# PIC Ebola Outbreak Model

Chelsea Sandridge, Eric Jones, Kelsey Kalmbach, and Paul Diaz *

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## 1 Background

The most recent Ebola outbreak has ravaged through the countries of Guinea, Liberia, and Sierra Leone since March 2014. This has been the most deadly outbreak of Ebola in the virus's history claiming more than 20,000 lives thus far [1]. The severity of this epidemic has prompted an international response in an effort to halt the further spread of the disease. The Ebola virus is known for its 21 day incubation period, during which it is not infectious. Once a patient turns symptomatic, they are able to pass on the virus to others. The virus can be transferred through direct contact with bodily fluids such as blood and vomit and is not known to be transmitted through the air. Another prevailing characteristic of the virus is that people who have passed away due to the disease are still able to transmit the virus. This is particularly a problem in areas where burial rituals require the handling of the deceased. While several outside governments have contributed aid in the forms of health care workers and treatment beds, this has not yet been enough to curb the rate of infection. Literature suggests a reproductive number $R_0$ of approximately 2.49, that is, every infected person will transmit the disease to approximately 2.49 other people [2].

## 2 Goals of Project

The main goal of this project will be to study and determine the optimal treatment facility placement in West Africa to mitigate the potential outbreak. Our expected result will be to consider and compare different site placements for one or each of the countries affected by the Ebola Virus for different scenarios.

## 3 Potential Methods

- Collect geographic information of current hospital network in each country (or in one of the affected countries)
- Gather epidemiological data for Ebola (e.g., incubation period, infectious period, treatment effectiveness)
- Gather information regarding hospitalizations
- Gather information regarding aid promises from different governments around the world (e.g., United States, United Kingdom)
- Perform sensitivity analysis with regards to parameter range
- Analyze different site placement algorithms (e.g., maximum coverage – maximize the total number of people within a specified distance, minimum distance – minimize the distance from each individual to the nearest treatment center)

If time allows we will also estimate the potential economic cost of differing strategies, and analyze the optimal deployment schedule for each proposed placement.

*Colorado School of Mines. Math 484: Capstone. Advisor: Stephen Pankavich

## 4 Mathematical Model

Due to the latent period of the Ebola virus, we have chosen to use a modified SEIR model, which will take into account people who have been exposed to the virus but are not yet actively showing symptoms. Here we list a standard SEIR model:

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$$\begin{cases} \dfrac{dS}{dt} = \alpha S - kSI \\ \dfrac{dE}{dt} = \mu SI - \mu E \\ \dfrac{dI}{dt} = \mu E - \gamma I \\ \dfrac{dR}{dt} = \gamma I - \beta R. \end{cases} \tag{1}$$

Here, the constants are as we would expect them to be for a typical SEIR model.

Eventually, we will implement a network of interacting cities, each with its own SEIR model (similar to Equation 1, and we will couple the models with transportation terms between cities. In addition, based on the features particular to Ebola (as mentioned in Section 1) we will introduce some additional terms: for example, the cultural funeral rites cause people to embraced their deceased family members, who may still be infectious (modeled possibly by having "dead and buried" and "dead and not buried" populations); too, the introduction of hospitals and quarantine centers to Ebola-infested regions will also impact our model.

## References

[1] Center for Disease Control. *Questions and Answers: Estimating the Future Number of Cases in the Ebola Epidemic*, 2015.

[2] J. Lewnard et. al. *Dynamics and Control of Ebola virus Transmission in Montserrado, Liberia: a mathematical modeling analysis* Department of Epidemiology of Microbial Diseases. Yale, CT. Dec 2014. ttthttp://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/qa-mmwr-estimating-future-cases.html