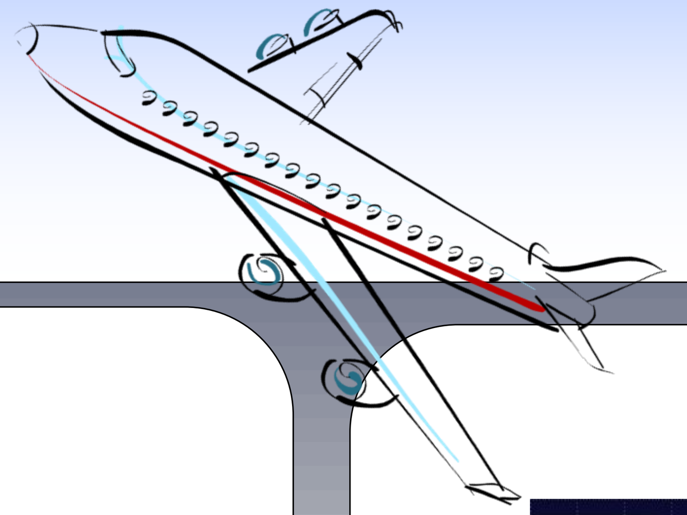
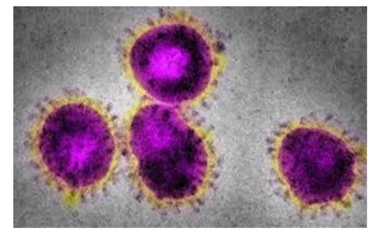
GERMS ON A PLANE: THE TRANSMISSION AND RISKS OF AIRPLANE-BORNE DISEASES

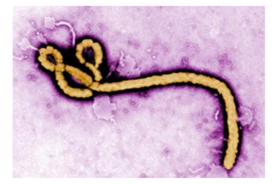
Sevilla, Nereyda L – George Mason University



Abstract

Purpose: This research explored the role of air travel in the spread of infectious diseases, specifically Severe Acute Respiratory Syndrome (SARS), H1N1, Ebola, and pneumonic plague. **Background:** Air travel provides the means for diseases to spread internationally at extraordinary rates as infected passengers jump from coast to coast and continent to continent within hours. Outbreaks of diseases that spread from person to person test the effectiveness of current public health responses. **Methods:** This research used a mixed methods approach, including using the Spatiotemporal Epidemiological Modeler (STEM) to model the spread of diseases, evaluating the impact of air travel on the spread of infectious diseases, and analyzing the effectiveness of different public health strategies and travel policies. **Results:** Modeling showed that the spread of Ebola and pneumonic plague is minimal and should not be a major air travel concern if an individual becomes infected. H1N1 and SARS have higher infectious rates and air travel will facilitate disease spread across the country. **Conclusion:** To contain the spread of infectious diseases, aviation and public health authorities should establish tailored preventative measures at airports, capture contact information for ticketed passengers, expand the definition of "close contact," and conduct widespread educational programs. The measures will put in place a foundation for containing the spread of infectious diseases via air travel and minimize the panic and economic consequences that may occur during an outbreak.

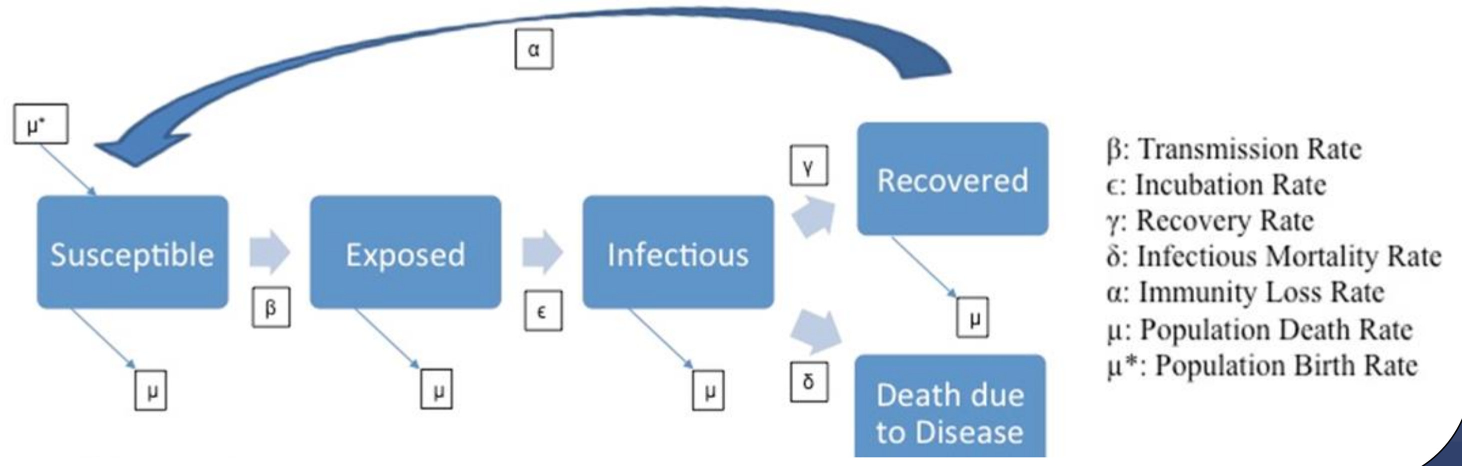




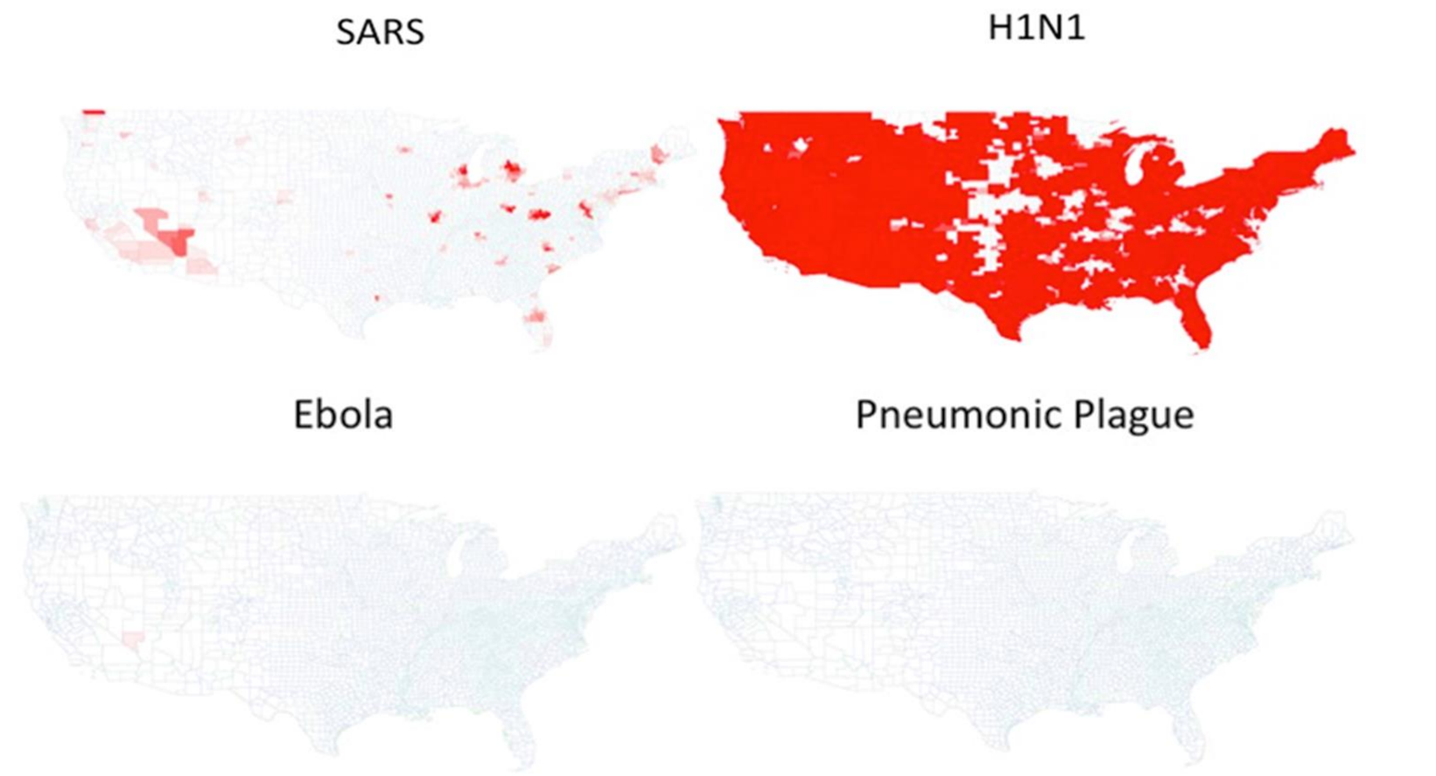
Methods

This research used a mixed methods approach to evaluate the impact of aviation on the spread of infectious diseases and the effectiveness of public health strategies to mitigate disease outbreaks. A tool known as the Spatiotemporal Epidemiological Modeler (STEM), developed by IBM as an open-source program, was used to simulate four disease outbreaks in the United States, specifically SARS, H1N1, Ebola, and pneumonic plague.

STEM is a multi-disciplinary, collaborative modeling platform that uses compartment theory to simulate disease spreads. The open-source characteristics of the system allow researchers to compare, refine, and validate different scenarios as well as add data, such as disease characteristics. STEM provides the built-in statistics such as county and country boundaries, transportation networks, air travel, and environmental conditions. The equations used within the compartment model provided the foundation of the model to compare the threat of disease spread while maintaining many characteristics constant. In compartment models, each person in a population is accounted for in a compartment, and no one person may be in more than one compartment at any given time. All the disease of interests for this research used an "S" – "E" – "I" – "R" model where each person in a population is in one of four states: Susceptible (S), Exposed (E), Infectious (I), or Recovered (R).



Results



When compared to historical accounts of SARS, H1N1, Ebola, and pneumonic plague, the hypothetical scenarios of each of the disease spreads follow similar patterns and results. The model shows that an outbreak of SARS in the United States would cause approximately 4 to 7 thousand cases and 500 to 1000 deaths. Though the United States experienced a small number of SARS cases in 2003 and no SARS deaths, its neighboring country of Canada did confront 438 cases and 44 deaths. Of the four diseases, H1N1 impacts the population the most according to the model with 5 to 18 million affected and 5 to 18 thousand deaths. During the 2009 H1N1 outbreak, the United States experienced approximately 22 million disease cases and approximately 4000 deaths during a 6-month period. During the Ebola crisis in 2014, the United States had two imported cases of Ebola, and two locally acquired cases by medical professionals. No cases of Ebola were acquired through air travel. Finally, the United States experiences approximately 10 to 15 cases per year of plague, but has not had a person-to-person spread of pneumonic plague since 1925. Never has there been a case of pneumonic plague associated with air travel. The model shows very small numbers of individuals infected and dying due to pneumonic plague and Ebola as compared to SARS or H1N1 should outbreaks occur.

Simulated and Actual Cases in the United States (% - the percentage of population affected.)		
Simulated Diseases	**Total Infected**	**Total Deaths**
SARS-1 case	4,042 0.0014%	572 0.0002%
SARS-10 cases	7,279 0.0026%	1,000 0.0004%
H1N1-1 case	5,617,702 1.9962%	5,374 0.0019%
H1N1-10 cases	18,363,550 6.5253%	18,856 0.0067%
Ebola-1 case	5 <0.0001%	1 <0.0001%
Ebola-10 cases	43 <0.0001%	19 <0.0001%
Plague-1 case	1 <0.0001%	1 <0.0001%
Plague-10 cases	25 <0.0001%	13 <0.0001%
Historical Diseases	**Total Infected**	**Total Deaths**
2003 SARS US	27 <0.0001%	0 0%
2003 SARS Canada	438 0.0015%	44 0.0001%
2003 SARS China	5327 0.0004%	349 <0.0001%
2009 H1N1 US (Apr – Oct 2009)	~ 22 million 7.8174%	~3,900 0.0014%
2014 Ebola US	4 <0.0001%	1 <0.0001%
2015 Plague US	11 <0.0001%	3 <0.0001%

Recommendations

Recommendation #1: Expand the Definition of "Close Contact"
Close contacts with ill individuals in airports may prove to be a more likely route of transmission than contacts on a aircraft. Policies must take into account the exposure window at the airport.
Recommendation #2: Health Contact Information Requirement
Efficient capture of passenger contact information is necessary. To improve contact information across airport populations, additional contact requests should be required on all ticket purchases.
Recommendation #3: Airport and Pre-Boarding Self-Sanitizing Measures
Airport announcements and visual aids around the terminal about preventive measures provide instant reminders and education. Just-in-time education would be fresh in passengers' minds.
Recommendation #4: Travel Alerts and Advisories During Ticket Sales
A strong message may trigger the public to find information about a disease and their risk of infection before flying. Clear and concise travel alerts will help in reducing the spread of infection.
Recommendation #5: Limited, Announced, Random Temperature Checks
Limited and announced, yet random, temperature checks during an outbreak may deter ill individuals from travel. These measures include a full refund or changes in dates without penalty.
Recommendation #6: Specific Crisis Communication
The groundwork for early containment procedures means constant and relevant communication. Education of the public is a crucial foundation and the most cost-efficient and effective way of slowing the spread of disease. A message map packages important facts about the disease.

Question: Will I get pneumonic plague on an aircraft to or from an outbreak area?		
Key Message 1	**Key Message 2**	**Key Message 3**
Pneumonic plague is extremely difficult to contract from person to person.	**Infection rate is extremely low.**	**It is very difficult to spread pneumonic plague from coast to coast.**
Supporting Information 1-1	Supporting Information 2-1	Supporting Information 3-1
85% of plague cases are transmitted from rodents, also known as bubonic plague, which does not spread from human to human.	**A person is only infectious for about 1-3 days.**	**The US reports approximately 25 cases of plague a year. There has not been a sustained outbreak for nearly a century.**
Supporting Information 1-2	Supporting Information 2-2	Supporting Information 3-2
Pneumonic plague spread from person to person usually occurs after long periods of close contact with infectious individuals such as in caregivers or medical professionals.	**A person becomes ill very rapidly and it would be difficult to travel while experiencing symptoms.**	**A disease with such a low infectious rate cannot sustain a US-wide outbreak.**
Supporting Information 1-3	Supporting Information 2-3	Supporting Information 3-3
A person is not infectious without symptoms.	**An ill person from pneumonic plague would be easier to spot than other diseases due to the rapid progression and severity of the disease.**	**Previous large numbers of plague deaths were due to unsanitary conditions, lack of modern medicine and antibiotics, and large numbers of rodents.**

Discussion

Disease spread during travel is a concern; however, diseases such as SARS and H1N1 with a high transmission rate will impact the population more in terms of infections and deaths than Ebola or pneumonic plague, even though the latter two may present more of a psychological panic. Efforts should be made to contain the disease and communicate the threat based on scientific evidence. The recommendations presented account for passengers who are near the vicinity of infected individuals at the airport and not just traveling on an aircraft.

Due to the advancements in travel technology and engineering, humans reach any part of the globe within the incubation time of most diseases allowing travelers to unintentionally carry a disease. Ebola and pneumonic plague have short illness durations with a high probability of death so the risk of transmission is low and the outbreak is not sustainable without further incubators. However, all public health professionals should be prepared to deal with a disease that may not be endemic to an area.

In each of the recommendations, the component of public education is the utmost of importance. The scientific and medical advancements of disease prevention and treatments have diminished many infectious diseases as serious biological threats. However, many diseases such as pneumonic plague remain as serious psychological threats. Public health officials need dedicated resources to create communication strategies to reduce the psychological fallout which in-turn minimizes economic consequences from an outbreak.

To contain the outbreak of diseases, aviation and public health authorities should establish preventative infectious disease measures at airports, capture contact information for ticketed passengers, expand the definition of "close contact," and conduct widespread educational programs. The measures will put in place a foundation for containing the spread of infectious diseases, minimize the panic, and reduce costs that may occur during an outbreak.

Acknowledgements

STEM is an Eclipse project originally created by IBM Research with contributors including the Federal Institute for Risk Assessment (BfR) in Germany, the Johns Hopkins Bloomberg School of Public Health, and many others. The STEM open-source community can be found at the project website: https://www.eclipse.org/stem/. Special thanks to Dr. James Kaufman and Judith Douglas who contributed to the research and article as part of the STEM IBM project team.

Development of STEM was supported in part by the U.S. Air Force Surgeon General's Office and administered by the Air Force District of Washington. Neither Eclipse, the United States Air Force, IBM, nor any of their employees, nor any contributors to STEM make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of the STEM data sets. The Air Force has not accepted the products depicted and issuance of a contract does not constitute Federal endorsement of the IBM Almaden Research Center.

Nereyda Sevilla was a Biodefense PhD student in the Schar School of Policy and Government at George Mason University in Fairfax, VA. Her dissertation used STEM to examine the role of the global aviation system for infectious disease outbreaks. Deep appreciations are given to Dr. Gregory Koblentz who, as dissertation chair, was instrumental in ensuring the completion and success of the research.