Executive Summary

As the world population grows and its distribution changes over time, mathematically modeling the spread of disease is an increasingly important means of developing rapid and effective response measures in diverse areas of the world. Quantitative knowledge of factors related to the spread of disease can be used to influence public policy to determine the best allocation of scarce medical resources to best combat disease. Given this need to address the spread of an unknown disease in a small village on an island in Indonesia, we have created a series of models that, when combined, can both predict the progression of said disease over time and recommend the necessary preventative measures.

Our first model uses a typical SIR model to provide an initial, simplified prediction of how the disease might spread over time absent any preventative measures. From this foundation, we then modified the SIR model into the SIRD model, which accounts specifically for deaths over time and contains a modification that allows for modeling the spread of the disease given some relative abundance of vaccines that have an average protection rate (i.e. the chance that a vaccine has of making an individual immune to said disease). Our third model is a decision tree that categorizes the severity of the disease based on quantitative thresholds of individual and community risk. The model then recommends treatment measures based on the category said disease falls under.

In a real world situation, all three of the previously discussed models would be used in conjunction to ascertain an appropriate response to the disease and adjust it over time. The three models all start with the same initial input of known disease characteristics, and result in a categorization of severity from the Decision Tree Model and an estimation of the progression of the disease from the SIR and the SIRD model. Appropriate treatment measures would likely be determined by adjusting the prescriptions of the Decision Tree using conclusions that can be drawn from the other two models. The interconnectivity between the models means that the effectiveness of the implemented treatment measure can be evaluated by re-running the SIRD model with data from the situation where treatment measures are in effect. If the effects of the disease are shown as being significantly mitigated, the effectiveness of the treatment has been confirmed; otherwise, a re-categorization of the disease and a change in the way resources are allocated may be appropriate. Therefore, the interconnectivity of the models serves as a way to confirm the effectiveness of our response.

Aside from the limitations of modeling with limited concrete data and assuming an essentially isolated population of interest, we have nonetheless generated some important insights from our models. Our models support the effectiveness of vaccination measures, especially on small populations, as each susceptible individual has a greater ability to become vaccinated, and classifies the disease as a “Risk Group 4”, the most severe classification, as it crosses our quantitative thresholds of high individual and community risk. This given risk group recommends the allocation of medical resources that prioritizes the reduction of community risk over individual risk.

2014 HiMCM Problem B

The Coming Plague

Team # 5325

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Interpretation/Problem Restatement

The problem is to determine the most optimal way to identify, treat, and contain epidemics utilizing limited resources. The initial task given was to develop a generic model that simulated the spread of disease and allowed for the determination of appropriate treatment steps to mitigate further spread and harm. Based off the model we built, we were to come up with suggestions for how our country's disease control center should address future epidemics and were required to improve and modify our model given new information specific to the disease in question. Finally, we were tasked with writing a summary of our findings for our local news station.

Our Models

SIR Model

Model Building

The basic SIR model is a widely accepted model regarding the population distribution between three different categories of people: susceptible to disease infection, those that are infected, and those that have recovered (dead or immune). We have decided to use this model as a basis for a more complex model due to its ease of modification, such as adding variables based on specific disease qualities.

Assumptions

Assumption 1: Time of contraction is considered to be the same as time of infectiousness.
Justification: The model is very time sensitive. This assumption avoids more variables between the susceptibility rate of change, latent period (the time it takes for an infected individual to become infectious), and infectious rate of change by grouping the latent and infectious periods together.

Assumption 2: Each individual in the population is equally at risk of acquiring the disease; therefore, no one is initially immune to the disease. Individuals are well mixed so that everyone in the population has the same probability of being in contact with one another.
Justification: There is no way to reliably determine the number of inherently immune members of the population, and no way to reliably determine the individuals in the population who have the most or least exposure to sources of the disease. This allows us to simplify the transmissibility of the disease.

Assumption 3: The only carriers of the disease are the ones that show symptoms.
Justification: If there were individuals who were able to transmit the disease without showing any symptoms, it would make the model less accurate because the calculations for the infected and susceptible individuals would have high margins of error.

Assumption 4: The time scale is small enough that population changes such as deaths, births, and migrations won't significantly affect the population.
Justification: This is to assure that the number of people in the population will stay constant as well as limit outside influences and maintain a consistent set of rates of change within the initial population.

Assumption 5: Once someone is immune to the disease they are no longer susceptible to the disease.
Justification: Without this assumption, the model would require additional variables, such as the rate at which a recovered individual becomes susceptible again, which would more closely resemble the SIRS, not SIR model. Furthermore, the initial information we were given prevents us from inferring that recovered individuals do indeed reenter the susceptible population.

Model

$\boldsymbol{N = S(t) + I(t) + R(t)}$
Where:
$\boldsymbol{N}$ is the total population
$\boldsymbol{S}$ is the amount of people potentially susceptible to the disease
$\boldsymbol{I}$ is the amount of people infected with the disease
$\boldsymbol{R}$ is the amount of people that have recovered from the disease (recovery includes death or immunization) and are "resistant" to the disease

Based off the definitions of $\boldsymbol{S(t)}$,$\boldsymbol{I(t)}$, and $\boldsymbol{R(t)}$, we can then derive them to find

$$\frac{dS}{dt} = -\frac{\beta SI}{N}$$
$$\frac{dI}{dt} = \frac{\beta SI}{N} - \gamma I$$
$$\frac{dR}{dt} = \gamma I$$

Where:
$\boldsymbol{\beta}$ is the infection rate of the disease (how often contact between susceptible and infected individuals results in successful transfer of the disease)
$\boldsymbol{\gamma}$ is the recovery rate (the rate an infected member of the population "recovers" and moves into the resistant group).

Strengths

1. The model allows for inputs and outputs that quickly estimate the effects of the disease on the population's rates of change.
2. The SIR model is prevalent in the real world and is a known standard in the medical community, allowing for easy interpretation.
3. Given more information pertaining to the scarcity, cost, and benefits of different resources, first order cost-benefit analyses can be easily applied in conjunction with the results of the SIR model. This is useful when making necessary policy or health management decisions involving best possible allocation of resources.

Limitations

1. The model is only accurate when dealing with a closed population, which may be an unreasonable assumption to make when dealing with areas with high levels of traffic in and out (such as urban areas). Since the prevention of the spread of a disease outside an observed area is a key priority when enacting measures to control an epidemic, the model may not suggest effective actions.
2. The model can't account for changes in variables such as recovery rate or immunization effectiveness, nor can it account for random variations in individual probabilities of infection and death, which are important when dealing with relatively small populations. The model's use of initial values make it deterministic and unable to adapt to change in

certain disease conditions over time; however, the sensitivity analysis done on the model decreases the effect of this limitation and makes the nature of the model more stochastic and representative of random variations.

3. The SIR model is unable to model multiple diseases at once because it can't handle the extra complexity. In a situation with multiple diseases, there would be an overlapping population that all the diseases would affect, but the multiple death and infection rates would make the model an ineffective tool for ascertaining useful data that can be used in decision-making.

Containment Standards

Containment shall be defined as stopping infection while there is population still remaining that is susceptible.

In order to define containment, the progress of the disease is considered over time using the previously discussed equation. Therefore, for both of the following definitions, t, the time, is greater than 0.

Definition of containment:

$$\boldsymbol{\frac{dS}{dt} = 0, S > 0, t > 0}$$

In this state, the susceptibility of the population remains constant while the susceptible population remains positive. $\boldsymbol{S}$ must remain positive as that shows that some of the population is still alive and able to become infected. $\boldsymbol{\frac{dS}{dt}}$ must remain zero as it shows that there is no change within the susceptible population which indicates that the disease is not infecting anyone.

An alternate definition for containment is the state in which $\boldsymbol{\frac{dI}{dt}}$, the change in infected people over time, is less than or equal to zero while $\boldsymbol{S}$, the susceptible population, is greater than zero.

$$\boldsymbol{\frac{dI}{dt} \leq 0, S > 0, t > 0}$$

In this situation, the number of people who get infected continuously decrease. $\boldsymbol{S}$ is always positive because if no one were susceptible, no infections would occur.

SIRD Model

Model Building

One of the key limitations to the original SIR model is the lack of distinction within the "Recovery" group between deaths and those that have become immune over time. Through manipulation of the SIR model inputs, a method was generated to differentiate between those that had died and those that had become immune. The model takes into account the mean mortality rate of the disease and uses that to calculate the population that dies or recovers.

Assumptions

Assumption: Vaccines are readily available at the beginning of the simulation period and can be evaluated with an effectiveness scale.
Justification: This is especially important for the vaccine modification. If it is determined that vaccination is an appropriate measure in the treatment of a disease, then the assumption is needed so that the simulation can accurately use the values prescribed to the vaccine and simulate the effects of it.

Model

$\boldsymbol{N = S(t) + I(t) + R(t) + D(t)}$
Where:
$\boldsymbol{S}$,$\boldsymbol{I}$, and $\boldsymbol{R}$ are the same to the SIR model
$\boldsymbol{D}$ is the amount of people that are considered dead

The value for $\boldsymbol{D(t)}$ is evaluated in the following equations:
$\boldsymbol{R(t) = R_{t-1} + \left((1-\alpha) * I_{t-1} * \gamma\right) * dt}$
$\boldsymbol{D(t) = D_{t-1} + (\alpha * I_{t-1} * \gamma) * dt}$
Where:
$\boldsymbol{\alpha}$ is the mortality rate
$\boldsymbol{X_{t-1} = X(t-1)}$

SIRD + Vaccine

Since vaccines are a likely preventative measure that would be taken to mitigate the spread of a disease, this modification allows the model to account for this impact. In this case, the population of interest is a small, relatively homogenous island population with minimal outside contact and migration, so shipments of vaccines would be very effective. Therefore, all individuals who are susceptible can be specifically treated and the amount of people infected over time would be greatly decreased.

Strengths

1. The model allows differentiation between those that have gained immunity and those that have died, which leads to better classification of the severity of the disease by providing an accurate measure of death over the course of the disease.
2. The use of Excel allows for easy understanding and utilization of our model by people with non-technical backgrounds.

Limitations

1. This death and vaccine modification requires more data, which may be costly and hard to find.
2. There is no calculable dD/dt value independent of the D(t) value. This means that we can't independently calculate rate of change in D which may hinder potential applications to containment calculations.

Sensitivity Analysis

See Appendix for Figure 1
The spider graph of the maximum number of infected individuals quantitatively shows how, as the infection and interaction rate increase, the maximum number of infected individuals increases (evidenced by the positive slope of the respective lines), while an increased recovery rate corresponds to a decreased maximum number of infected individuals (evidenced by the negative slope of the respective line).

See Appendix for Figure 2
The spider graph of the total number of recovered individuals quantitatively shows how, as the death rate increases, the total number of recovered individuals decreases, while an increased interaction rate corresponds to an increased total number of recovered individuals. Surprisingly, an increased recovery rate and vaccine protection rate do not correspond to an increased total number of recovered individuals. This may be due to the fact that, in our model, an increased vaccine protection rate results in a greater rate of removal of individuals from the susceptible population, and these individuals are not added to the total recovered population.

See Appendix for Figure 3
The spider graph of the total number of vaccinated individuals quantitatively shows how, as the infection rate and available number of vaccines increases, the total number of vaccinated individuals increases, while an increased recovery and interaction rate corresponds to a decreased number of vaccinated individuals. This may be due to a greater recovery rate reducing the need to vaccinate individuals, while a greater interaction rate may contribute to a greater number of infected people over time and, therefore, reduces the total number of susceptible individuals that are able to be vaccinated.

See Appendix for Figure 4
The spider graph of the total number of protected individuals (due to vaccinations preventing them from being infected) quantitatively shows how, as the vaccine protection rate and vaccine availability increase, there is a large corresponding increase in the total number of infected individuals. To a lesser extent, an increased death rate also corresponds with an increased total number of protected individuals, possibly because of a lurking variable of time. As time advances, more people are protected and more people die.

Decision Tree Model

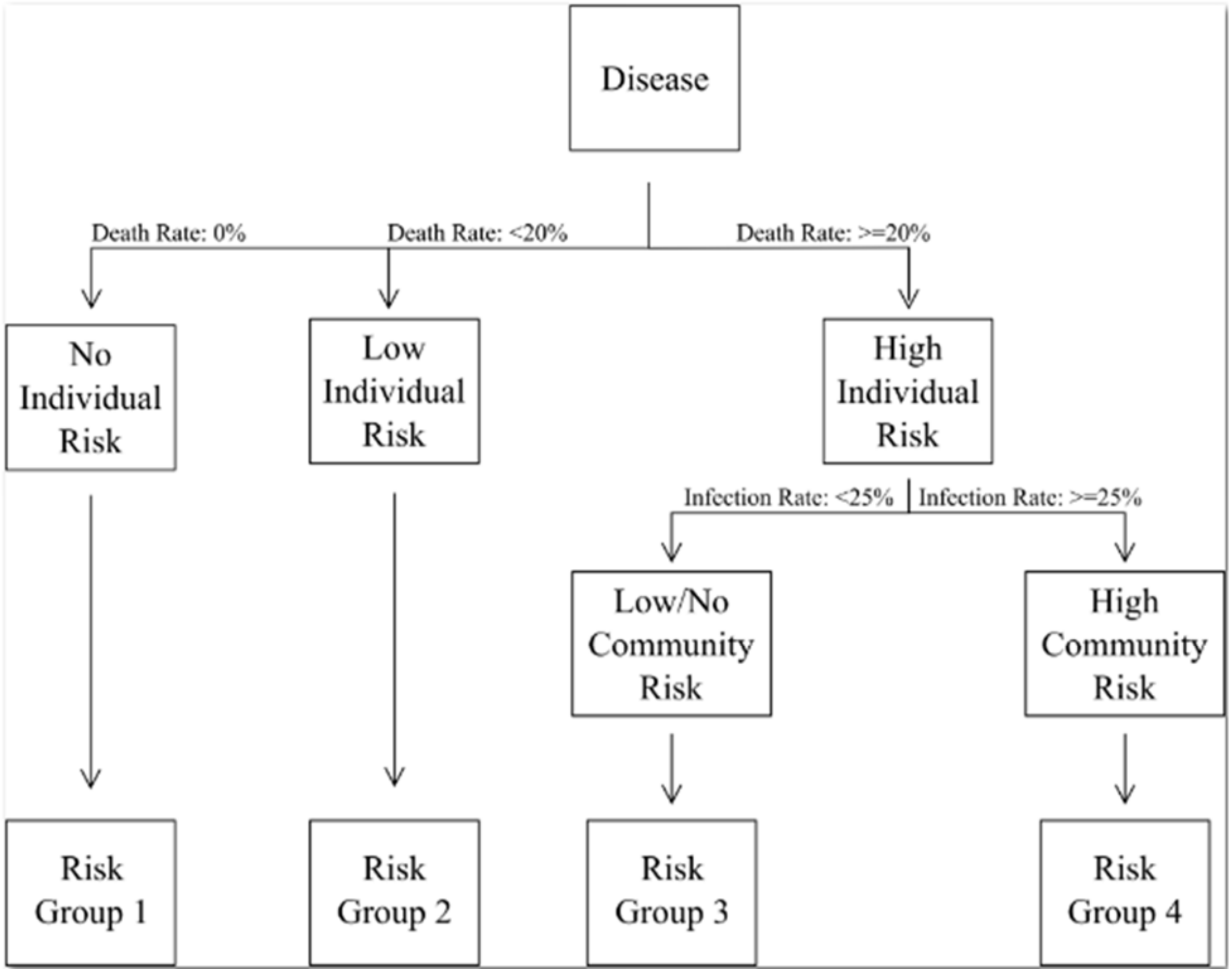
Model Building

Based on the World Health Organization (WHO) guidelines for categorizing the severity or risk associated with a certain outbreak of disease, the model uses the quantitative measures of death rates and infection rates to categorically describe the "risk group" a certain disease situation falls under. The decision tree was built using WHO categorizations of disease severity and empirical examples of infection rates to build the decision tree. The two main factors in play during the determination were community risk (how infectious the disease is to the overall population) and individual risk (the effects on a single person, which may include death). The final risk group that is determined can be used to assign appropriate treatment measures.

Assumptions

1. The values for infection rate and mortality rate in the SIRD model are consistent and reflect an accurate measure for classification of the disease. This is necessary to create the quickest and simplest way to classify between the various WHO groups.
2. The threshold values for disease are estimations. The threshold value for individual risk is based on the lowest value of mortality rates within already classified Risk Group 3 and 4 (which are classified by the WHO as high individual risk), which happened to be around 20%. The rate of infection threshold of .25 is also an estimation based on reasonable averages from a variety of example diseases.
3. We assume that all other variables can be ignored when it comes to the calculation of thresholds to allow for simplicity and to avoid categorical data from coming into play and to avoid variables that would require more data, which would make it incompatible with the SIRD models.

Model



KEY:
WHO Risk Group 1 - Little to no severity for individuals or the community - usually this classification reflects either the lack of individual risk of death or simply that immunization methods are already in place to dangers.
<u>Preventative Measures and Allocation of Resources</u> - No preventative measures are really needed, however, the CDC of said country may wish to allocate the most resources towards the creation of vaccines against the strain of disease to preempt potential evolution of the non-harmful strain.

WHO Risk Group 2 - Low severity risk to individuals and little to no community risk - usually this classification is assigned to diseases that have a potential to cause harm or death to individuals with a disease. However, the disease is either non-transmittable (geographically or pathologically) or the subject is isolated and presents no risk to the community overall. Usually preventative and treatment measures are readily available.
<u>Examples include</u> - Hepatitis A and B, Staph., typhoid, and the common flu
<u>Preventative Measures</u> - If available, administer vaccines. If not, implementing hospitalization to reduce the risk of spread of the disease may be needed. The needed resources for research and

development of preventative measures regarding immunization may be necessary to prevent spread of similar diseases in the future.

WHO Risk Group 3 - This classification refers to diseases that have been diagnosed as high risk toward individuals, usually referring to high possibility of death or serious problems with host, but lacks the potential to spread, usually due to the difficulty to spread (e.g. blood to blood, sexual intercourse, or sheer lack of transmissibility). Another possibility is that a vaccine is already available for the disease in question which reduces community risk and increases preventability.
Examples include - HIV, Monkeypox, and chlamydia.
Preventative Measures - If available, vaccination is once again recommended as it is the fastest way to reduce symptoms and infectiousness. However, if unavailable, careful measures must be taken to prevent contact between the susceptible and infected beyond just hospitalization. Quarantine should remain the last ditch option if the infected is noncompliant to warnings. Education of the population regarding the causes of infection may be another potential to reduce spread.

WHO Risk Group 4 - This classification refers to diseases that have been diagnosed as high risk towards both individuals and the community. These are diseases that have both a high risk of death/serious injury for the infected as well as high risk for spread throughout the community due to high transmissibility rate between the infected and susceptible. These diseases are usually viral in nature and are difficult to generate a vaccine for which means that preventative measure are not as readily available.
Allocation of resources – Due to the high community risk associated with this group of diseases, priority should be given towards preventing new infections rather than treating existing infections. Therefore, money and human resources should be spent educating the population on how to avoid the disease and implementing measures to separate the infected from the uninfected. A maximum possible usage of containment facilities would be appropriate in this circumstance due to the importance of decreasing the likelihood of contact with the disease. The next priority in this scenario would be vaccination research, so that efforts are made to make probability of disease spread extremely low.
Example Include- Ebola and serious strains of Herpesviruses.
Preventative Measures- Strict quarantine on the infected or susceptible may be necessary to mitigate the overall harm on the population. Based on multiple case studies done by the WHO and international health organizations, quarantine seems to be the most feasible way to prevent spread of disease. Quarantine should begin with the individuals infected and, if that fails to prevent spread, isolation of the geographical region should be implemented to prevent further spread into other regions as well.

Strengths

1. The model is highly non-technical and can be easily interpreted by those whom may not have the expertise to assess the results of a more technical model. Therefore, this model can be more easily translated into practical medical solutions.

2. The simple categorization tool provided by the model is highly useful in time-sensitive situations or emergency situations in which a reasonable estimate of appropriate action and involved risk would be more valuable than the rate of change measurements that the other models provide.
3. This model is the only one out of the three that suggests how to deal with a given disease based on how risky it is.

Limitations

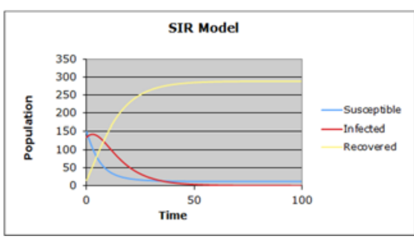
1. Once again there is a lack of data used in obtaining the numbers used for the decision tree model. The percentages could vary from disease type, strain of disease, and the area's population and development.

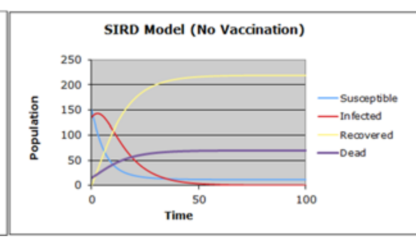
The Question of Ethics

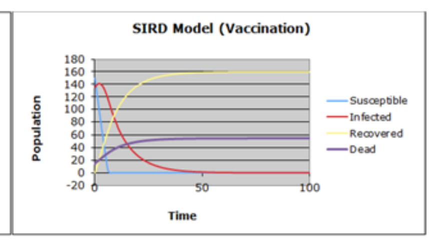
Due to the high controversy behind quarantine and isolation, the CDC should also consider the ethical backings behind each option. First, the idea of quarantine is backed by the notion of utilitarianism, the philosophy that the maximum number of lives should be saved. However, this directly contradicts the idea of human rights and the medical code of ethics in which every life is considered worth saving. The act of quarantine may not be inherently an act of "giving up" on those in isolation, but ethically it may not allow for maximum resources to be allocated towards preventative measures and treatment. Although this question is beyond the scope of the paper, it is an important question to ask and consider when selecting preventative measures to implement.

Scenario

Implementation into Our Model







The models shown above are the simulations of the situation given in the problem (Initial Population = 30 people, Initial Infected = 135 people, Initial Recovered/Dead = 15) along with estimated constraints based off the values used for our research and reasonability regarding the most common mortality rates and infection rates (Mortality rate = 20%, Infection Rate = .2 and Recovery rate = .1). Figure 3, with the SIRD model with vaccination takes into account vaccination factors (Vaccination Protection = 70% and 30 Vaccinations Delivered Per Time Period). The graphs above show the data based on each individual model.

Recommendations for the CDC

Send a research team to study the disease.
Justification: Due to the high amount of uncertainty, specifically with regards to the infection rate, medium of transmission, and mortality rate, additional information is needed on how to address the disease. The research team would first be sent to obtain more information to better model the type of disease and the rate of spread. The team could also obtain strains of the disease and begin research and development on vaccines. Based on our preliminary estimations with a mortality rate of 20%, 1/10 of the population was already dead within 10 days of the disease. Thus, preventative measures should be implemented quickly if the disease appears on US soil, especially in a case that mortality or infection rate is underestimated.

Use a model similar to the SIRD model that constantly accounts for new and updated data in order to accurately project the effects of a disease on a population over time.
Justification: Because the SIR family of models (which includes variations such as SIRD) is already well established and proven across a wide variety of diseases, the recommendation allows the CDC to create an accurate model for the analysis of risk of the diseases. The simplicity of the SIR family of models also allows for quick analysis with simple inputs. However, due to the limitation of dependence on initial values, the CDC should also continuously update the model in accordance with changing factors, such as immunization, quarantine, and geographical changes to take proper action.

If the disease appears in the US, immediately implement the WHO Risk Group 4 protocol assigned by the decision tree model shown above.
Justification: Based on the data given, we see that the community risk of the disease is quite high already; shown by one half of the population already being infected and showing symptoms. However, we lack the data for mortality rate regarding the disease. We can technically create an estimation of 10% based on the 15 people dead in the past week but this value is unreliable as it attempts to apply short term probability to a long term mean value. Therefore, we recommend that the CDC treat the disease as highly deadly to avoid the consequences of underestimation.

Questions for Clarification

What is the medium of transmission of the disease?
Justification: The medium by which the disease spreads has a powerful impact on both factors relating to the spread of the disease and recommended preventive measures. For the latter case, an airborne virus, for instance, would most likely need additional safety measures such as Airborne Infection Isolation Rooms (AIIRs) and the adequate distribution of facemasks to patients and medical workers. These precautionary measures would account for a potentially unnecessary financial burden if the transmission turned out to be only through bodily fluids, for instance. For the former case, an airborne virus would also have a fairly high infection rate, while bodily fluid transmission rate would be considerably lower. This new information would also allow us to classify more specific prevention techniques within the different WHO Risk Groups.

Are those who have recovered from the disease still susceptible to infection again?
Justification: Our model assumes that individuals who are in the recovered group are not able to be infected or infect others again (i.e. they're no longer susceptible to disease). In the case where individuals of the recovered group can rejoin the susceptible class, we would have to modify our model to include the chance of an individual rejoining the susceptible group, more closely resembling the widely accepted SIRS model. Another modification based on this answer would be changes in preventative measures regarding those that recover but are still susceptible, such as longer periods of quarantine to reduce the chance of becoming infected or infecting others again.

What is the relative abundance of government resources, in regards to preventative measures for disease?
Justification: Knowledge of the availability of resources can be used to improve the specificity of the preventative measures taken in our decision tree model. Specificity of scarce resources in particular is crucial to what measures can be implemented. For example, a lack of research facilities and lack of hospitals would have different effects in regards to the effectiveness of implementing certain preventative measures. Therefore, specificity allows us to better establish what specific guidelines proposed by the decision tree model to follow and which are impossible, particularly in the case of Risk Group 4 diseases.

Model Modifications and Refinement based on Supplemental Information

Appears to spread through contact with bodily fluids of an infected person
This conclusion means that infection rate will be considerably lower given that bodily fluid transmission rate (especially in the case of proper isolation treatments are administered) is less contagious than transmission through indirect and airborne contact. This also helps with classification, as it reduces the risk of community infection which potentially lowers the Risk Group Calculation.

The elderly and children are more likely to die if infected
This gives us more of an idea to the extent of the disease and its effects on different types of population. If data is given regarding the age groups, such as the population numbers within each of the "elderly" and "children" age groups, then we would be able to create multiple models with each model specific to each age group with a more accurate mortality rate. Furthermore, this allows us to better analyze the proper WHO Risk Group classification.

A nearby island is starting to show similar signs of infection
The SIR model and the family of SIRD models are limited in the assumption of an isolated population. Potentially, we would be forced to apply this model again to the new susceptible population. This point may also require us to modify our model to account for changes in total population to better account for changes in susceptibility of the disease.

One of the researchers that returned to your capital appears infected
Similarly to the previous scenario, we would have to reapply the parameters of the SIRD models to the geographical region in question. Instead of an island, we are dealing with a contiguous landmass, which means that the population parameters will be different. The US probably has a lower infection rate due to better preventative measures and greater access to hospitals. Finally, we could use the decision tree model to enforce a higher classification group in order to implement the necessary preventative measures. In the case of our country, more direct control over how we allocate our scarce medical resources means we should over rather than underreact to the introduction of new diseases, in order to ensure that the disease is quickly contained and eliminated.

Conclusion

Results

By utilizing three different mathematical models in conjunction-the SIR, SIRD, and the decision tree model-we were able to classify diseases by both individual and community risk factors. We also assigned numerical values based on the SIR family of models to determine whether not a scenario is considered contained or not. Finally, we used the classifications and severities to generate a basic model for different preventive measures for each type of risk group.

Through our analysis of these various models we determined that overall the best way to deal with risk is to limit the interaction of those infected and those that are susceptible to disease. By limiting infection rate down to as close to zero as possible, we can limit the chain of procession incorporated in the SIR model. This can be done by quarantine and other methods of isolation which are recommended by our model.

When the models were applied to the scenario of the island in Indonesia, we were able to make some assumptions regarding rates of infection, mortality, and recovery, and apply the general population data. The situation in Indonesia was categorized as a “Risk Group 4” scenario and its severity was supported by the high death rates found in the SIRD model. The recommended measures for treatment included vaccinations (if possible), using the SIRD model to run again while accounting for the effect of vaccines. The much lowered death rate indicated that vaccines were a highly effective tool in the small population of the village. Furthermore, the high community risk associated with a “Risk Group 4” disease suggests the appropriate response measure should focus on isolating infected individuals from uninfected individuals rather than focusing on the treatment of infected individuals.

Potential Extensions

Potential extensions, if time were admissible, for the overall model would be:

- Use of more empirical data to find out more mortality rates, infection rates, and other data to create better informed estimations.
- Use of more empirical data to test out already accepted models with the ones we created and do error analysis of the model with this data.
- Evaluation of more potential variations in SIR, such as, SEIR or SIRS, and their effectiveness within the situation given as well as sensitivity analysis toward the respective variables within each mode.
- Creation of more variable models, such as the one we created regarding vaccination, to factor in other preventative measures and their effect on the population.

News Report

In Indonesia, there is an outbreak of a viral disease in a small village. So far, 5% of the total village population has died from the disease. In an effort to address the potential impact such a disease could have if it were to spread in other countries, our team has modeled the disease through predicting the changes in the susceptible, infected, and recovery populations of the island's population and underlined some measures to be taken if a country finds itself in a similar situation.

We have found that the disease has high individual and community risk (relatively high mortality rate and infection rate). According to the World Health Organization's disease classification system, the disease would then be considered a Risk Group 4 disease. The disease serves as a major problem within the region as there is a lack of resources for disease prevention. Although no specifics have been found, the nation of Indonesia has historically disregarded rural regions when it comes to disease. Furthermore, due to the unknown nature of the disease, there are also no preventative measures available such as vaccines. What we do know is that the disease is transmittable only thorough body fluids and is more deadly amongst the young and elderly.

What happened in Indonesia may become a very real risk in the United States, as there have been rumors that a researcher recently returned with Indonesia showing symptoms of the viral disease. These rumors are true. Despite all this, there is little need to fear, as US protocol in dealing with highly deadly and infective diseases is to quarantine and treat the patients to avoid further infection; therefore, there is a low risk that anyone will be immediately in danger. However, if you are still worried about the disease, basic preventative measures can be taken by each individual to avoid the risk of infection. Avoid any transfer of body fluids, such as blood, saliva, or sweat, with someone who seems to be sick or show symptoms.

Although our models show a high severity and potential for large casualties, preventative measures in the US are enough to lower the infection rate to a manageable level to where normal citizens have little to no risk at all. As President Kennedy once said, we have nothing to fear but fear itself. In the midst of the growing Ebola epidemic, such words have never rung more true.

Appendix

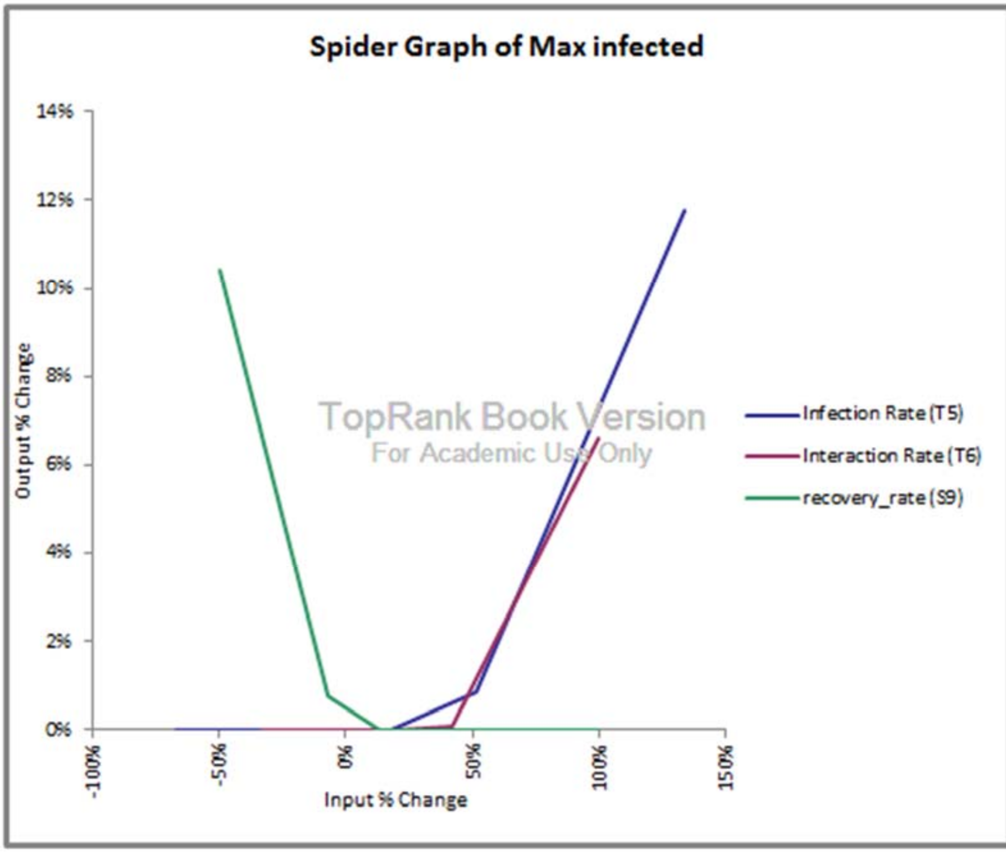
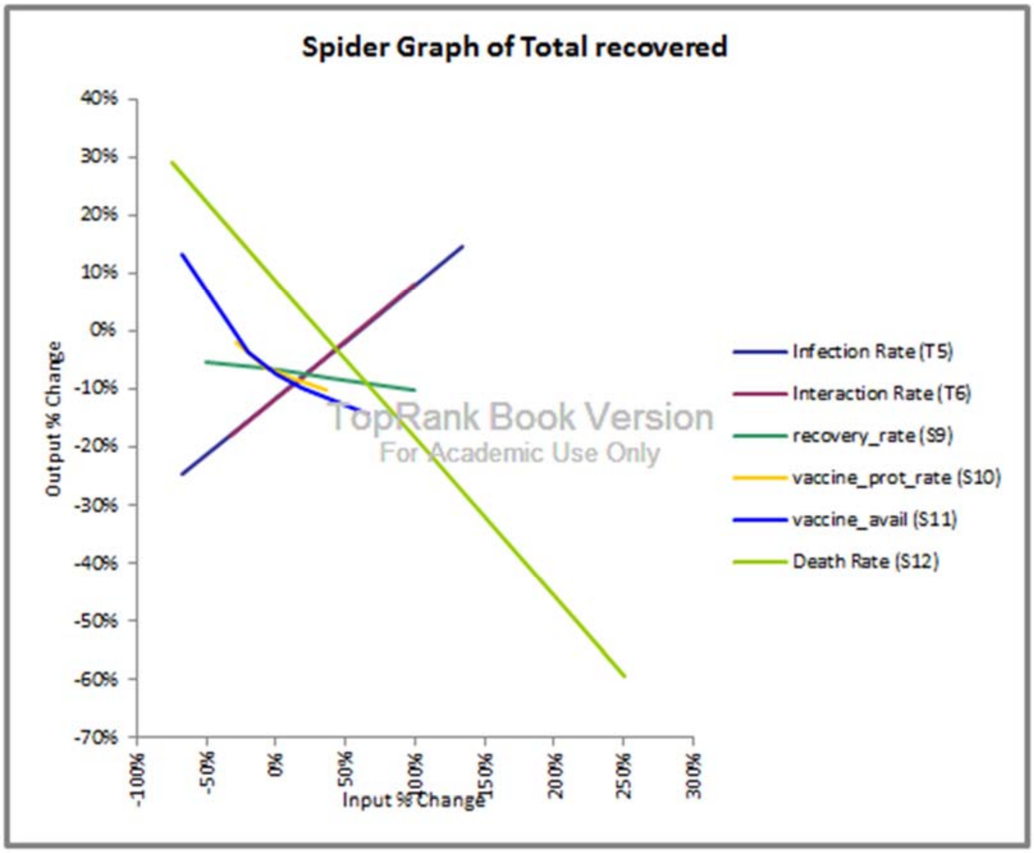


Figure 1


Spider Graph of Total recovered
40%
30%
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-20%
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Output % Change
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Infection Rate (T5)
Interaction Rate (T6)
recovery_rate (S9)
vaccine_prot_rate (S10)
vaccine_avail (S11)
Death Rate (S12)
TopRank Book Version
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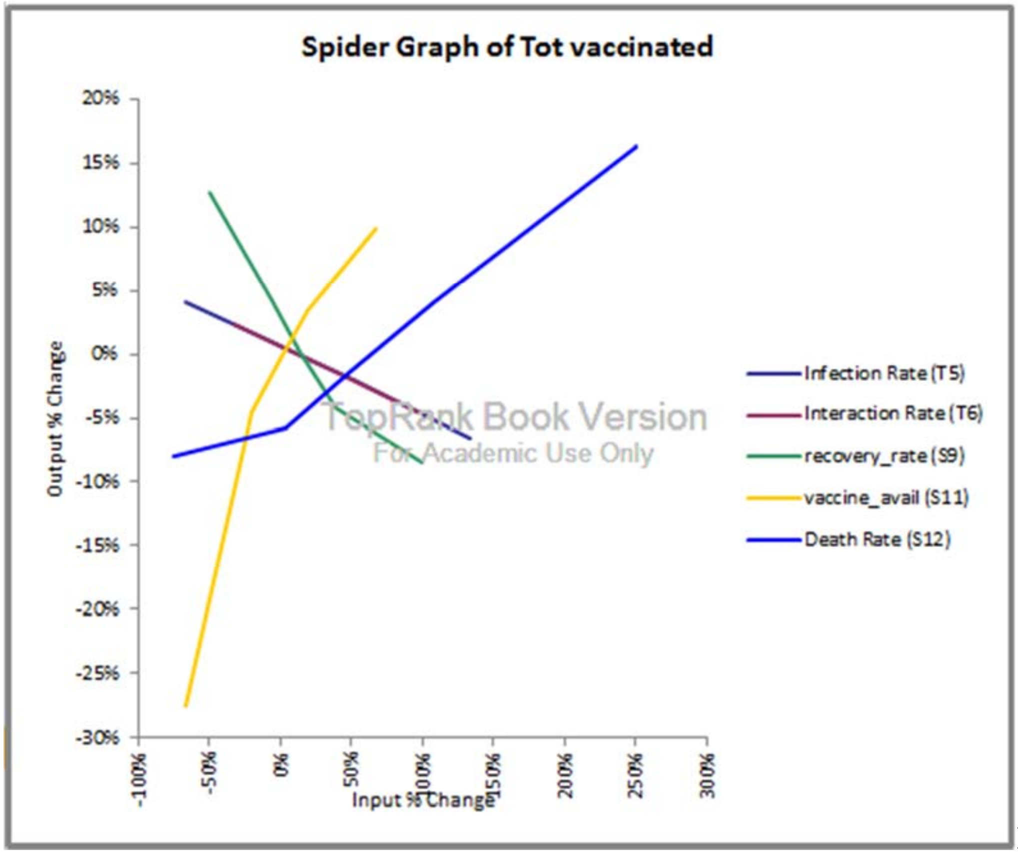
Figure 2


Spider Graph of Tot vaccinated
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Input % Change
Infection Rate (T5)
Interaction Rate (T6)
recovery_rate (S9)
vaccine_avail (S11)
Death Rate (S12)
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Figure 3

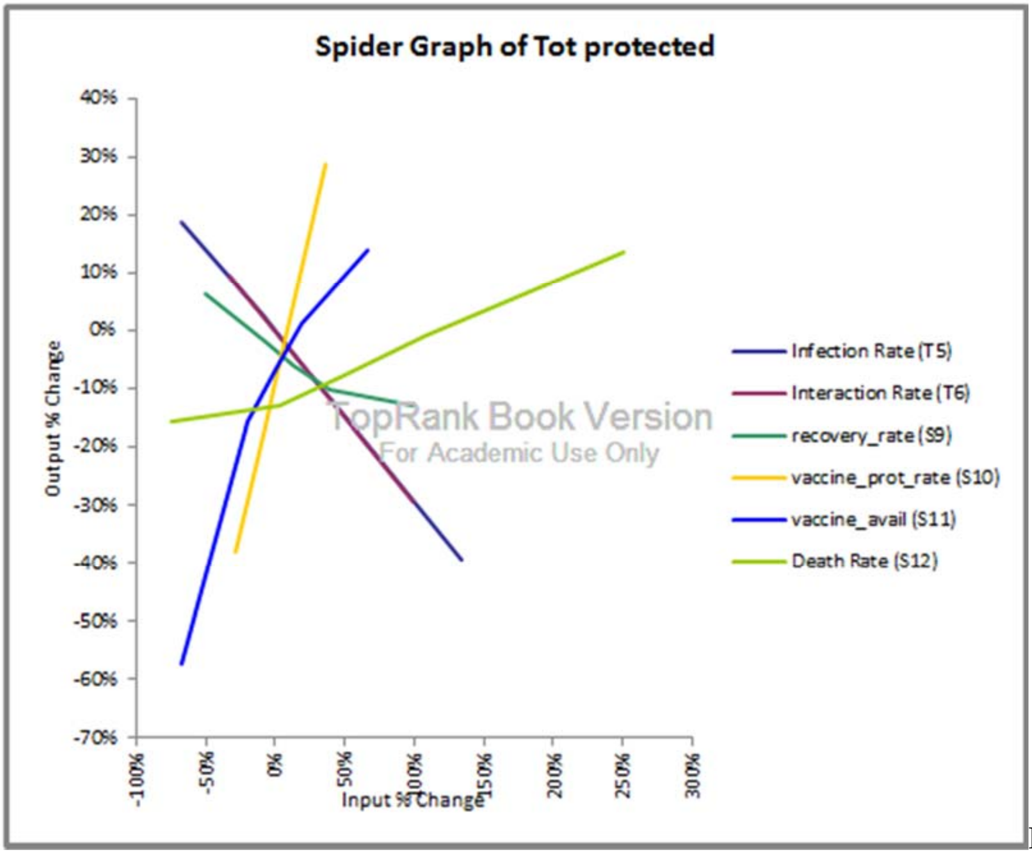
Spider Graph of Tot protected
Output % Change
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-60%
-70%
-100%
-50%
0%
50%
100%
150%
200%
250%
300%
Input % Change
Infection Rate (T5)
Interaction Rate (T6)
recovery_rate (S9)
vaccine_prot_rate (S10)
vaccine_avail (S11)
Death Rate (S12)
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Figure 4

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