CALIFORNIA STATE SCIENCE FAIR
2011 PROJECT SUMMARY

Name(s)
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Project Number
S1418

Project Title
Stochastic Epidemic Simulations on the US Transportation Network

Abstract

Objectives/Goals
How do epidemics spread on the US transportation network? What is the role of air travel vs. long distance auto travel? Is the nature of epidemic propagation on the network such that epidemics can be mitigated with policy interventions? A large literature has simulated the spread of epidemics on the global aviation network and has concluded that large hub airports are preferred epidemic pathways at the global, national, and regional levels, simulations that involve randomness in both the infection and recovery processes within and travel across population units. This finding implies that epidemiologists can use these models to predict the spread of epidemics and to design policy interventions to mitigate it. My research is a stochastic simulation study of epidemic propagation on a model of the US transportation network that describes air and long distance auto personal and business trips to and from all 3076 counties in the continental US. Long distance auto travel has not been considered in the literature to date and auto trips might prove to be important since they are five times more numerous than airplane trips.

Methods/Materials
Each county was modeled as a homogeneous population unit described by a Susceptible-Infected-Removed model. For each day and county, random changes in the number of newly infected and recovered were simulated along with the random net travel of infecteds to and from all 3076 counties. A simulated epidemic ran until infection died out in each county. I ran 50 simulations each on the air and auto travel networks alone and 50 more with both modes operating. I also ran simulations as robustness checks using other parameter values.

Results
My simulations suggest a much diminished role for air travel and that auto travel, a previously ignored transportation mode, drives most of epidemic propagation in this model. Exponential infected growth results primarily from the local county infection process after initial seeding by infected travelers, all of which occurs in the first 7-10 weeks, who have little subsequent impact.

Conclusions/Discussion
Vaccine development must be extremely rapid or travel restrictions must be implausibly effective if this trip-based network architecture is a more accurate model than the flight based ones in the literature because, once the county infection level has reached 0.02%, an epidemic has taken root and is probably unstoppable.

Summary Statement
My project shows that epidemics largely spread by auto travel in the US and that epidemics are probably unstoppable once they have taken root.

Help Received
I discussed my project with my parents and they read several paper drafts. I wrote all code in Mathematica and ran it from home on the Triton supercomputer at the San Diego Supercomputer Center, who provided 3500 hours of cpu time. Wolfram Research provided a copy of network Mathematica.