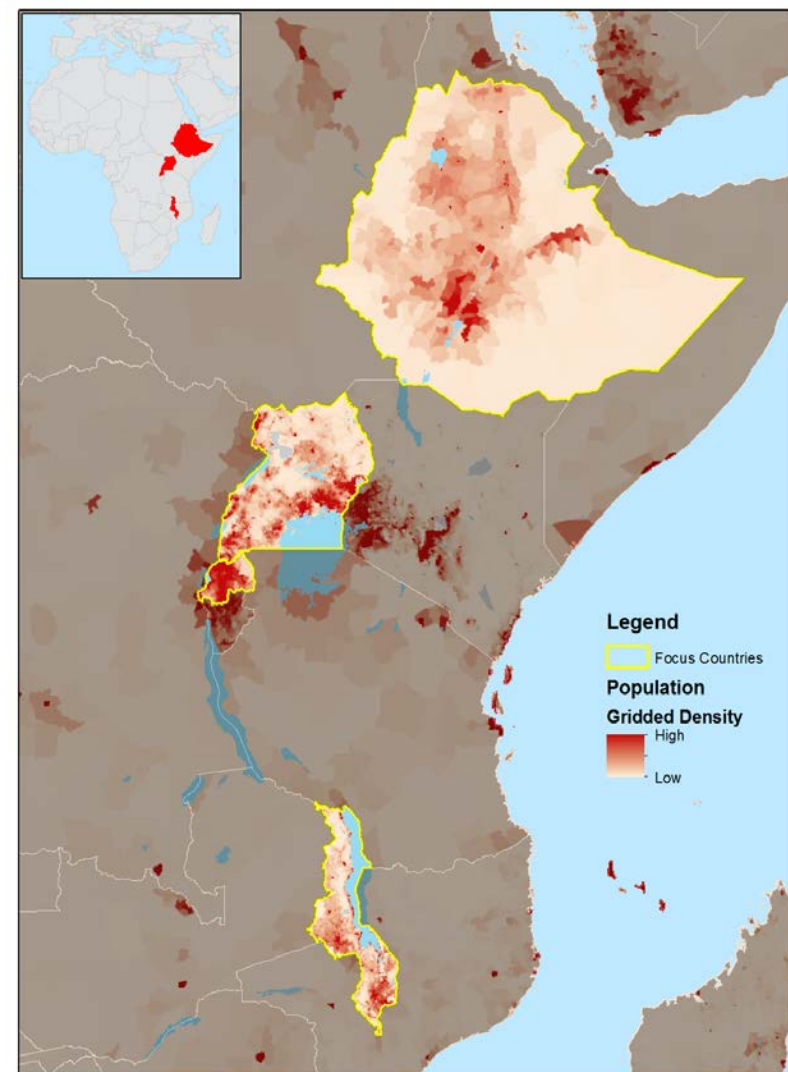
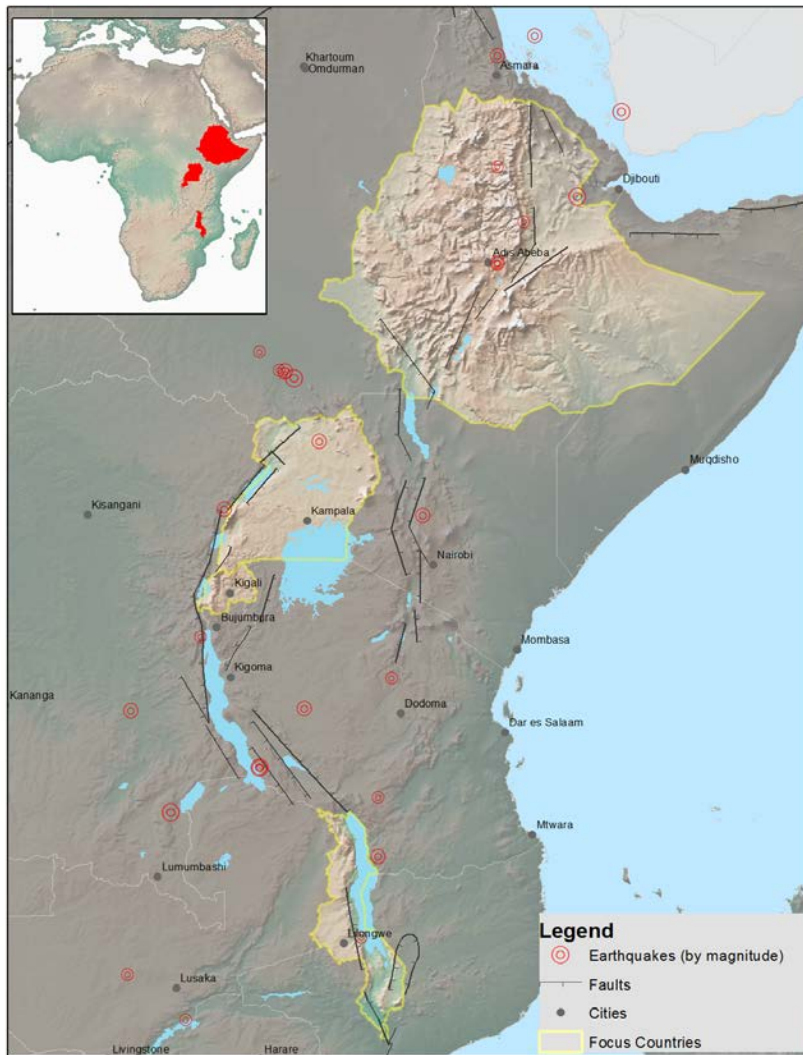
## *Our Methodology*

- Household data
- Expert interviews
- Rich data from a variety of sources.

# Case Study: Ethiopia, Basic Facts



# Terrain and Population Density



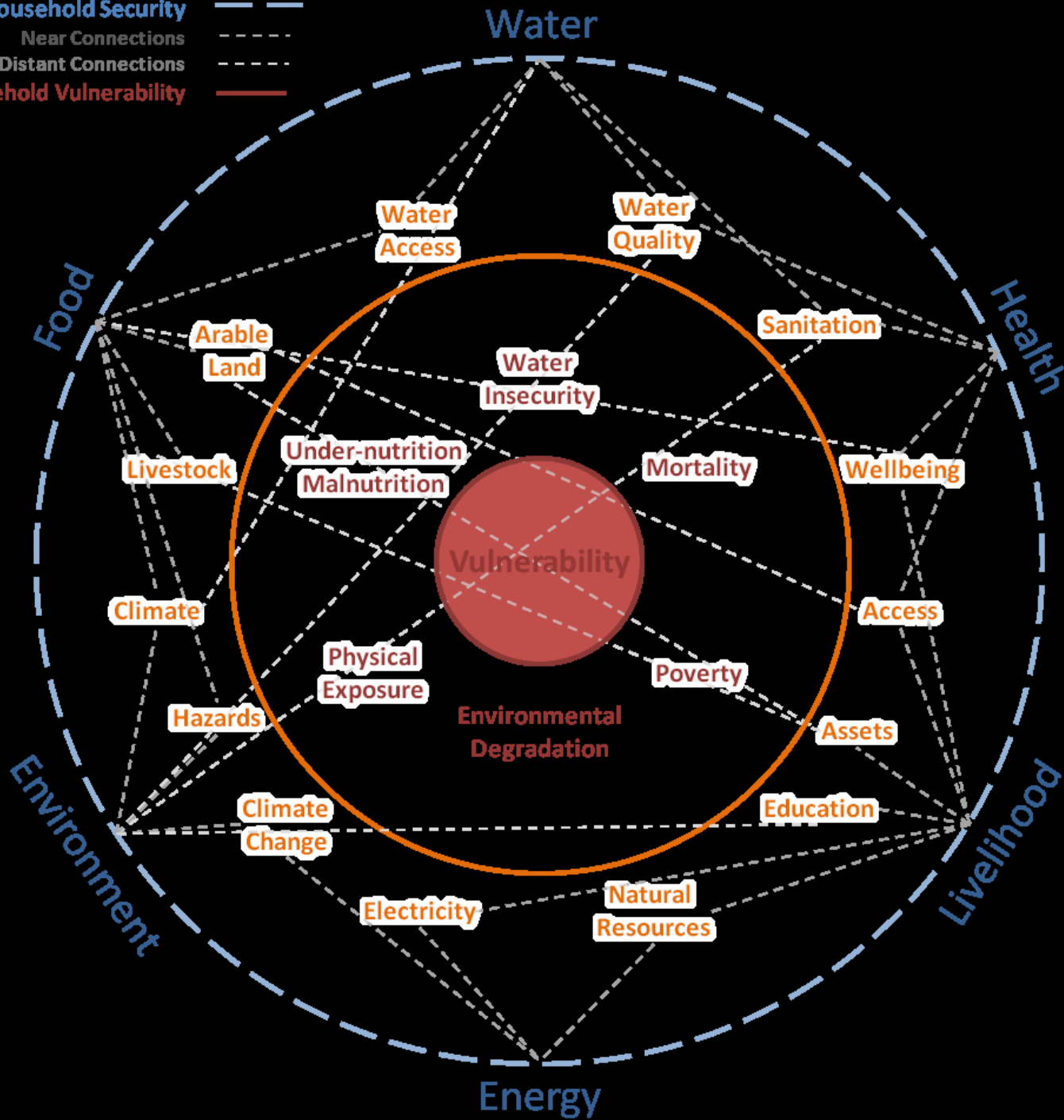
# Pushing towards a middle-income country





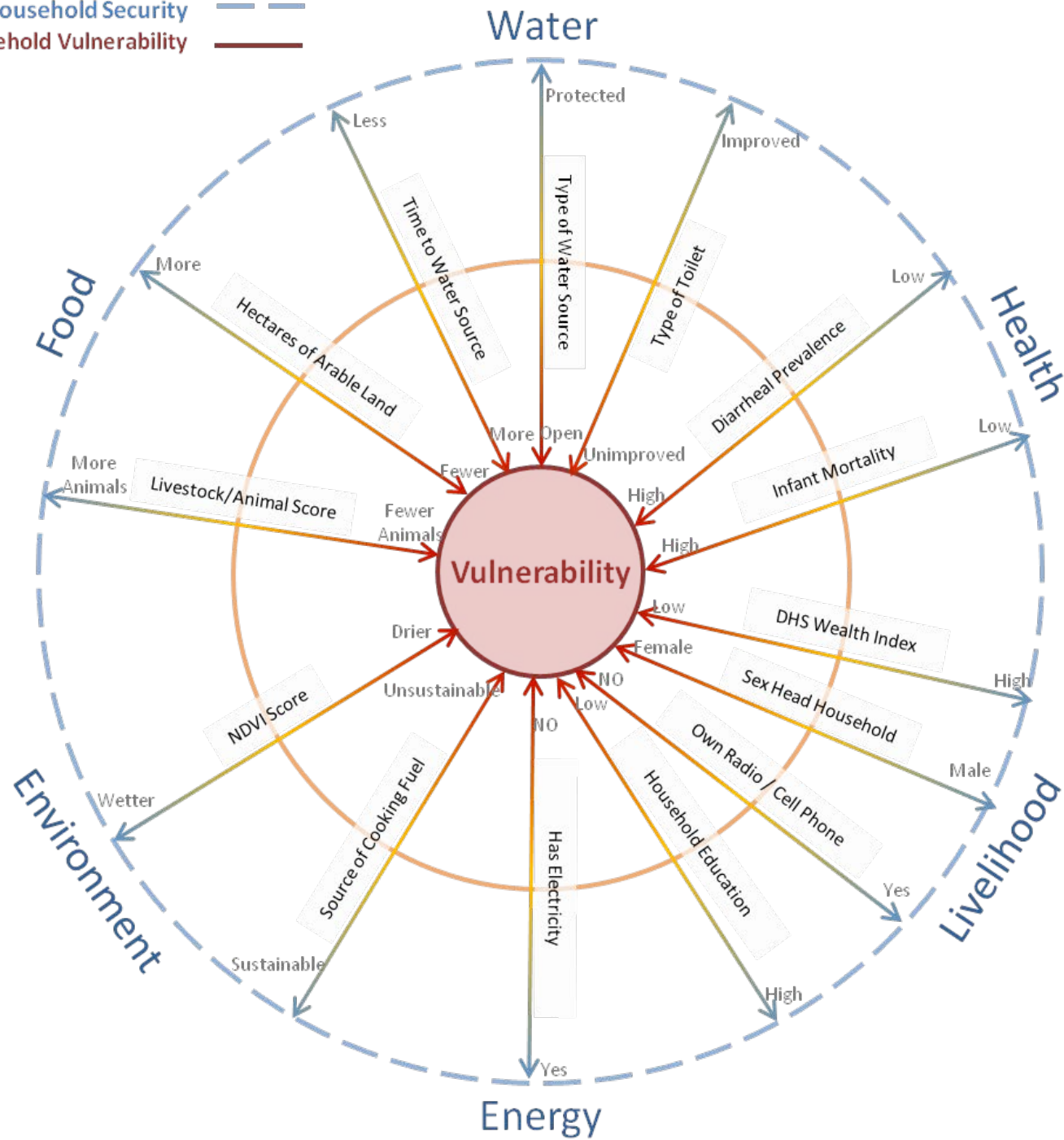


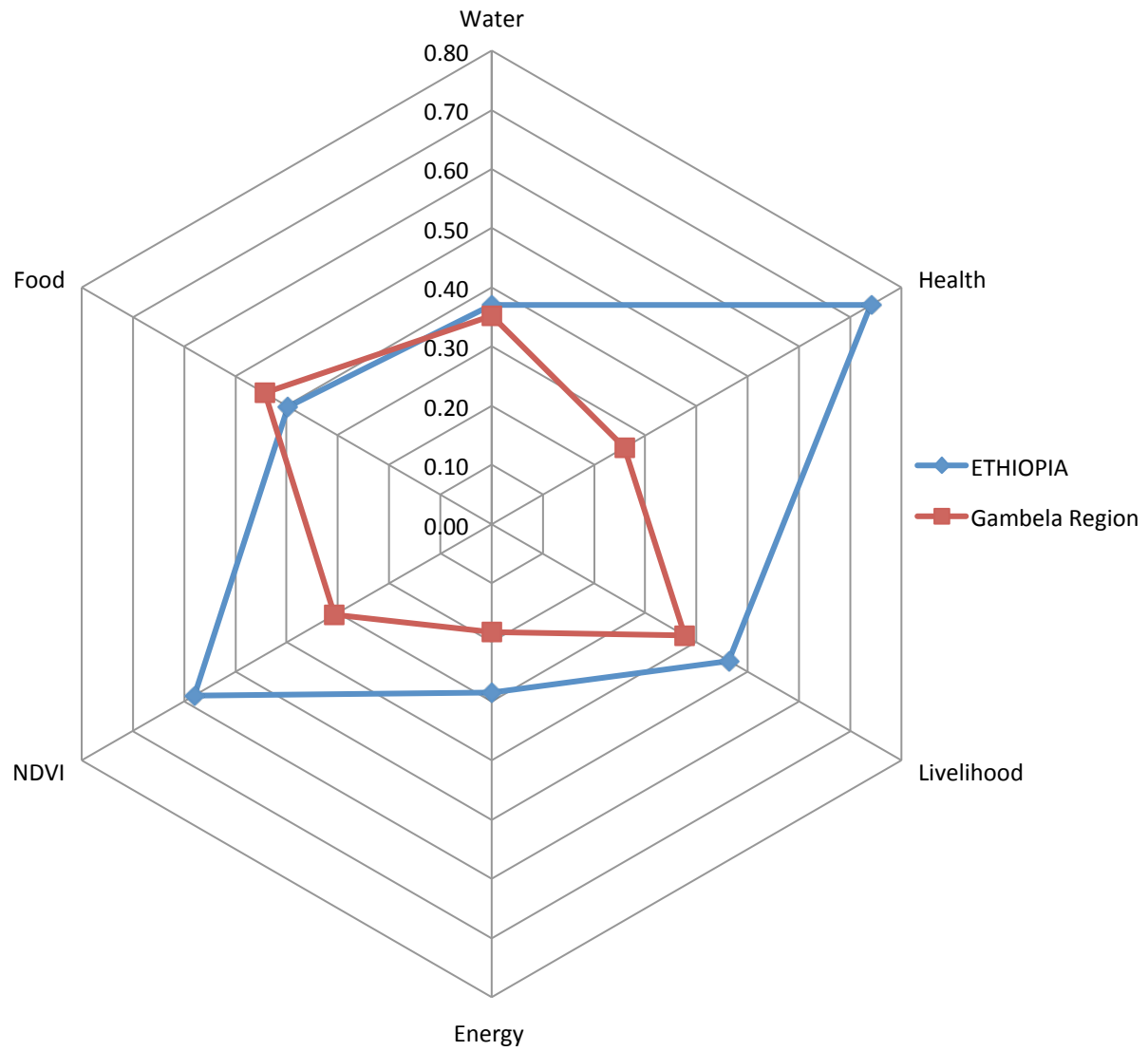
**Household Security** ———  
Near Connections - - - -  
Distant Connections - - - -  
**Household Vulnerability** ———



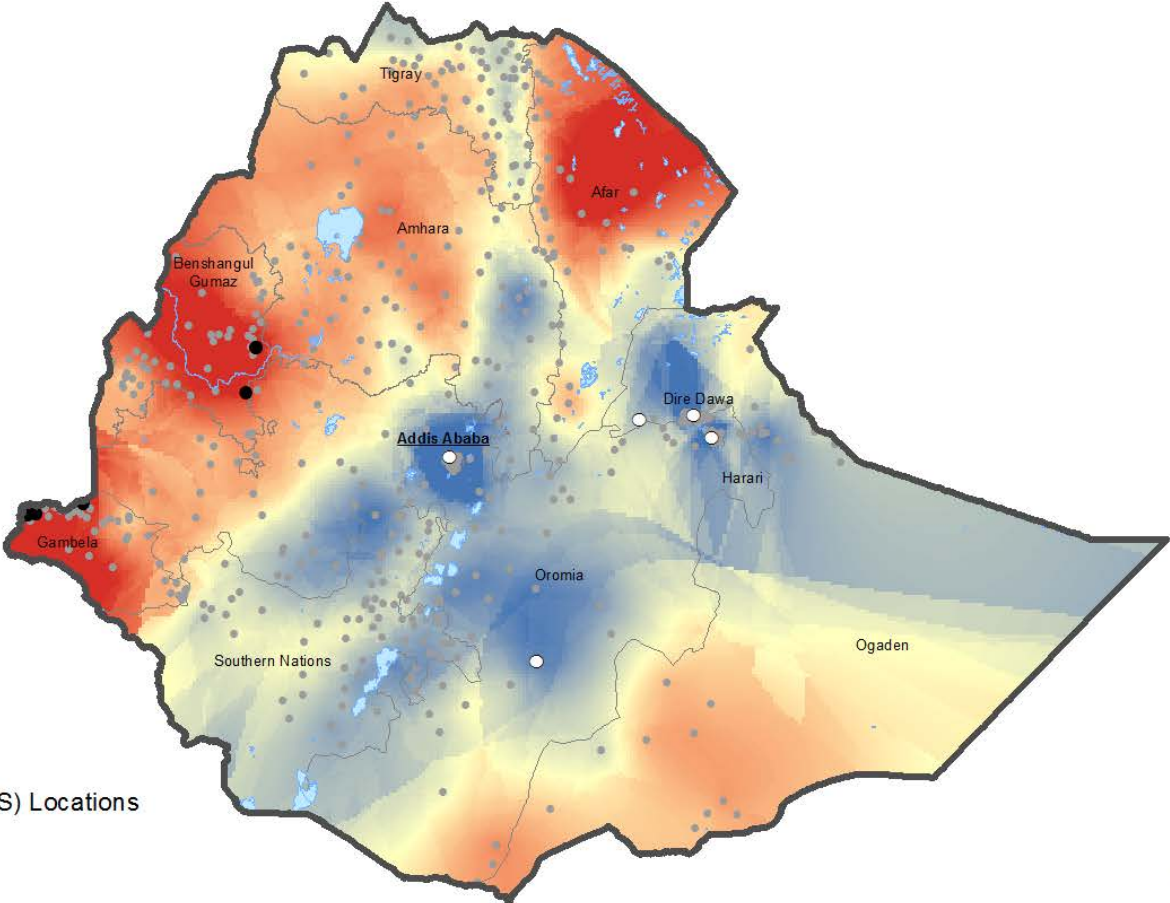


Household Security ---  
 Household Vulnerability ---





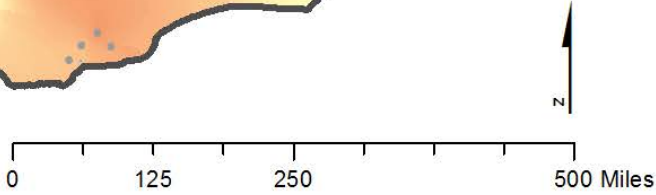
# ETHIOPIA



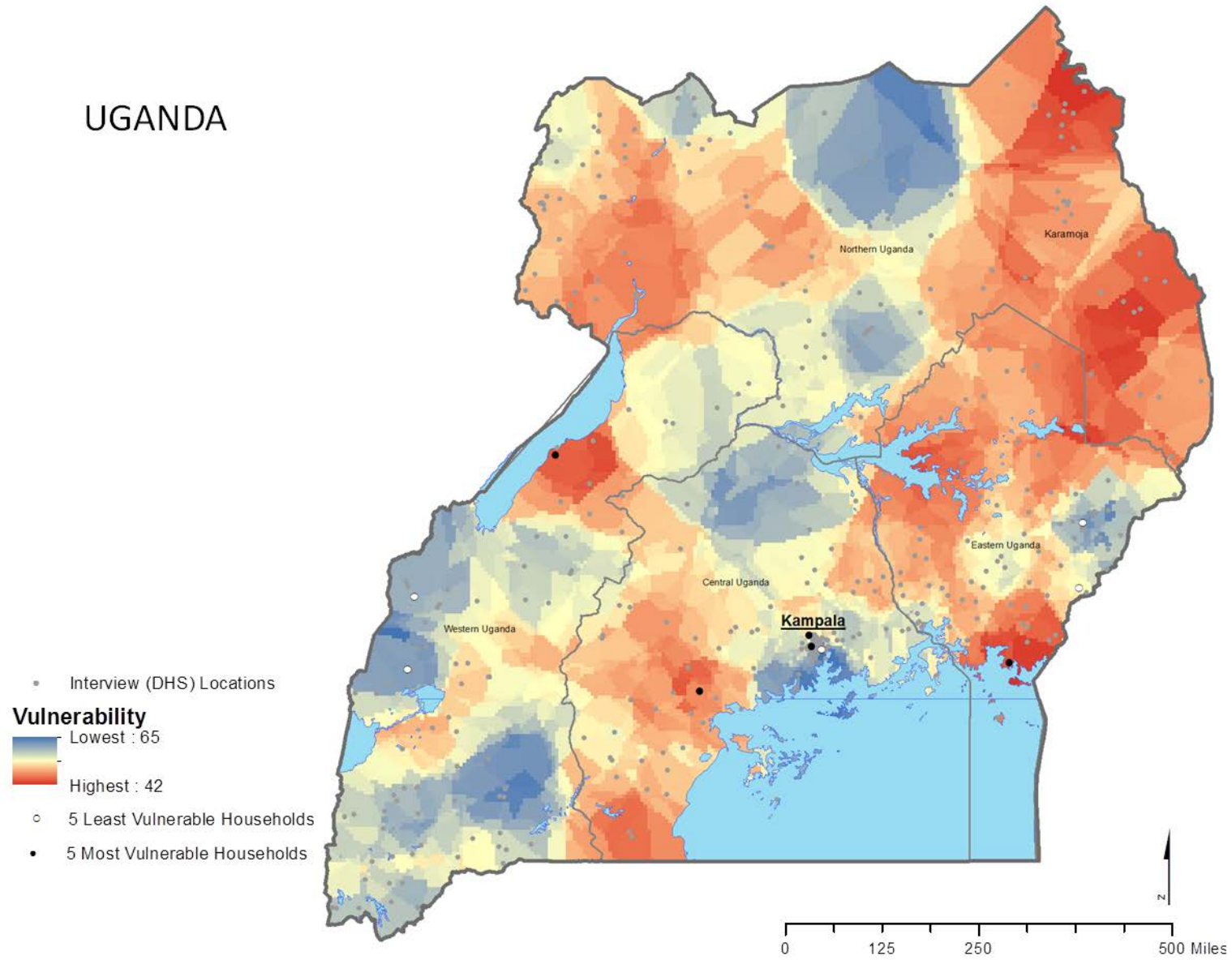
• Interview (DHS) Locations



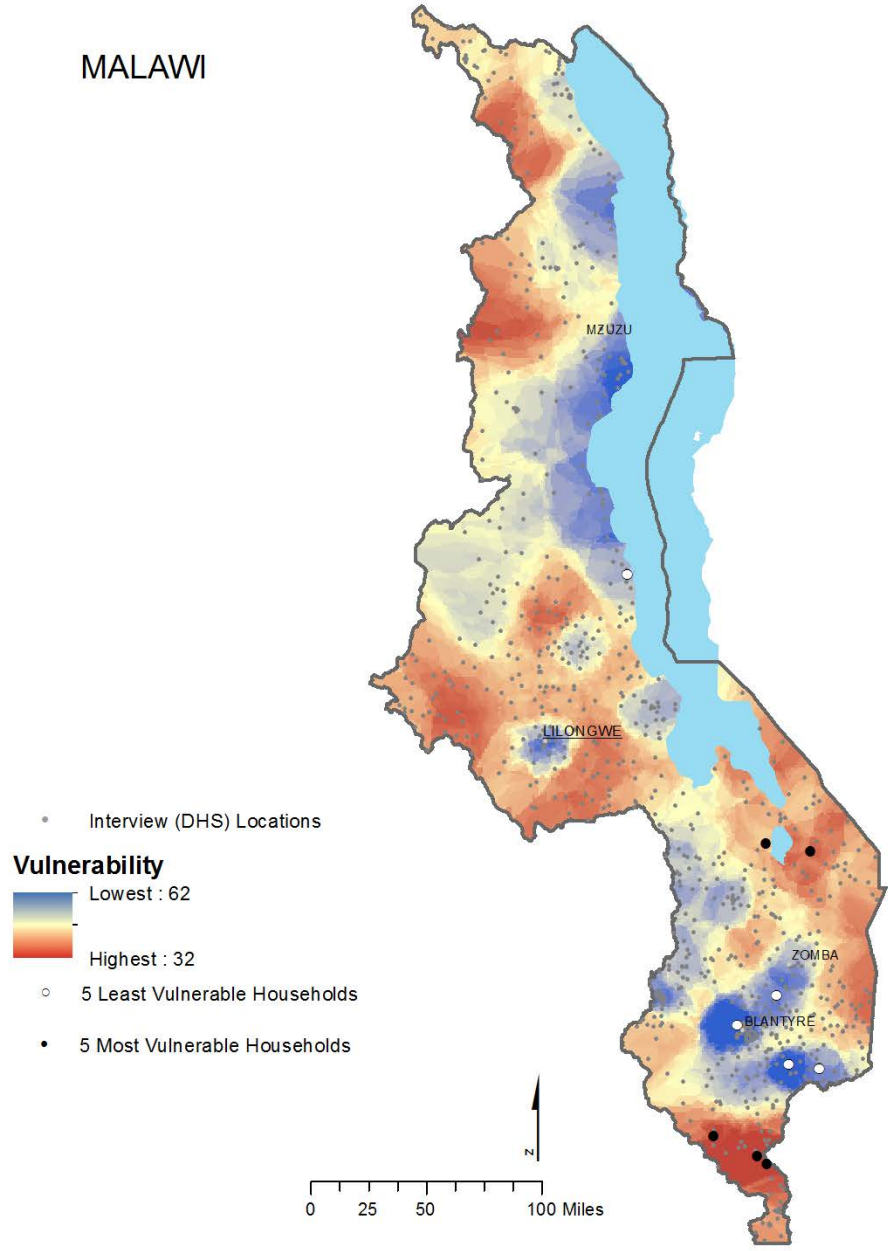
- 5 Least Vulnerable Households
- 5 Most Vulnerable Households



# UGANDA



# MALAWI



• Interview (DHS) Locations

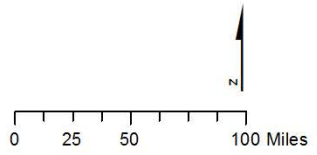
### Vulnerability

Lowest : 62


Highest : 32

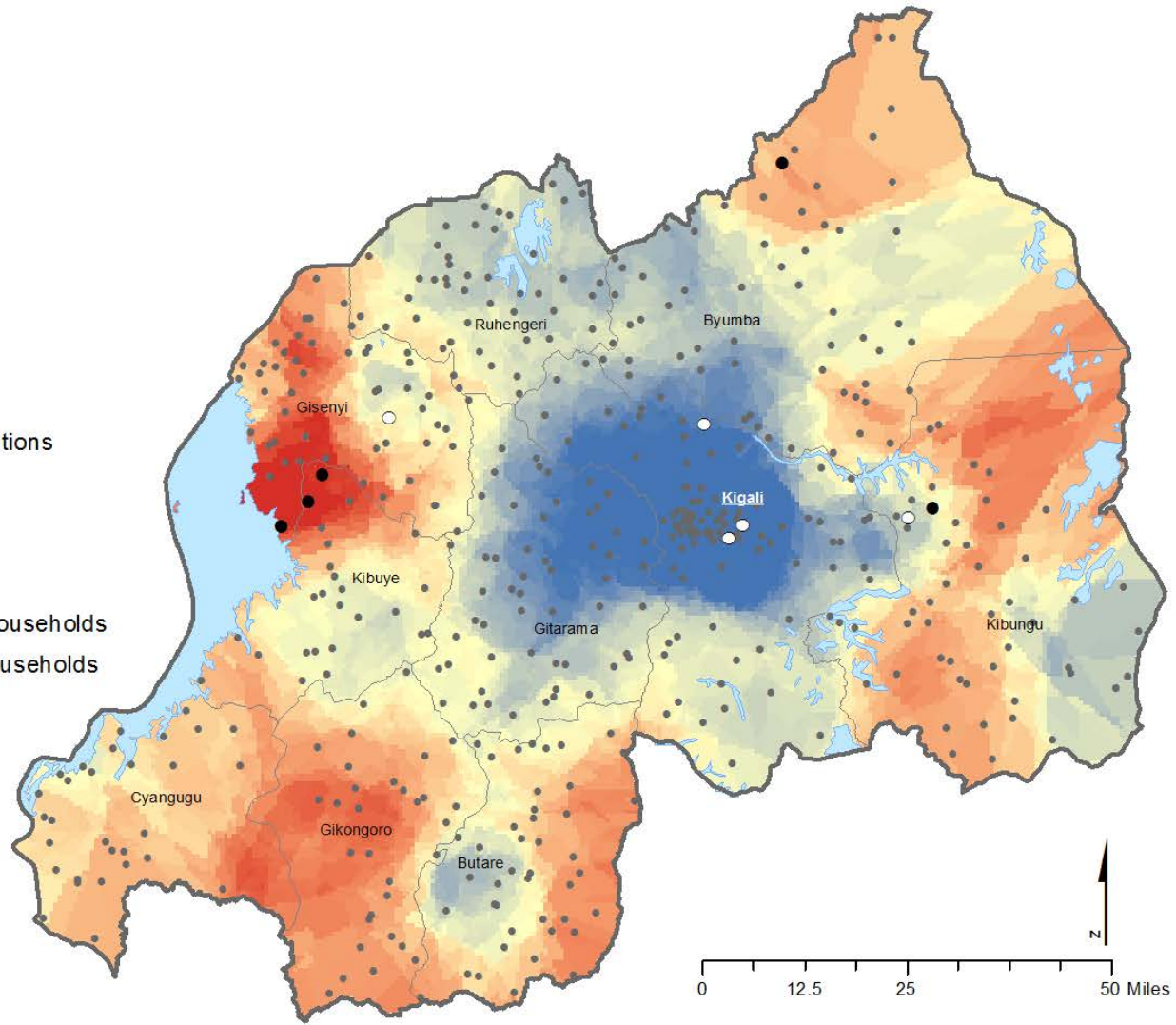
○ 5 Least Vulnerable Households

• 5 Most Vulnerable Households



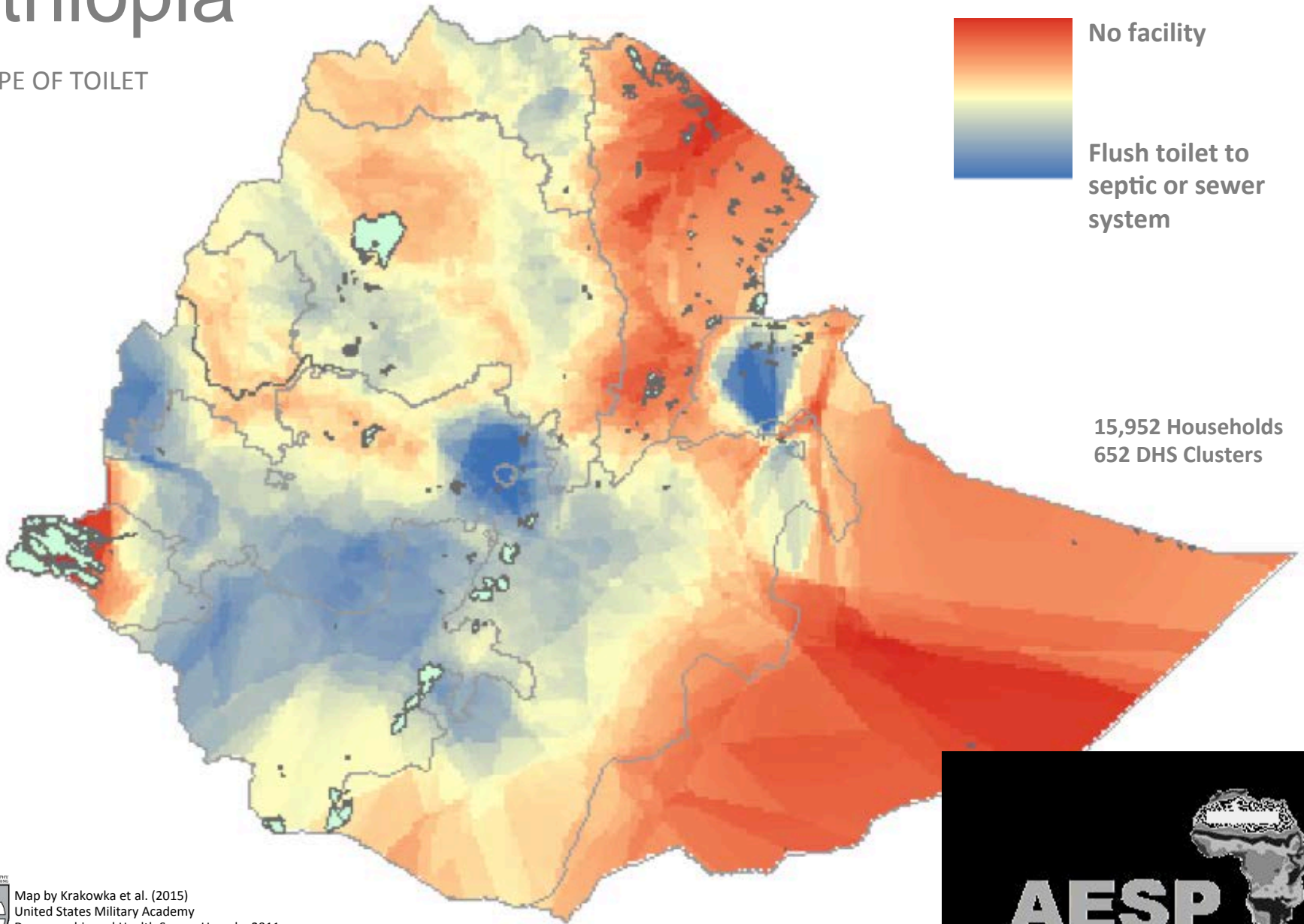
# RWANDA

- Interview (DHS) Locations
- Vulnerability**
- 
- Lowest : 58  
Highest : 34
- 5 Least Vulnerable Households
  - 5 Most Vulnerable Households



# Ethiopia

TYPE OF TOILET



15,952 Households  
652 DHS Clusters

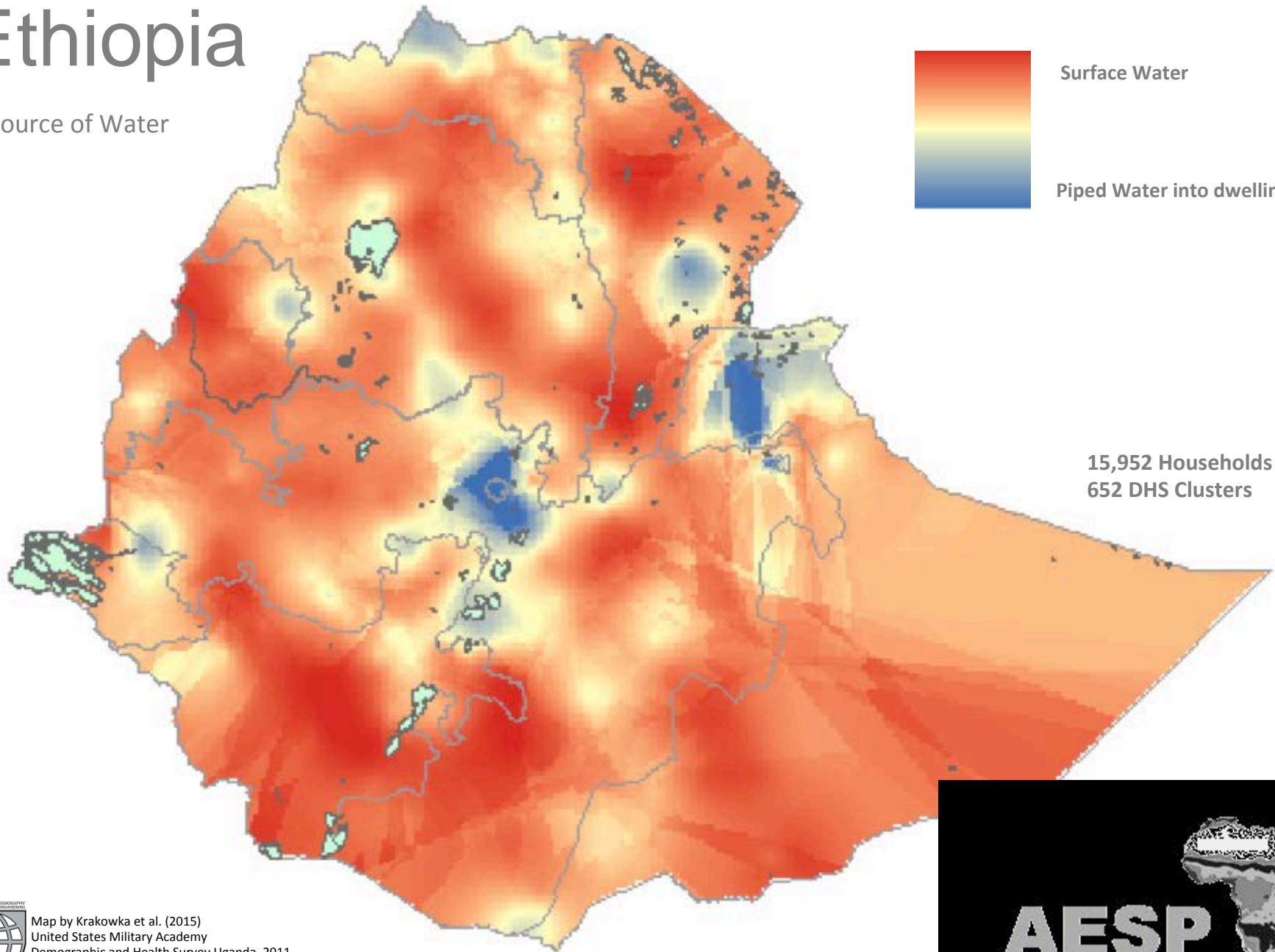


Map by Krakowka et al. (2015)  
United States Military Academy  
Demographic and Health Survey Uganda, 2011  
Administrative Boundaries (GADM.org)



# Ethiopia

Source of Water



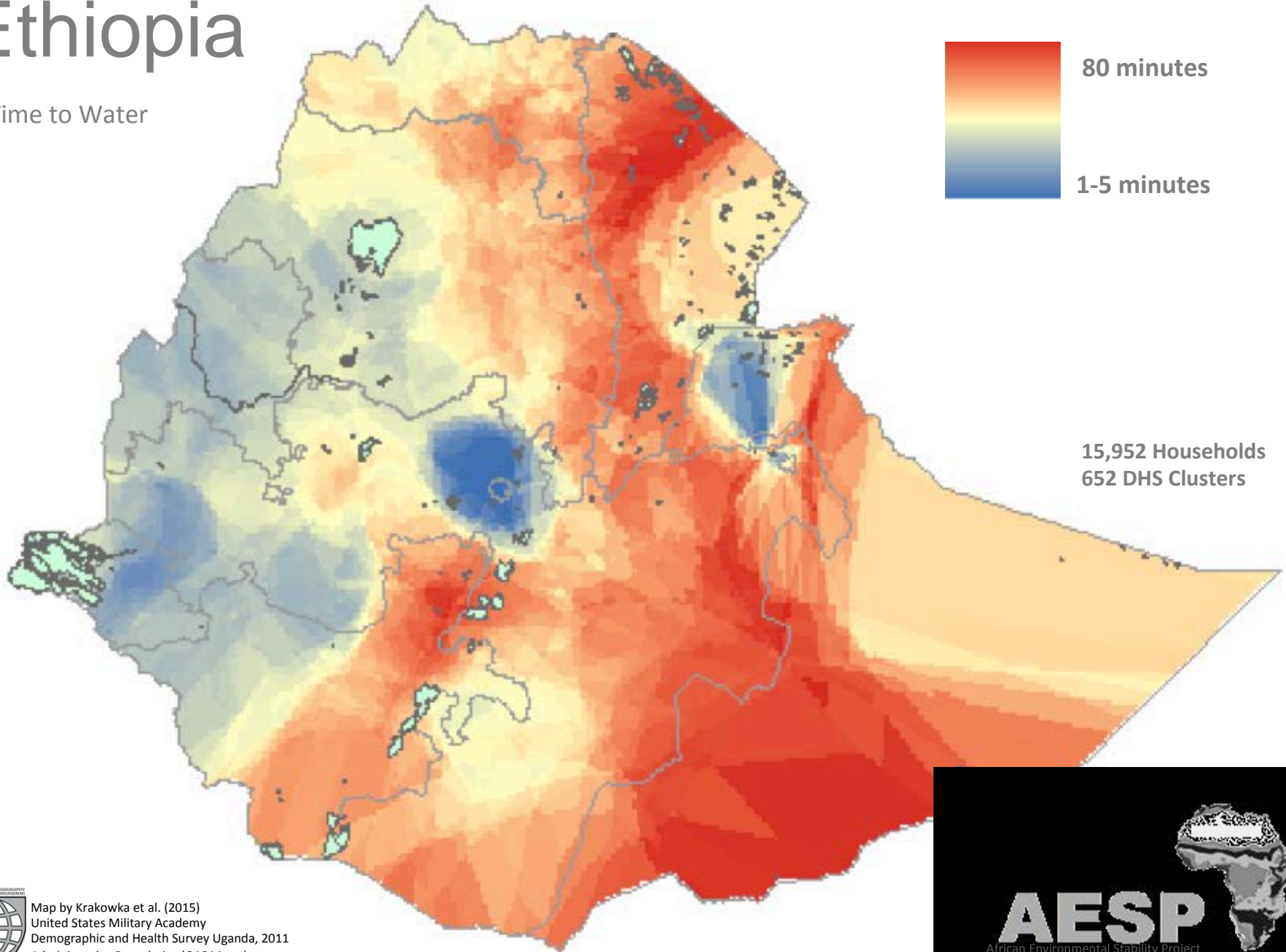
Map by Krakowka et al. (2015)  
United States Military Academy  
Demographic and Health Survey Uganda, 2011  
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# Ethiopia

Time to Water



15,952 Households  
652 DHS Clusters

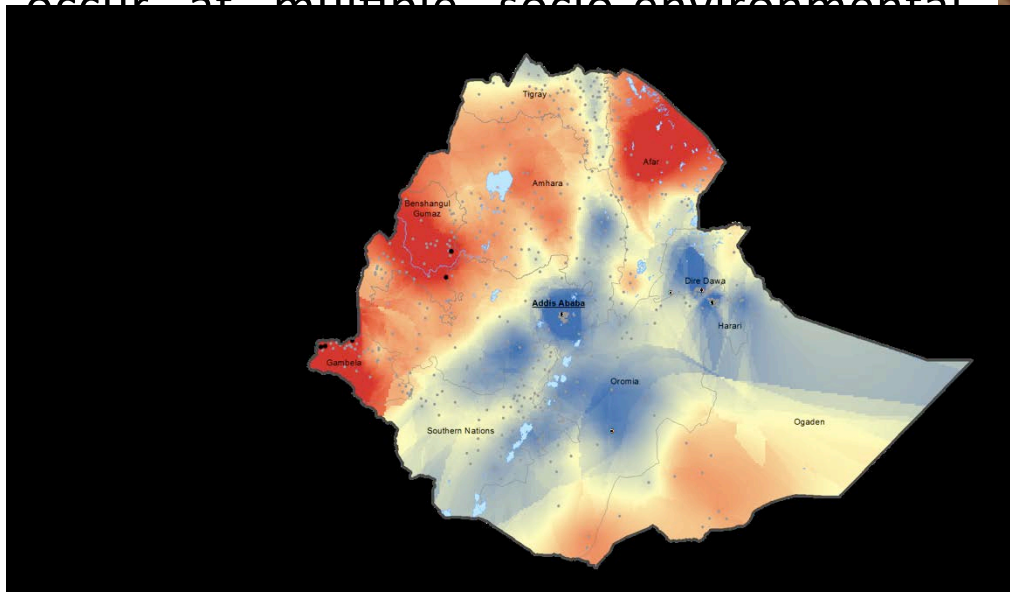


Map by Krakowka et al. (2015)  
United States Military Academy  
Demographic and Health Survey Uganda, 2011  
Administrative Boundaries (GADM.org)



# 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

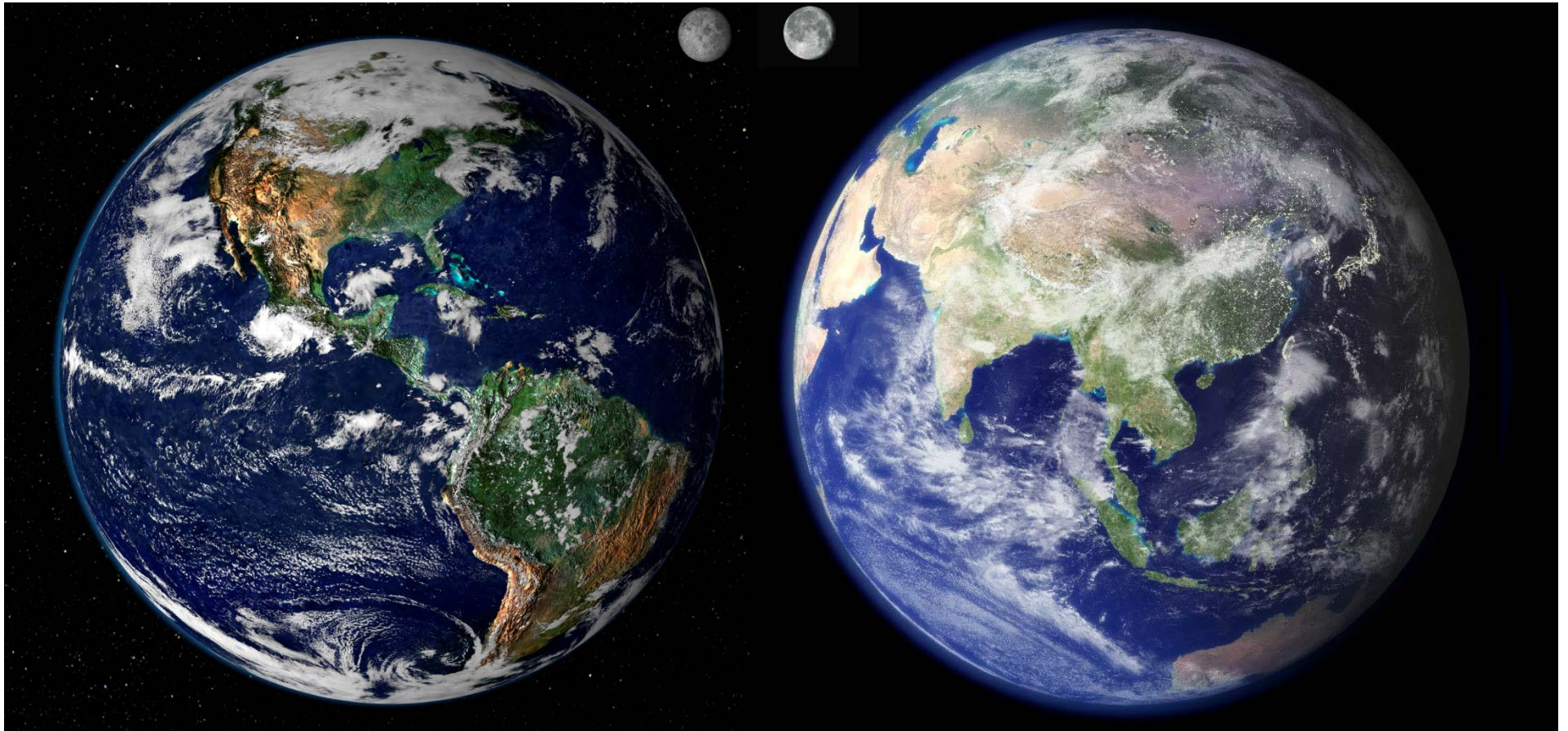


# Outline

- 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?

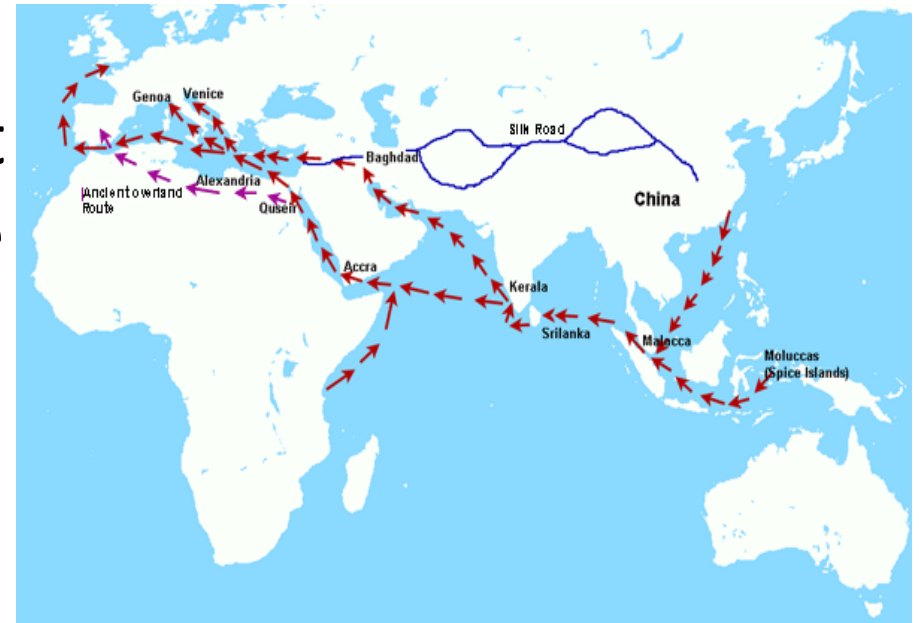
## 2015

- 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](http://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

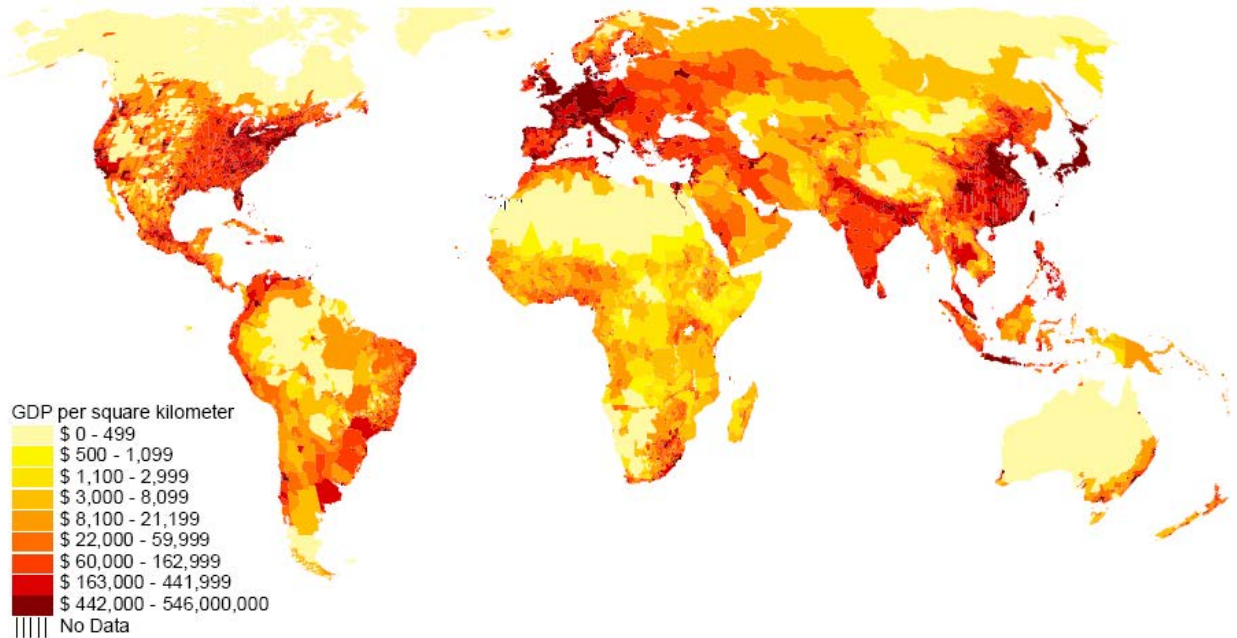


- Spatial Cohesion & Social Contagion
- Vulnerability & Security factors
- Human elements -- political, diplomatic, gov't
- National Measures, Regional Measures, Global Measures
- Goals: Economic (prosperity) vs Social (Human Rights)
- Policy Decisions (questions: to participate, to develop systems,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



# Philosophy of the Health Model

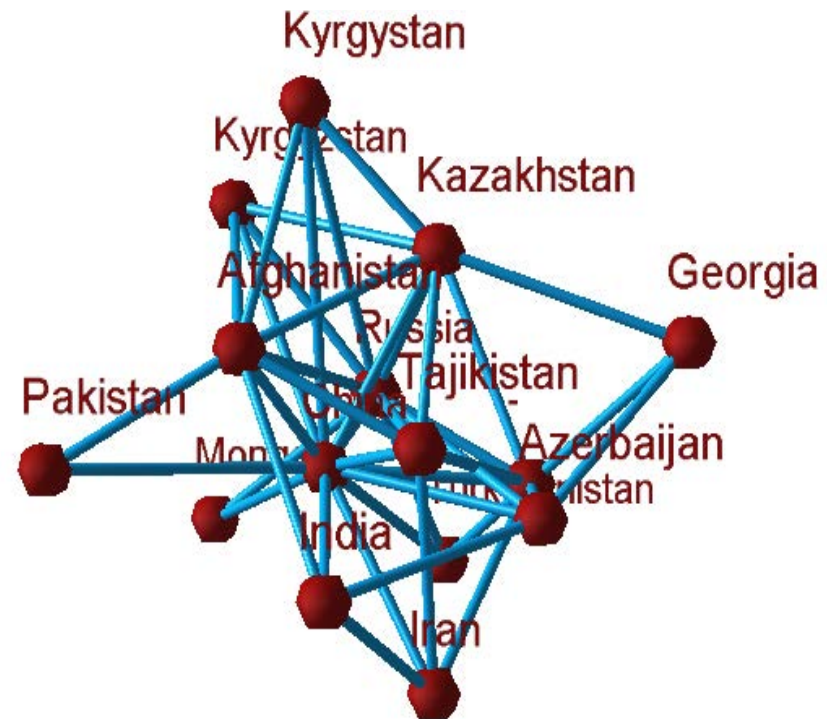
GDP Density



- 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)
- Northern Distribution Network --- NDN (1980-2015)
- New Silk Road
- Speed factors:  
Time vs distance  
(road, rail, sea)



# The New Era in Central Asia

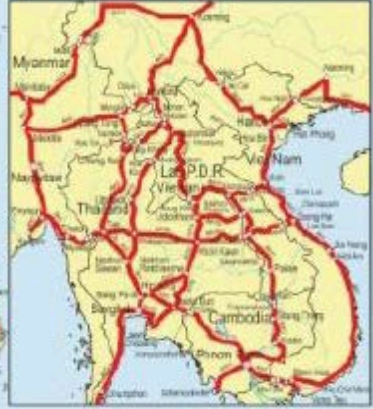
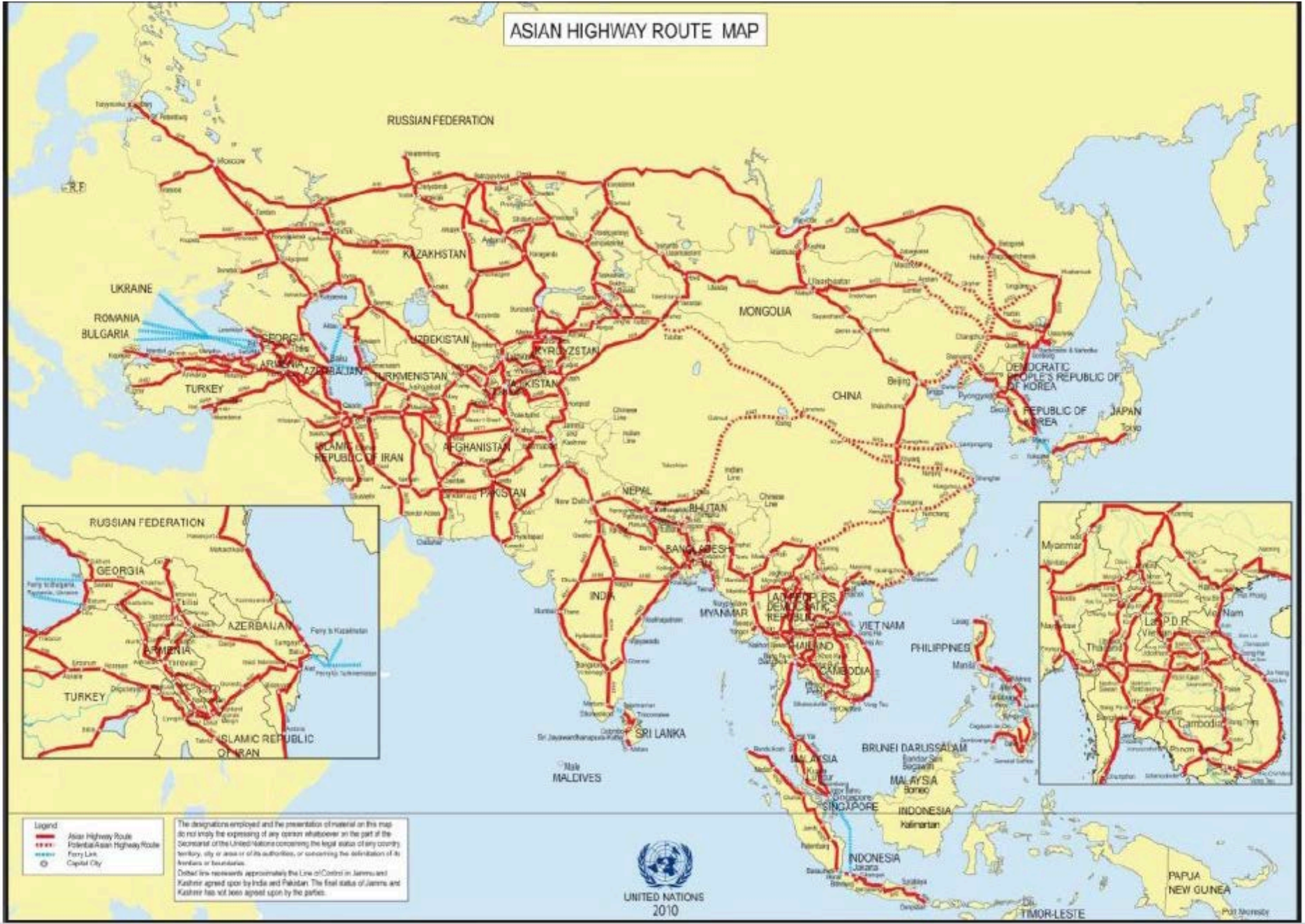
- Kazakhstan (16.6 m), Kyrgyzstan (5.5 m), Tajikistan (7.6 m), Turkmenistan (5.1 m), & Uzbekistan (29.5 m), the region's potential is finally realized by other nations.
- US resupply in Afghanistan developed the NDN.
- China, Russia, Iran, and US have strong competing and cooperative reasons for developing the NSR (roadways, railways, pipelines)
- Ultimate Multi-modal transport network



# One View: A Giant (8,000 mile) Land Bridge through Central Asia



# ASIAN HIGHWAY ROUTE MAP



- Legend**
- Asian Highway Route
  - - - Potential Asian Highway Route
  - Ferry Link
  - Capital City

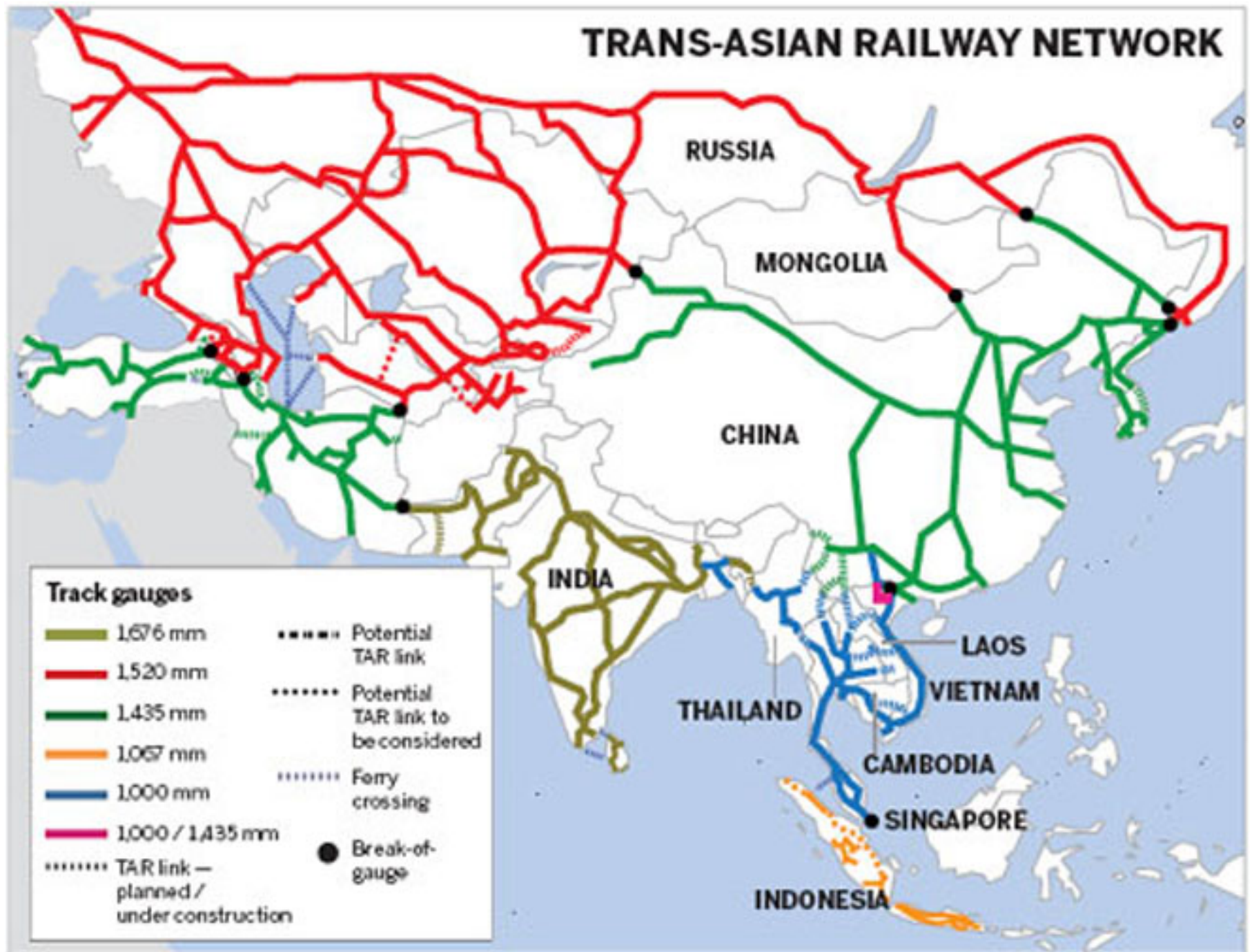
The designations employed and the presentation of material on this map do not imply the expressing of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Dashed line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not been agreed upon by the parties.

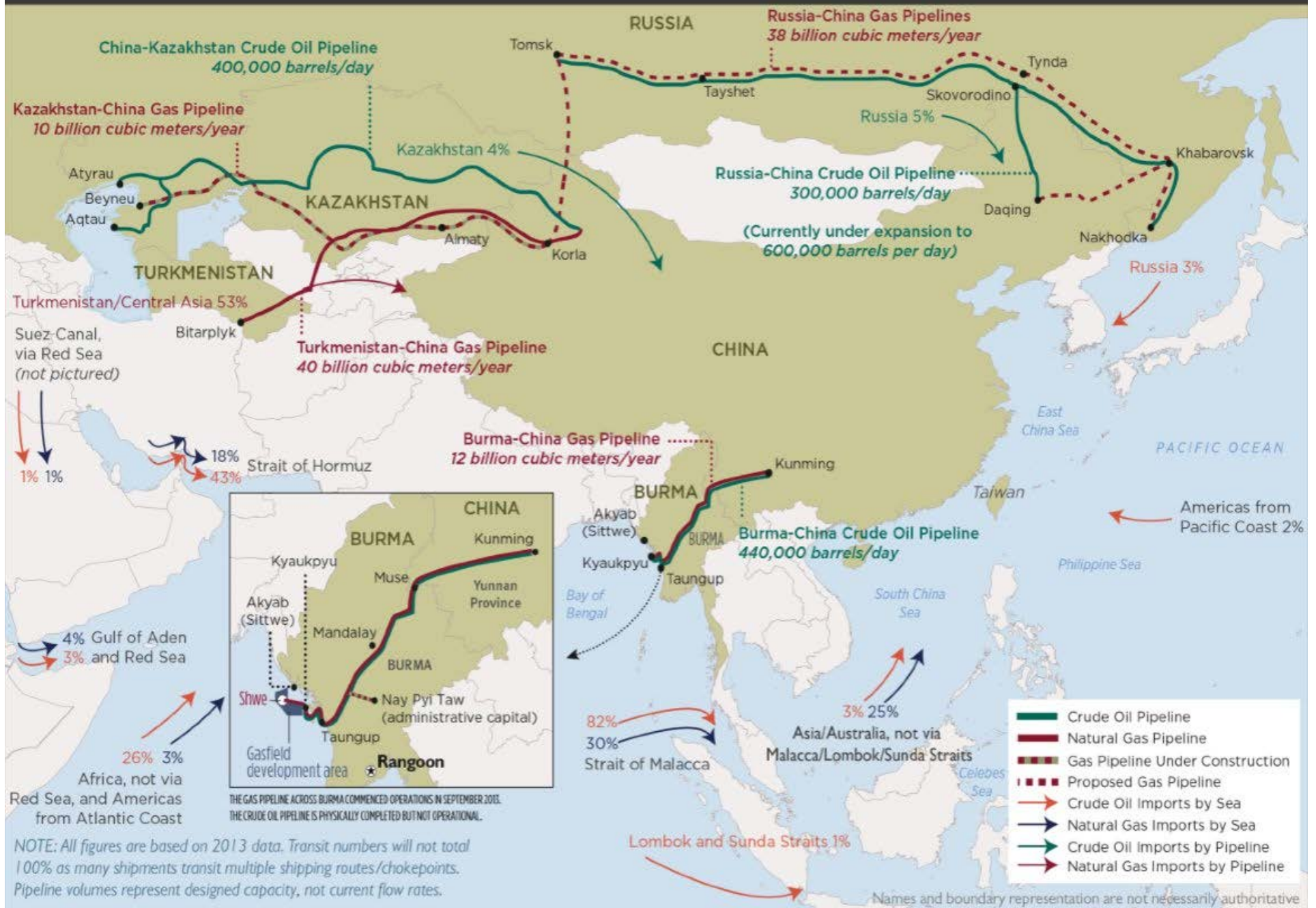


UNITED NATIONS  
2010

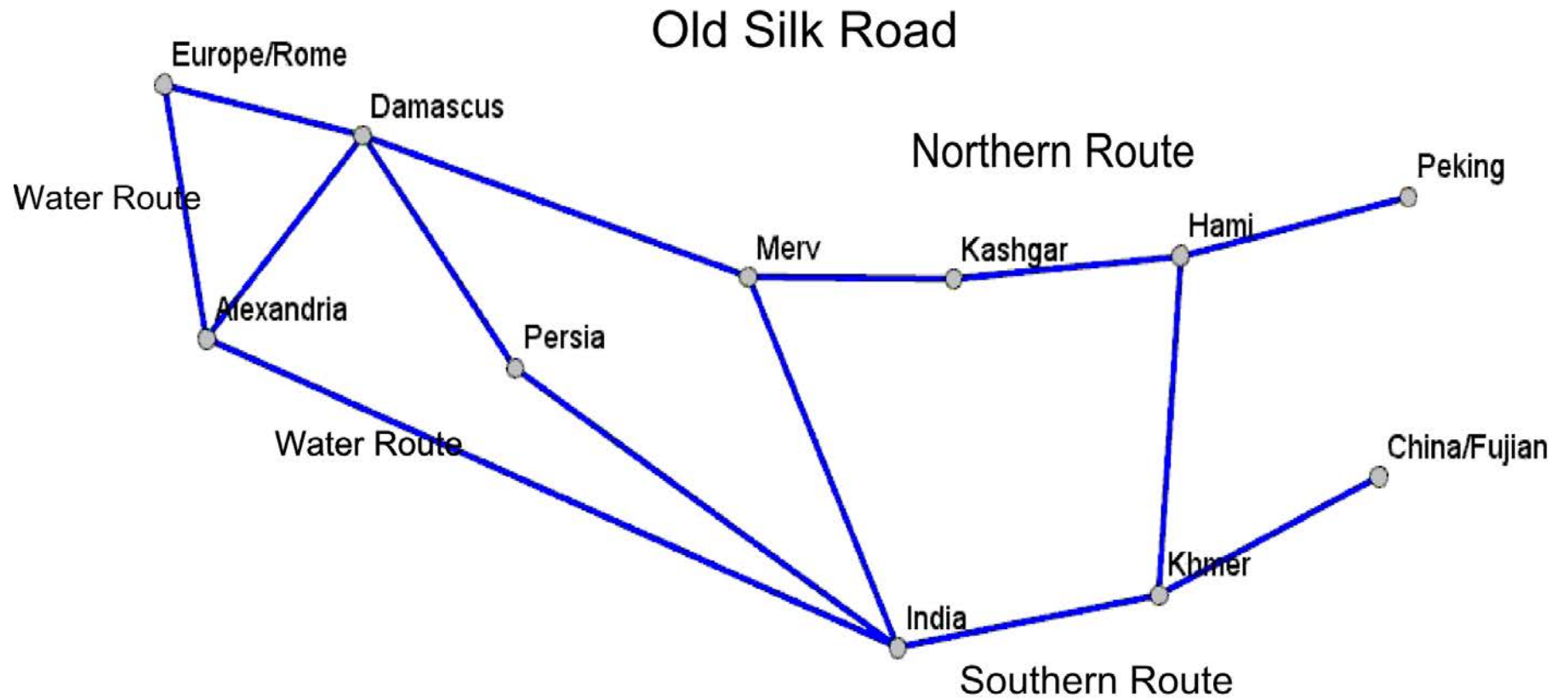
# TRANS-ASIAN RAILWAY NETWORK



(U) China's Import Transit Routes/Critical Chokepoints and Proposed/Under Construction SLOC Bypass Routes



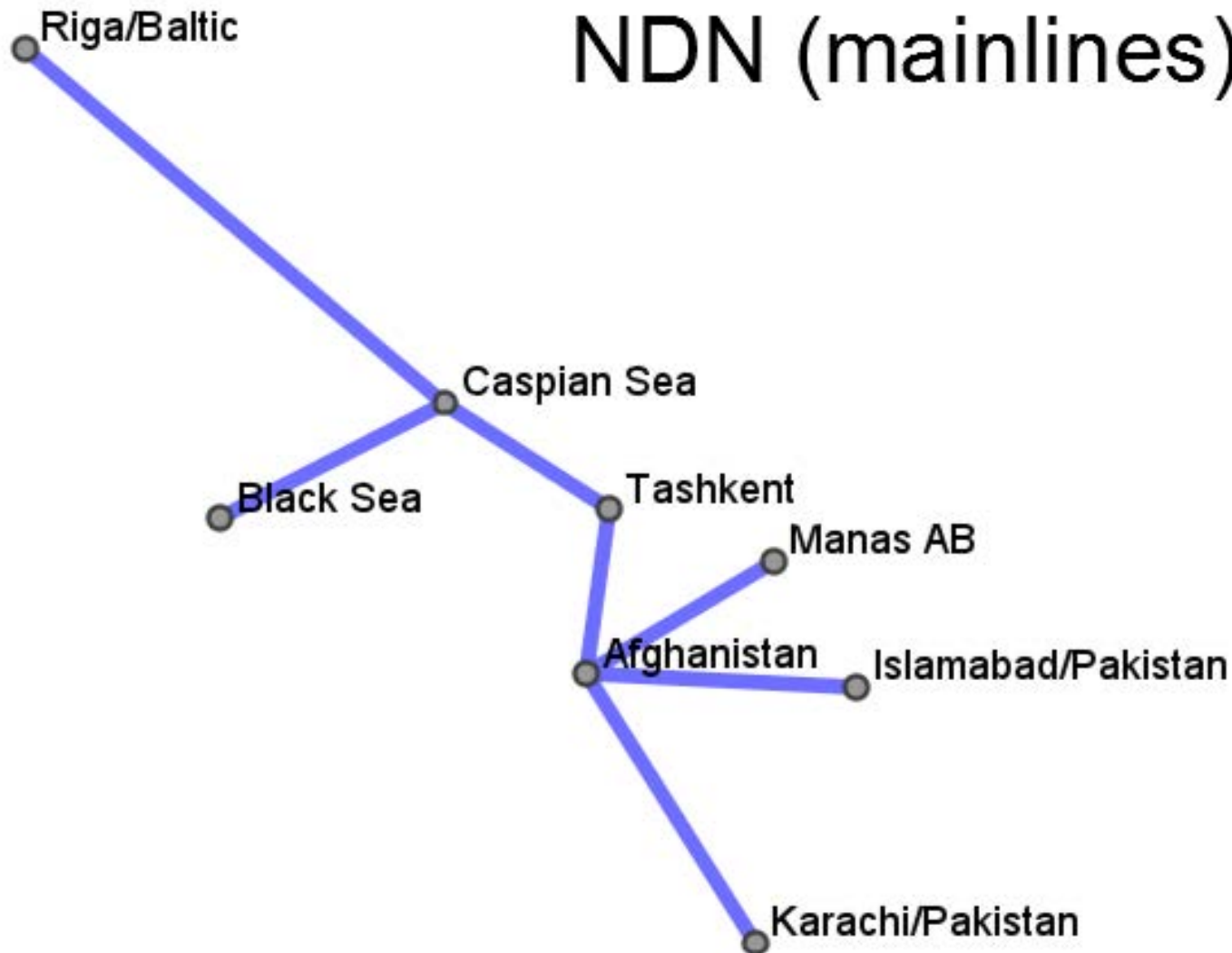
# Another view: The Transit Map of OSR





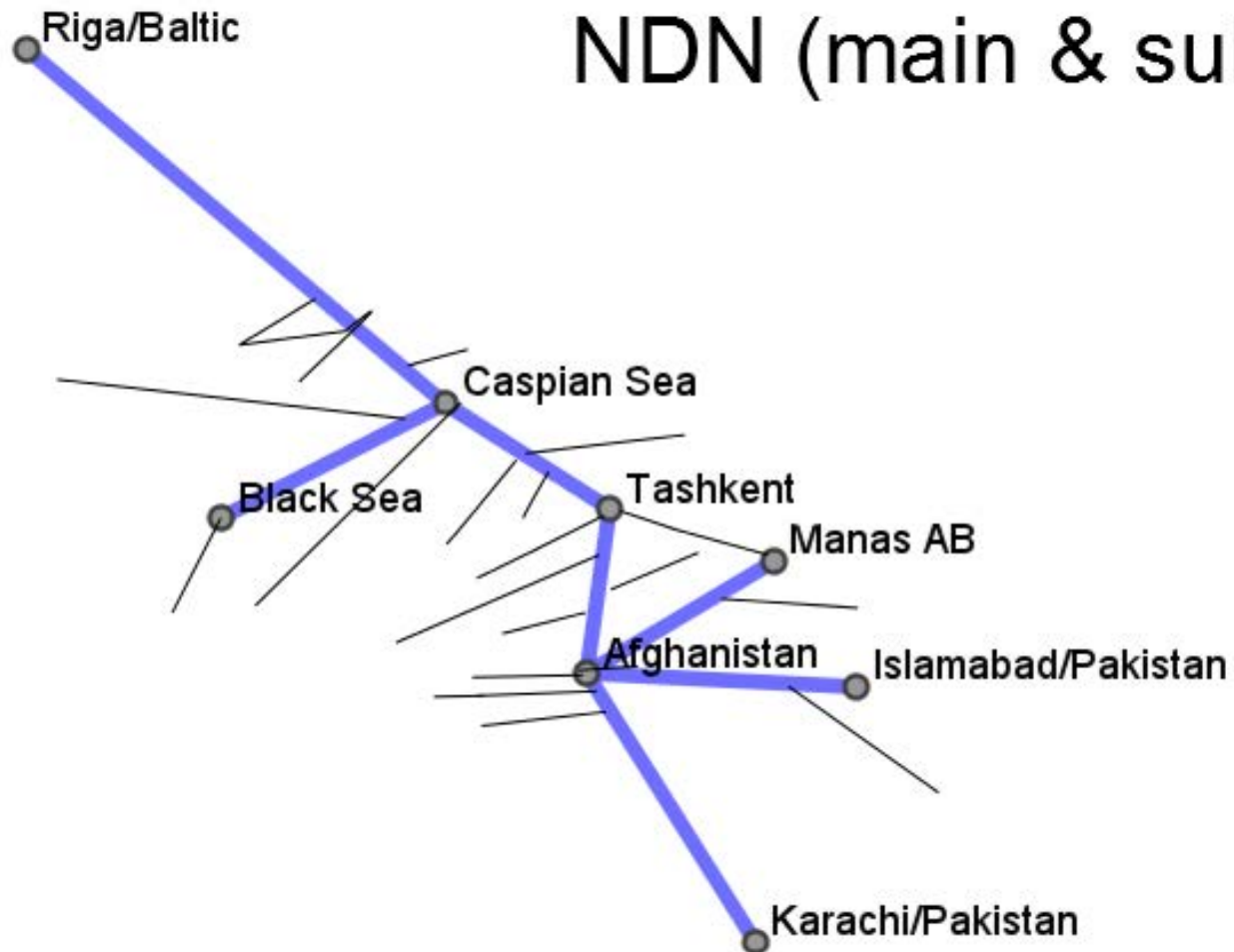
# The Transit Map of NDN

NDN (mainlines)

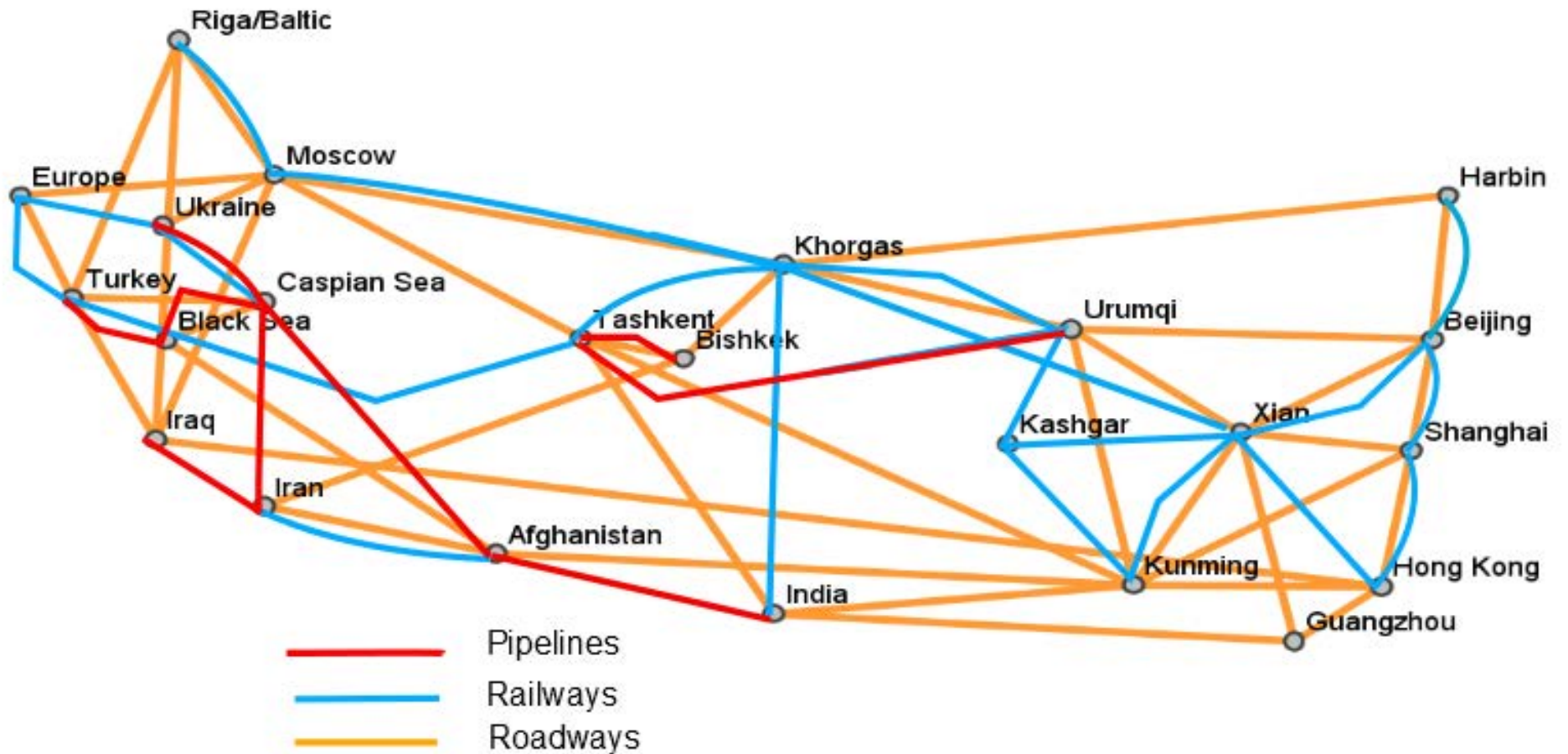


# There is more, much more

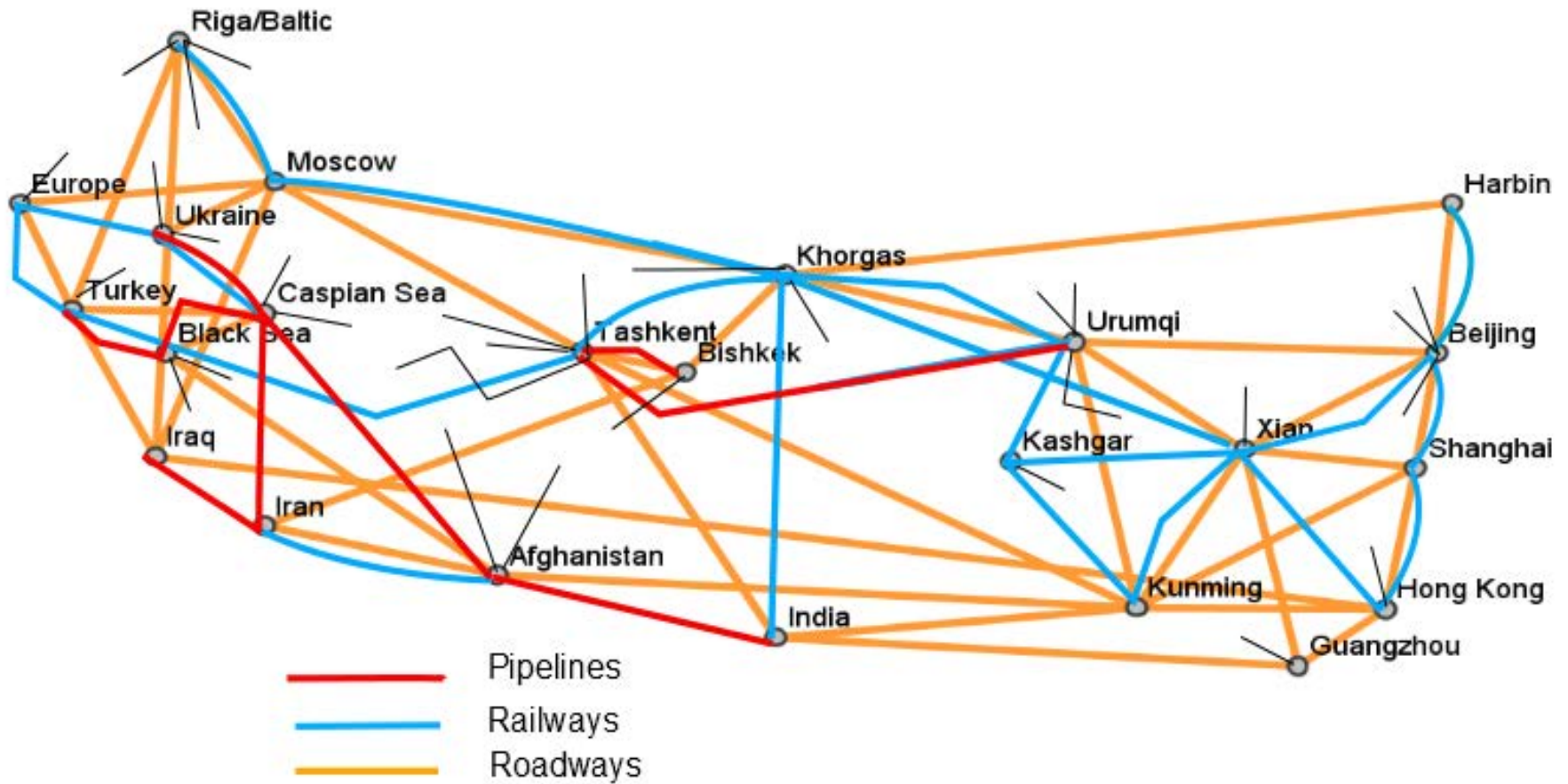
## NDN (main & subs)



# Transit Map of NSR



# 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

## Before Canals

- No containers
- Suez --- 1870
- Panama -- 1914

## Modern Shipping

- 5,000 container ships
- Efficient-designed ports
- Suez (26 ft depth, 16 hrs for 120 miles)
- Panama (40 ft depth, 20 hrs for 48 miles)

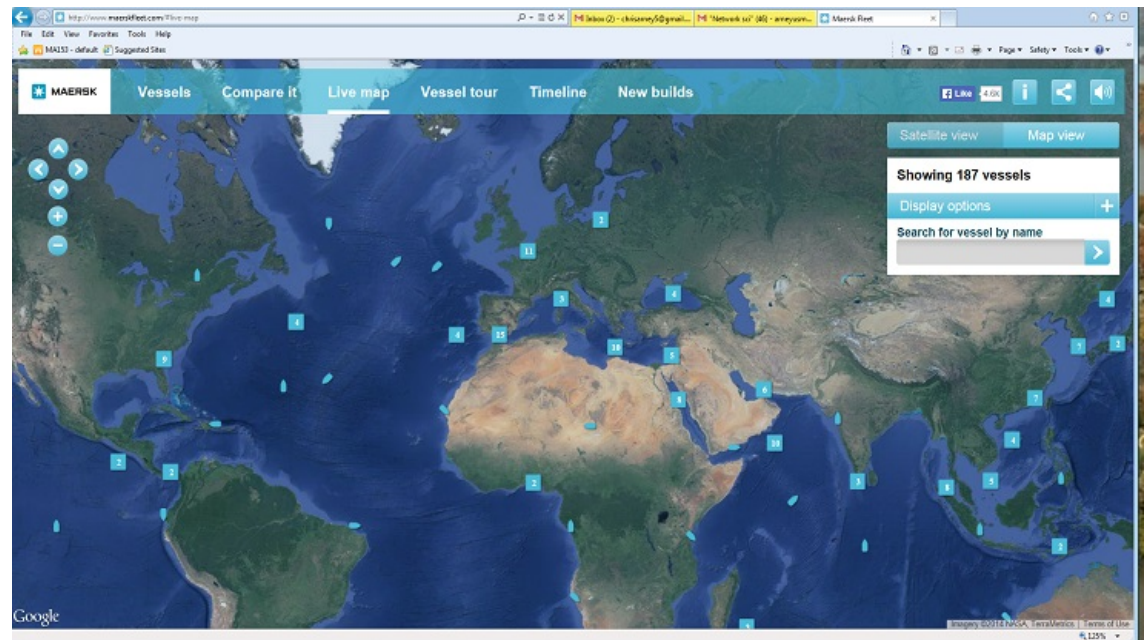
## Mega Shipping

- 18,000 container ships
- 600–ship companies
- New Panama Canal (25% longer, 50% wider, 25% deeper)
- Net Suez facilities (79 ft depth)
- North Passage studies



- 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.

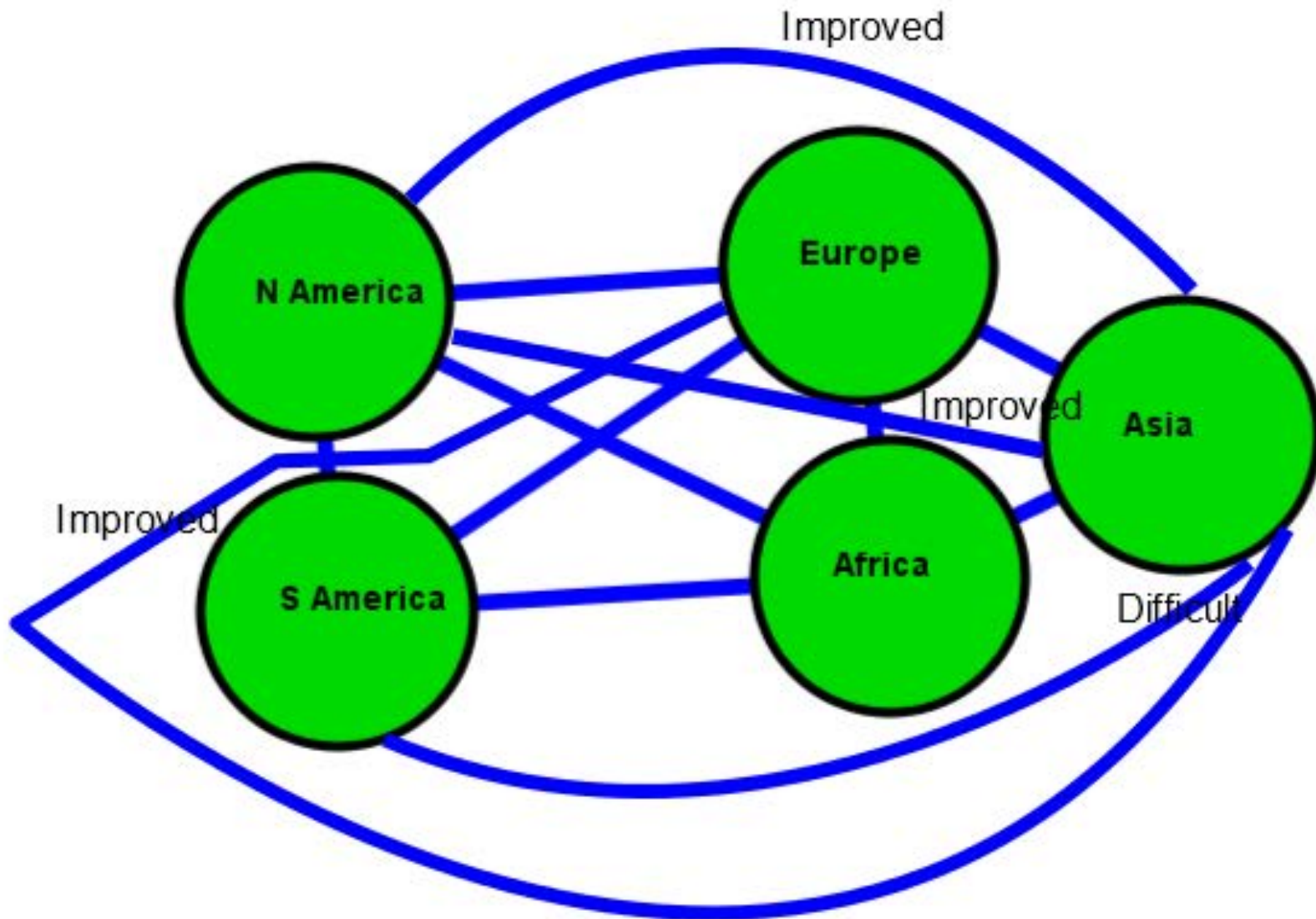




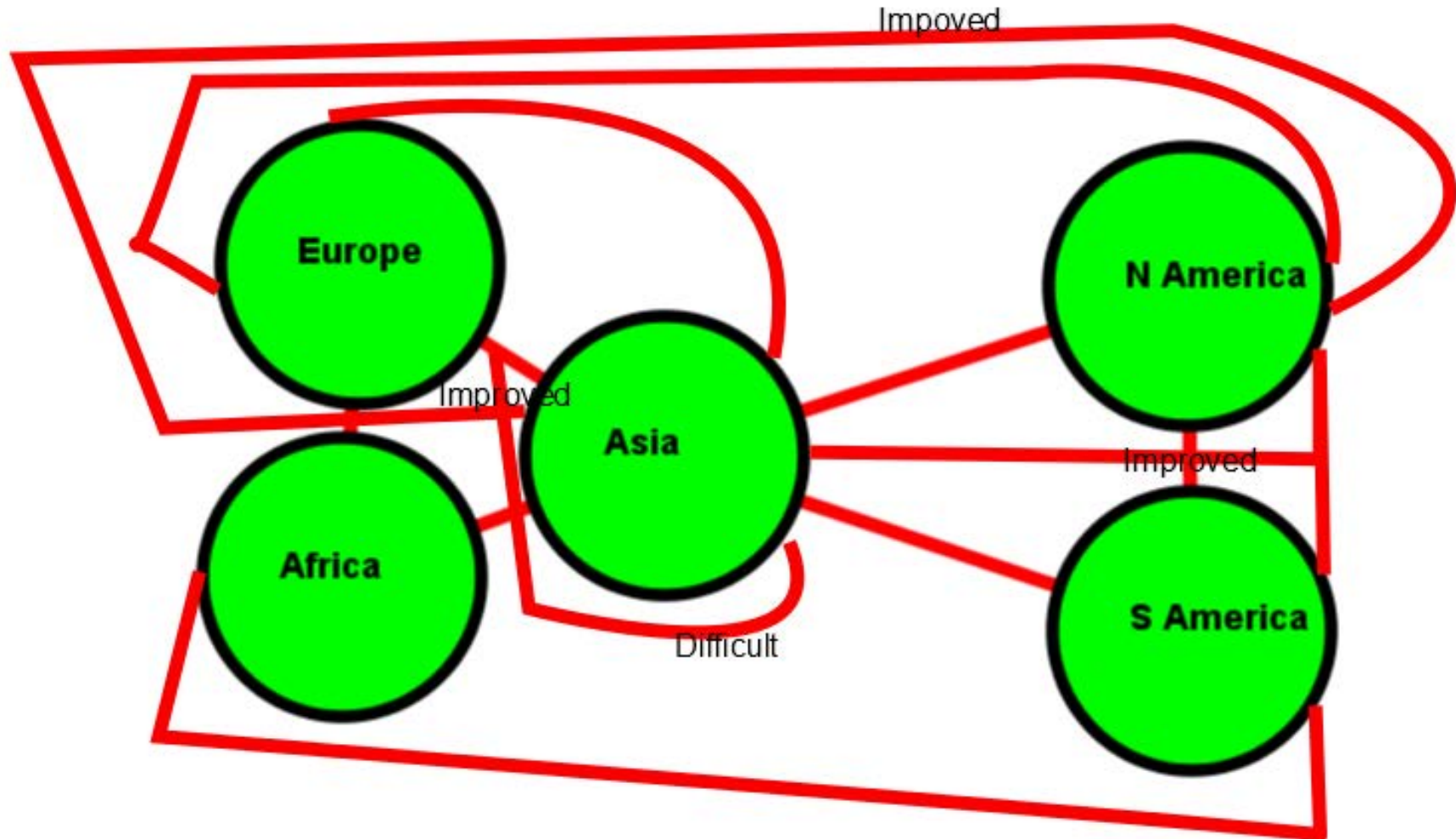
# The Good, Bad, and Cold (the north is open for business)



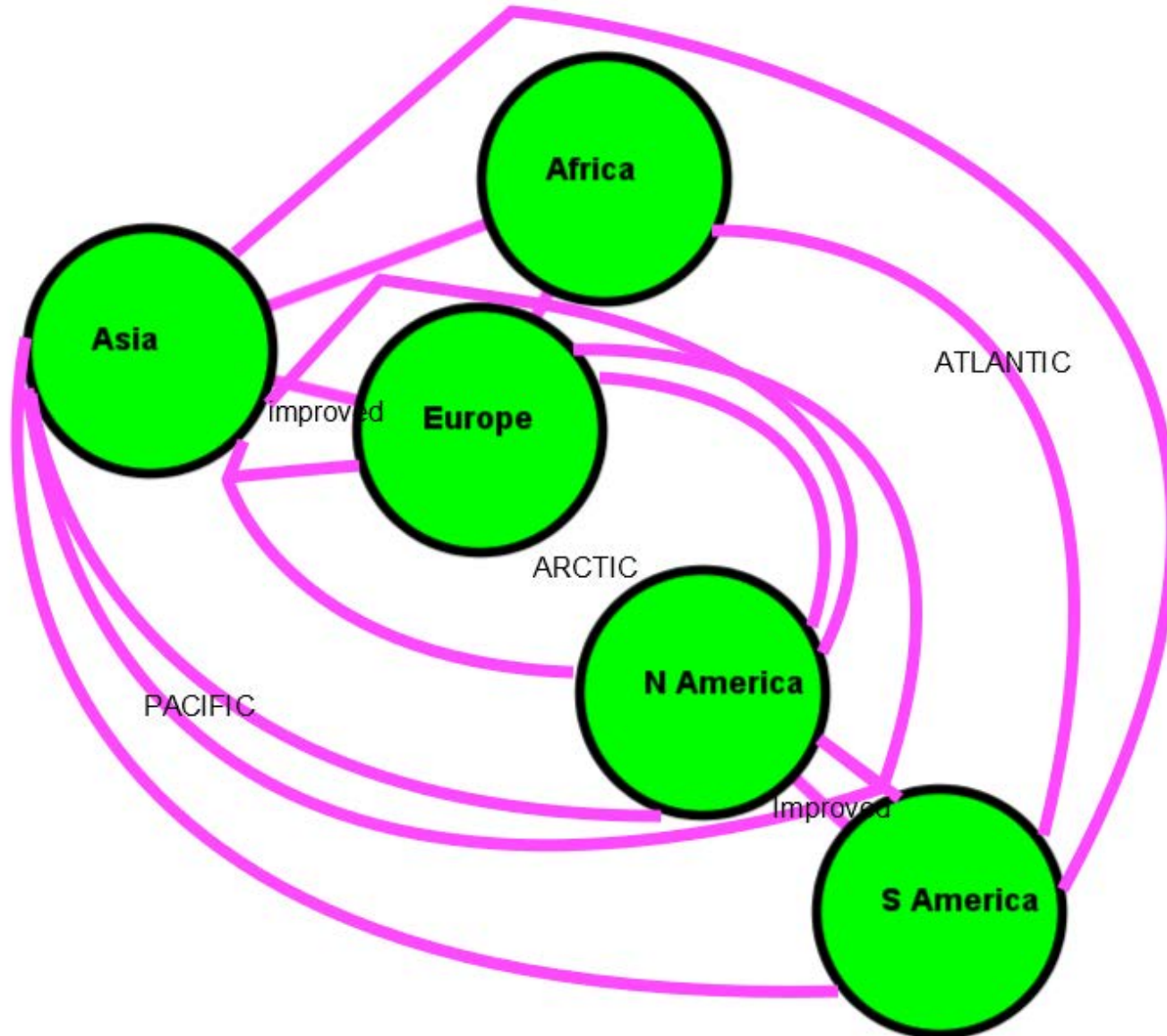
# The Transit Map of Sea-lanes (Atlantic-centered)



# The Transit Map of Sea-lanes (Pacific Centered)



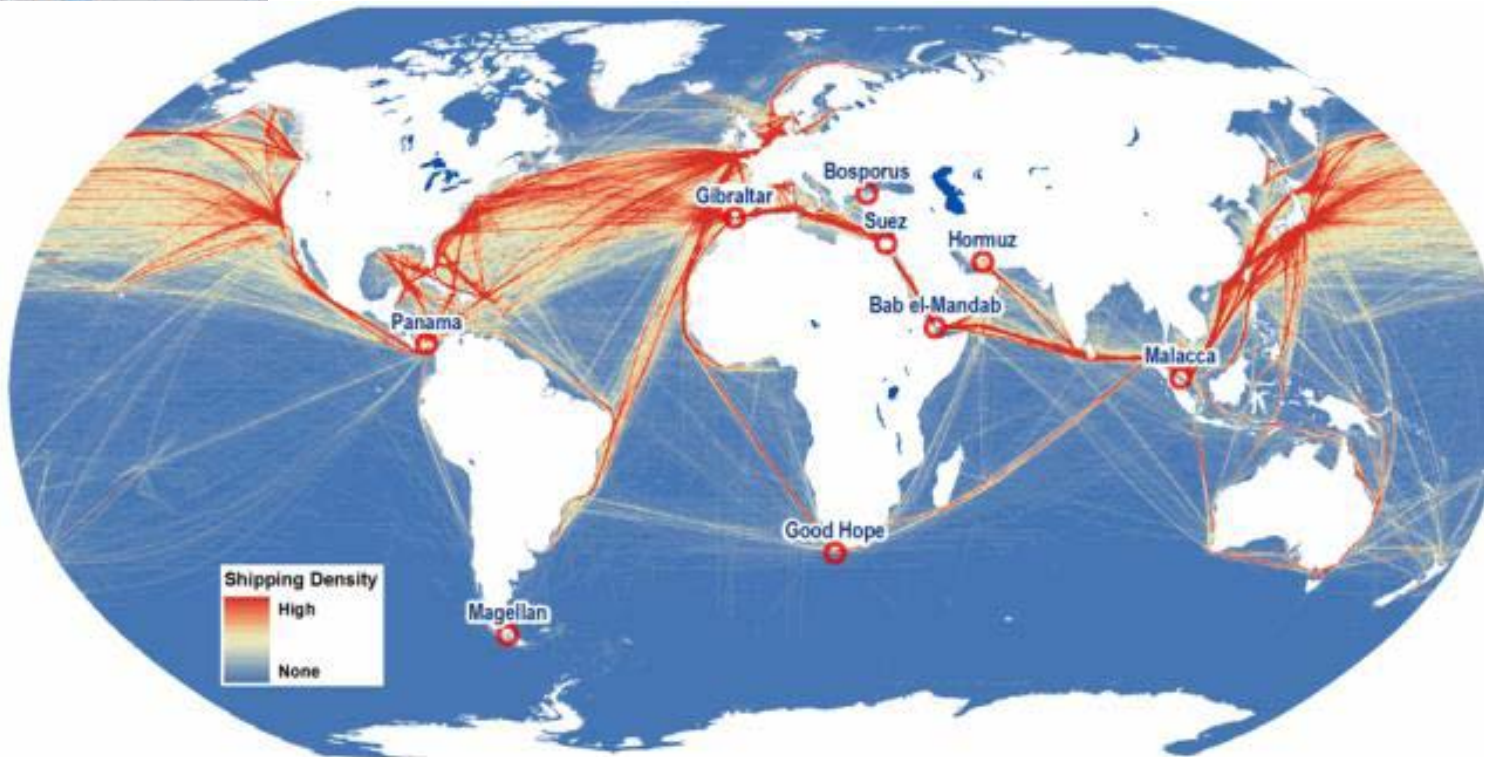
# A Transit Map of Sea-lanes (Arctic-Centered)





# 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.*