Mathematical Competition in Modeling (MCM)

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May 2nd, 2015

The MCM

- ➔ teams of 2-4 students
- ➔ takes place over a weekend
- ➔ applied mathematics
    - ◆ examples of problems
- ➔ **communicating** mathematical ideas

The 2015 Problems

PROBLEM A: Eradicating Ebola

The world medical association has announced that their new medication could stop Ebola and cure patients whose disease is not advanced. Build a realistic, sensible, and useful model that considers not only the spread of the disease, the quantity of the medicine needed, possible feasible delivery systems (sending the medicine to where it is needed), (geographical) locations of delivery, speed of manufacturing of the vaccine or drug, but also any other critical factors your team considers necessary as part of the model to optimize the eradication of Ebola, or at least its current strain. In addition to your modeling approach for the contest, prepare a 1-2 page non-technical letter for the world medical association to use in their announcement.

PROBLEM B: Searching for a lost plane

Recall the lost Malaysian flight MH370. Build a generic mathematical model that could assist "searchers" in planning a useful search for a lost plane feared to have crashed in open water such as the Atlantic, Pacific, Indian, Southern, or Arctic Ocean while flying from Point A to Point B. Assume that there are no signals from the downed plane. Your model should recognize that there are many different types of planes for which we might be searching and that there are many different types of search planes, often using different electronics or sensors. Additionally, prepare a 1-2 page non-technical paper for the airlines to use in their press conferences concerning their plan for future searches.

The 2015 Problems

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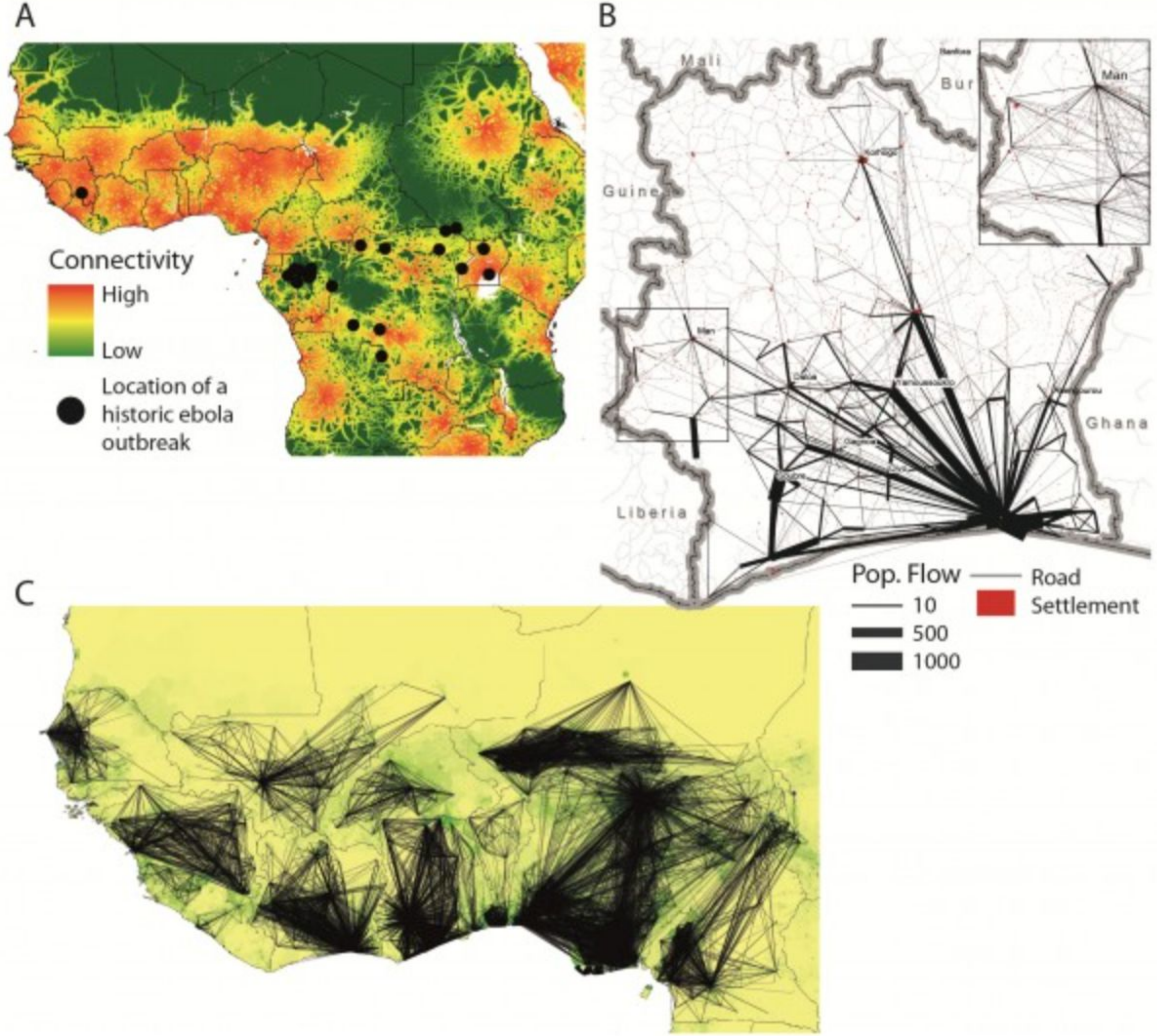
Key Strategies

- ➔ carefully and rigorously make assumptions
- ➔ choose somewhere to focus
  - ◆ there’s only so much that you can do over a weekend…
- ➔ refinement vs. comparison



source:
http://currents.plos.org/outbreaks/article/containing-the-ebola-outbreak-the-potential-and-challenge-of-mobile-network-data/

Our Focus

How to best geographically distribute a constant supply of medication to minimize the **duration** of the outbreak?

Our (Major) Assumptions

- constraining factor was production
- control over distribution
- vaccine/cure combination
- as the pandemic spreads, R_O decreases on a community by community and global scale
- only individuals who show symptoms are less likely to travel
- travel patterns in West Africa are similar
- effects of cure versus vaccine on duration of outbreak

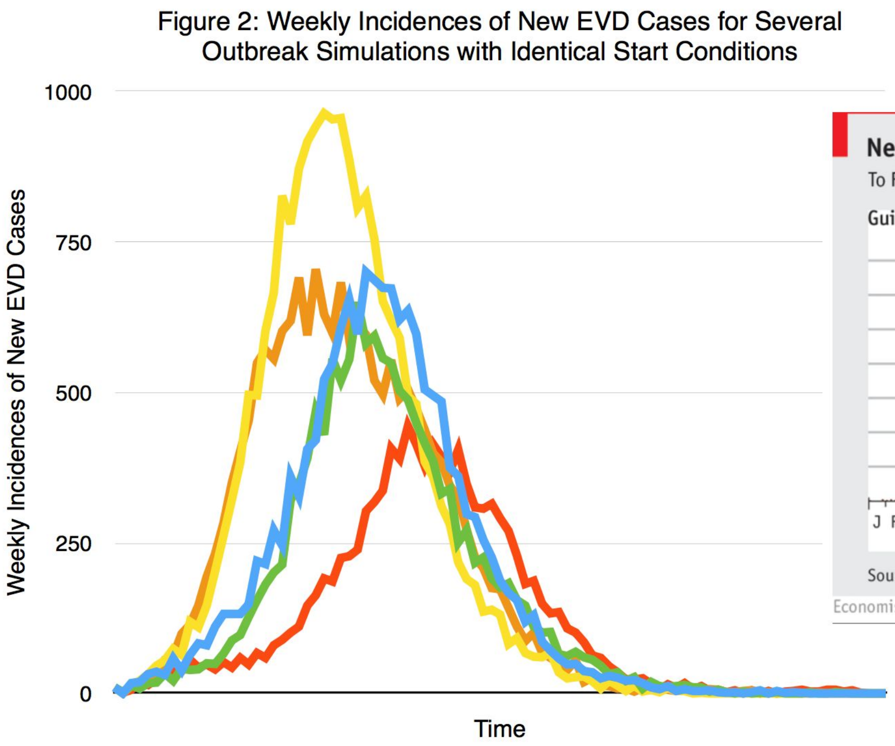
Our Model: Design

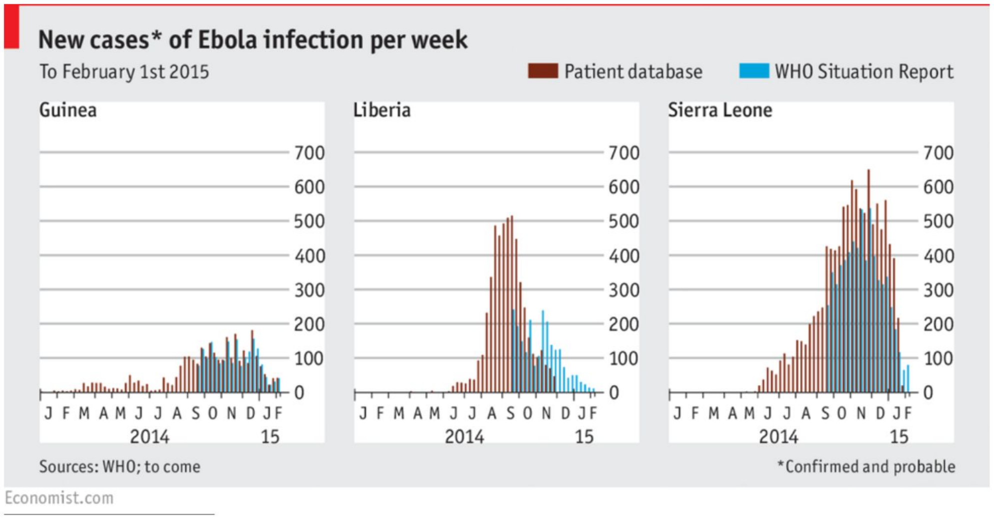
- ➔ Susceptible, Infected, Recovered (SIR) model
- ➔ Cell data from Senegal --> 167 communities in Senegal with a population and proportional trip frequency to all other communities.
- ➔ individual cases were tracked in these communities on a day by day basis

Our Model: Design

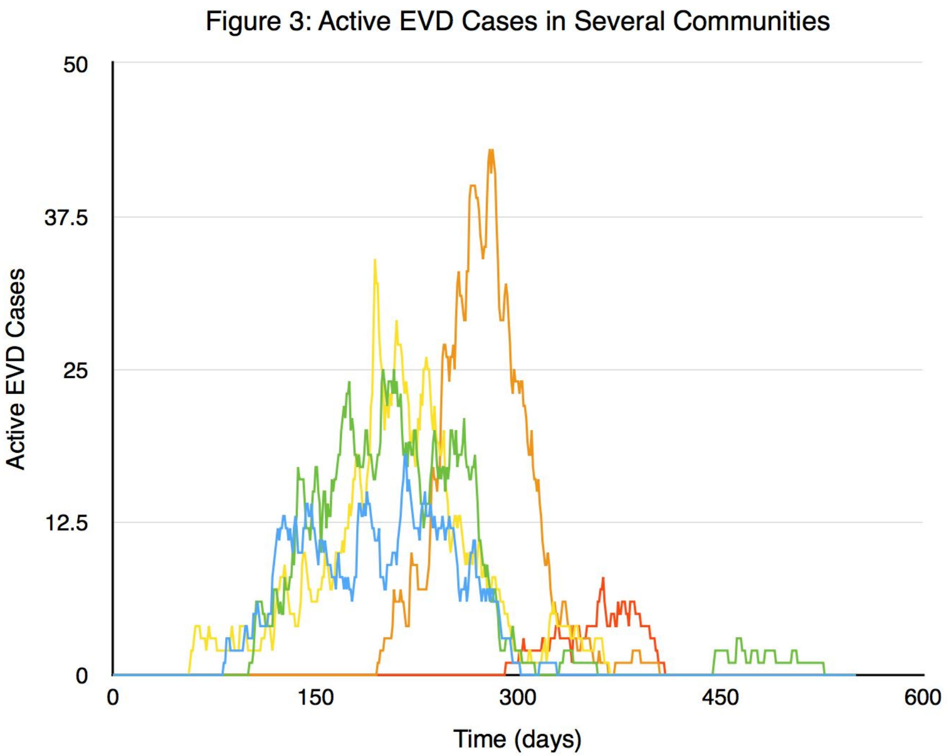
- ➔ updated on a day by day basis
  - exchange between communities
  - quarantine efforts
  - advancement of existing cases
  - generation of new cases
  - global and local efforts to stem the spread of the disease
    - exponential decay in chance of transmission
    - logistic increase in chance of quarantine

Our Model: Parameterization

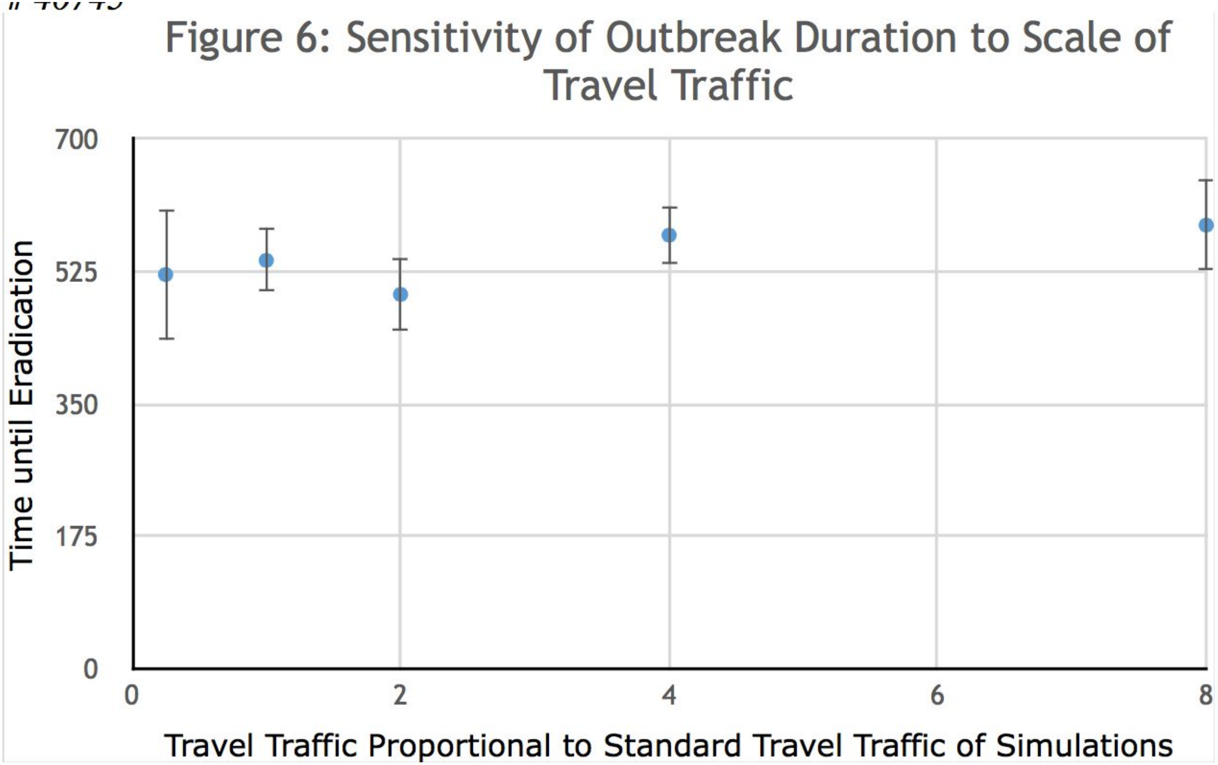




Our Model: Parameterization

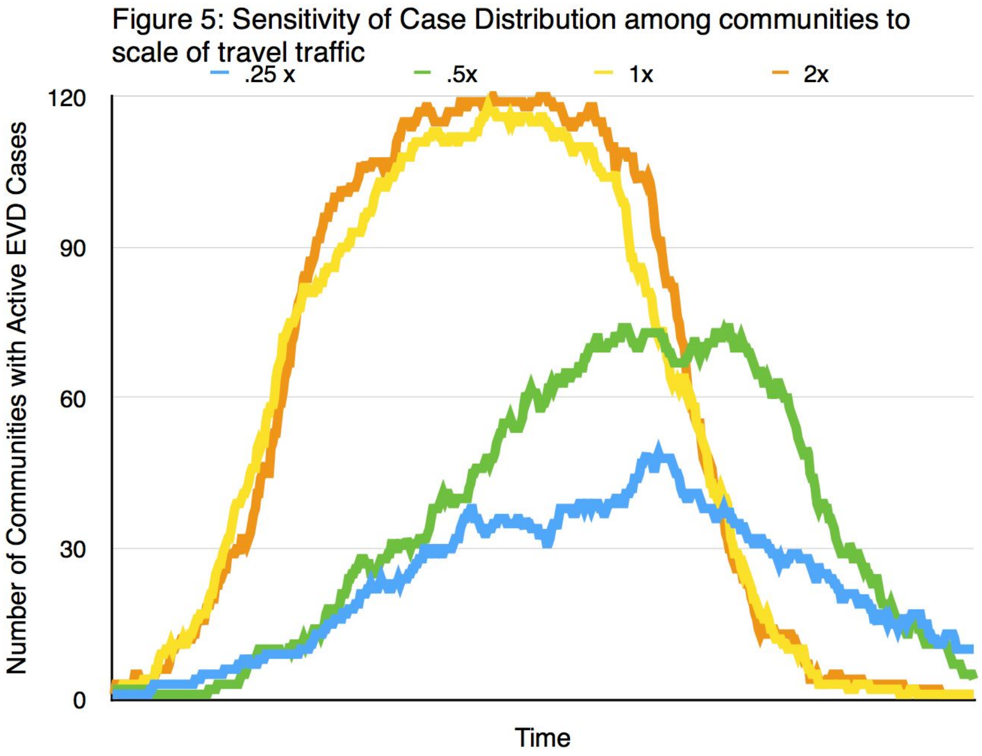


Our Model: Sensitivity Analysis



➔ Travel traffic magnitude somewhat affected outbreak duration.

Our Model: Sensitivity Analysis



- ➔ Increased traffic seemed to increase the rate and the reach of transmission between communities.

Results and Recommendations

- ➔ human mobility broadens **scope** and **quicken the spread** of EVD **between communities**
- ➔ human mobility does not appear to significantly lengthen the **duration** of outbreaks according to our model.
- ➔ Although further inquiry into its effects on mortality should be considered, this model suggests that **economically- damaging travel restrictions may be eased to some degree without sacrificing public health.**
- ➔ If you have a **lot of vaccines**, try to **distribute them** as **widely** as possible.
- ➔ If you have a **restricted supply of vaccine** they should be distributed as **efficiently and not necessarily as widely** as possible.

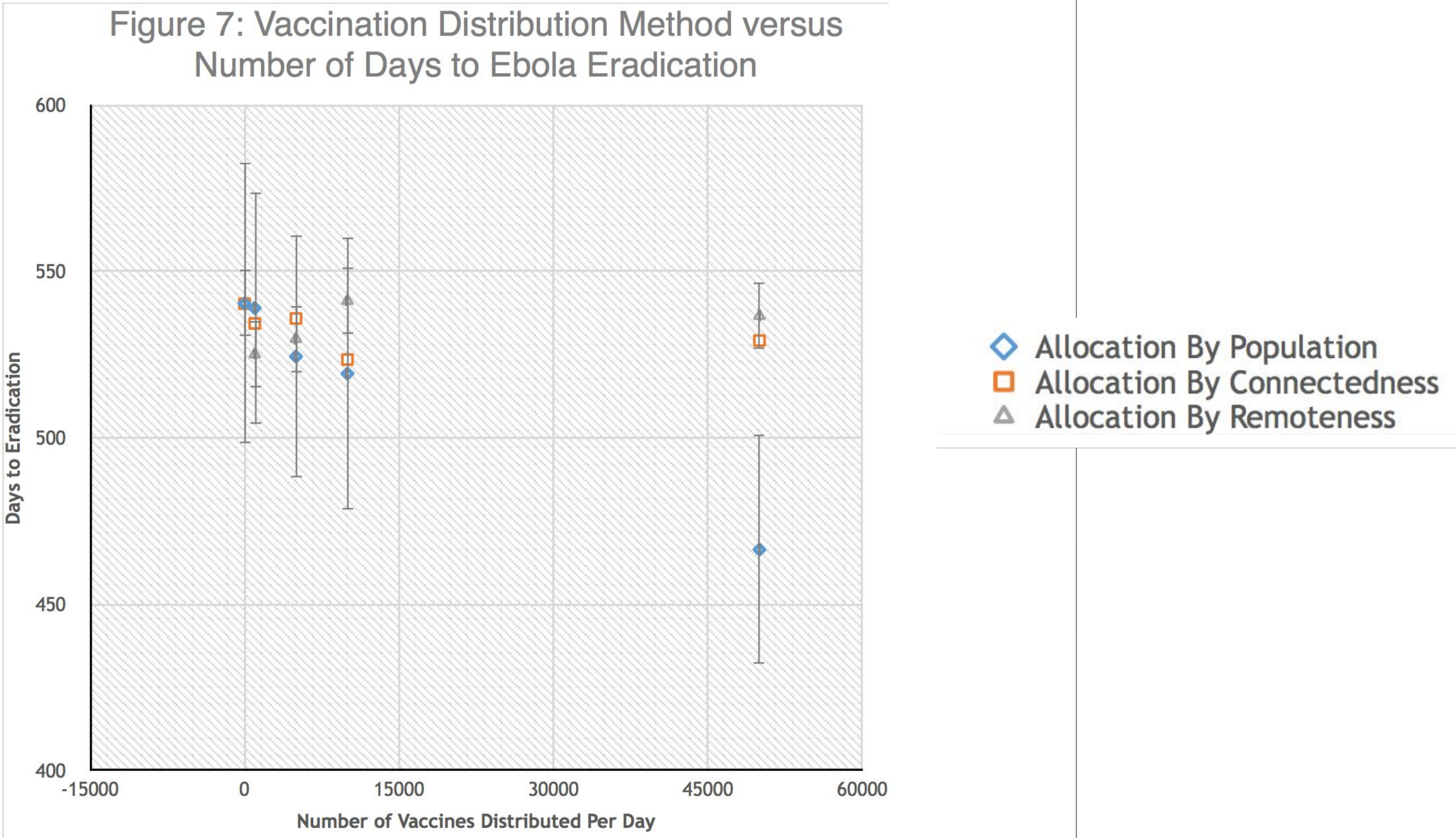


Figure 7: Vaccination Distribution Method versus Number of Days to Ebola Eradication
Days to Eradication
600
550
500
450
400
-15000
0
15000
30000
45000
60000
Number of Vaccines Distributed Per Day
Allocation By Population
Allocation By Connectedness
Allocation By Remoteness

What We Would Do Differently...

- ➔ data sanitation
- ➔ more careful choice of parameters (i.e. quantitative rather than qualitative)
- ➔ runtime efficiency of simulation
- ➔ formal statistical analysis of results