Is Travel Restriction the Answer to Liberia's Ebola Pandemic?

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1 Abstract

In this project, we model the spread of Ebola virus disease (EVD) in Liberia, West Africa using the pandemic model, with population of Liberia at various stages of the disease (susceptible, exposed, infected, and recovered) as the stocks, and in relation to various factors that influence the rate of infection of EVD. It is found that travel restriction – the strategy implemented by Liberian government, has not been very effective in curbing the rate of spread of EVD. Modeling this problem using the "Shifting the Burden" archetype, it is shown that the quick-fix to the problem has made it more difficult to achieve the long term goal of eradicating the disease. Finally, we propose to lift the prevalent travel restriction policy and additional measures to further ameliorate the situation, namely increasing government responsiveness to take actions against EVD, implementing the contact tracing system and educating the public. We believe these proposals could help the government to dampen the spread of Ebola virus in the long run. As a school project, this was completed in November 2014 when the Ebola pandemic was still on going.

2 Introduction

Ebola virus disease (EVD) is a severe, often deadly illness in humans. While the virus was initially introduced to the human population through contacts with bodily fluid of infected animals, it can also be spread through human-to-human transmission via direct contact with organs, blood, secretion and other bodily fluids of infected people, and with surfaces and materials contaminated with these fluids. Humans will only start to transmit EVD once they develop symptoms. The early symptoms are fever, fatigue, muscle pain, headache and sore throat. The later symptoms are vomiting, diarrhea, rash, symptoms of impaired kidney and liver function, and in some cases, both internal and external bleeding (World Health Organization, 2014a).

The EVD outbreak in Liberia has claimed many casualties. As of 22 October 2014, around 7 months after the start of the outbreak, there have been almost 7000 cases reported and more than 2700 deaths in Liberia alone (Centers for Disease Control and Prevention, 2014). The spread of the disease is aggravated by the low level of education of the general population, as shown by the relatively low literacy rate of 60.8% there (Index Mundi, 2011a). Poor sanitary, lack of medical centers and experts and economic problems have also hindered the government to effectively contain this outbreak.

Faced with the current crisis and compounded by the inadequacy of the country's health system and insufficiency of international response towards the epidemic (Boseley, 2014), the Liberian government has chosen to implement the drastic measure of travel restriction by closing off their borders except major entry points (International Monetary Fund, 2014). In this project, we model the current situation of Liberia: the rate of spread of EVD under the condition of travel restriction and evaluate the effectiveness of the travel restriction.

3 Problem Description

There are several reasons why the Ebola virus disease (EVD) epidemic is very dangerous for Liberia. Firstly, it has a high death rate of 55% (Center for Disease Control and Prevention, 2014). Without proper measures being taken, the disease can easily reduce the size of the population significantly. Furthermore, an infected person will remain infectious for a long duration of 9 weeks. He will exhibit symptoms for 2 weeks before he recovers. In addition, he is still infectious up to 7 weeks after recovery (World Health Organization, 2014a). Lastly, as a developing country, Liberia lacks the capacity to build a strong foundation in health care sector. Most of the capital is channeled into social and economic sector for the development of Liberia. Therefore, the existing healthcare sector of Liberia is not robust enough to deal with the EVD epidemic.

The mixture of Liberia's weak healthcare system, low GDP per capita, insufficient international humanitarian aid and the severity of EVD itself has prompted the government to resort to the short-term solution of travel restriction in order to deal with the problem immediately. Travel restriction will indeed help to inhibit the immigration and emigration flow of people into and out of Liberia. There will be lower chance of an exposed person entering the country and thus there will be decrease in the number of exposed and subsequently infected people in the country. This will lower the rate of spread of EVD and prevent the aggravation of the current epidemic.

However, this policy is a classic example of “Shifting the Burden" archetype. It has failed to ameliorate the situation in the country as many people still get infected and die as a result of EVD. While in the short run it manages to reduce the rate of spread of disease, eventually the travel restriction will affect Liberia’s national income as it has become more difficult for Liberia to export its goods. Moreover, travel restrictions impede health workers from other countries from working in Liberia.

As export is a major part of Liberia’s national income, its national budget will be severely affected. This will affect Liberia’s ability to increase its healthcare spending, which will improve the infected individuals’ survival rate and reduce the rate of transmission of EVD. Therefore, increasing healthcare spending could actually help to alleviate and solve the problem of EVD epidemic in the long run.

4 Model Description

In modeling the Ebola virus disease (EVD) transmission in Liberia, iThink[1] by isee systems was used. The time unit used in this model is days while the model itself will have study period of four years starting from one *Exposed* individual in Liberia.

We have observed that the case of EVD transmission in Liberia follows the Shifting the Burden archetype as shown by the presence of the two balancing loops and one reinforcing loop. This archetype illustrates the problem of favoring the symptomatic solution over the fundamental solution to solve the problem of EVD transmission, which is represented by the rate of infection in Fig. 4a. Moreover, this symptomatic solution will actually make it harder to execute the fundamental solution.

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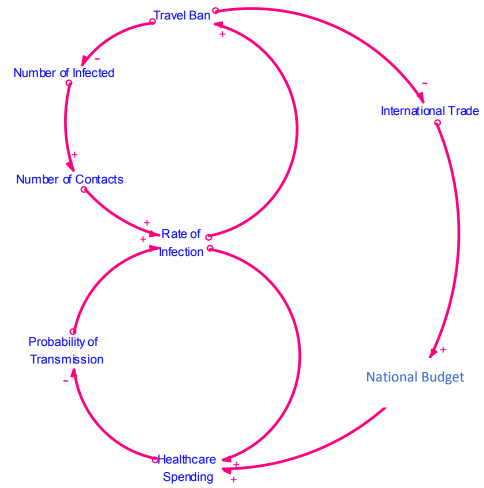

Figure 4a

As shown in Fig. 4a, in Liberia, the government chooses to reduce travel liberty by imposing *travel ban* both domestically and internationally (International Monetary Fund, 2014). Without the inflow of immigrants and tourists, the possibility of having exposed individuals coming into Liberia will decrease. With less number of exposed population, there will be lower *number of infected* people in the country, and consequently, the *number of contacts* between the contagious and the susceptible will decrease. Therefore, the possibility of EVD transmission to the susceptible population, and thus the *rate of infection*, will be reduced. A better, long term solution to the EVD epidemic would be aimed at the underlying structures of the problem, which is the quality of healthcare services available to the population. Obviously, the healthcare quality is proportional to the *healthcare spending*, which means that *healthcare spending* needs to be increased. With a better healthcare quality, infected individual will be able to receive proper treatment, thus improving their survival rate. Moreover, exposed individuals could be identified with regular health screenings and immediate follow-ups such as quarantine and contact tracing to reduce the *probability of transmission* between the contagious and susceptible.

However, that long term solution may not be preferred by the Liberian government due to the delay involved between increasing *healthcare spending* and its intended result of decrease in *probability of transmission*. Consequently, the symptomatic solution of *travel ban* is preferred. However, this solution could undermine Liberia's capacity to implement the long term solution of improving its healthcare sector. This is because a reduced mobility severely disrupted the flow of goods and people between Liberia and its trading partners. Eventually, Liberia's export which mainly consists of agricultural products such as rubber and palm oil will drop (Washington Post, 2014), hence decreasing Liberia's *international trade*. With a reduction in *international trade*, Liberia will earn less export income which will in turn, reduce its *national budget*. With less capital reserve, Liberia's capacity to increase its *healthcare spending* will be reduced. Hence, they might not be able to afford expensive medical equipment and train workers that would help to alleviate the EVD epidemic in the long run by decreasing the *rate of infection*.

4.1 Main Population Stock-and-Flow

Liberia's population is modeled as a stock-and-flow diagram with six stocks. The SEIR (Susceptible-Exposed-Infected-Recovered) model is used to model the Ebola epidemic in Liberia. Each individual in Liberia falls into one of the six categories:

Susceptible: Population that is vulnerable to Ebola infection. These individuals have not yet been infected with the disease.

Exposed: Population that have contracted the Ebola virus from the contagious populations, i.e. *Infected* and *Recovered but Contagious*, but are currently unable to spread the disease. Ebola has what is described as latent phase which is a period of time for an individual between contracting Ebola and becoming an *Infected* person, who develops the Ebola Virus Disease (EVD) symptoms. According to World Health Organization (2014a), the incubation period for Ebola ranges from 2 to 21 days. Taking the median of the data, we assume that an *Exposed* individual will become *Infected* after 14 days incubation period.

Infected: Individuals who have contracted the disease and are now capable of spreading the disease to the *Susceptible* population.

Recovered but Contagious: *Infected* individuals that have recovered from EVD. However, they remain capable of spreading the disease to the *Susceptible* population.

Fully Recovered: After 49 Days (World Health Organization, 2014a) the *Recovered but Contagious* individuals will fully recover from EVD and no longer be able to spread the disease.

Death: The critical period for Ebola virus is 14 days. After 14 days, an *Infected* individual have 45% chance of recovering and 55% chance of dying.

At the beginning of the simulation, every individual in Liberia falls into the *Susceptible* category except for 1 *Exposed* individual. We have chosen only 1 *Exposed* individual as our starting point to model the best case scenario. After 14 days, the *Exposed* individual will become *Infected* and spread EVD to the *Susceptible* population. Some of the *Susceptible* population who come in contact with the *Infected* person will get infected with EVD and enter the *Exposed* population. These *Exposed* individuals will then turn into *infected* individuals and spread the EVD even further. After the critical period of 14 days, an *infected* individual could either recover, entering the *recovered but contagious* population, or die, entering the *death* population. An individual in the *recovered but contagious* population will remain contagious for the first 49 days of recovery, after which, he will be *fully recovered* and develop immunity to EVD.

4.2 Mechanism of Infection

There are various ways in which the EVD can be transmitted; contacts between the contagious and *susceptible* through blood or body fluids, objects contaminated with the virus, and infected animals. For the discussion in this model, we limit the transmission method to contacts between the contagious and *susceptible* only. This is because the cases of EVD outbreak in various countries originated with the contacts between the contagious and *susceptible* population. In the model, the *number of new exposed per day* is a product of the total *number of contacts with susceptible per day* and *probability of transfer upon contact*, that is the probability that the disease will be transmitted on any contact. Although there are many contacts that one makes per day, the chance of EVD being transferred upon each contact is assumed to be low as the EVD transmission requires bodily fluids to be involved upon each contact. As such, the *probability of transfer upon contact* is assumed to be 0.2. The *number of contacts with susceptible* is a product of the *probability of meeting a susceptible person* and the *total number of contacts that contagious makes per day*. As there are two groups of population that are considered to be contagious, two converters are defined for each type of stock: *number of contacts an infected person makes per day*, set to be 4, and the *number of contacts a recovered but contagious person makes per day*, set to be 0.2. Each is multiplied by its corresponding stock and added together to obtain the *total number of contacts that the contagious population makes per day*. The *probability of meeting a susceptible person* is defined as the ratio between the number of *Susceptible* population and (*total population* - 1). The reduction of the *total population* by 1 is necessary as it is impossible for an individual to meet and infect himself. According to World Health Organization (2014b), Liberia has a population of 4.4 million people.

4.3 Migration

Our model assumes that there are only two types of population involved in migration; the *susceptible* population and the *exposed* population. According to Index Mundi (2011b), Liberia's *immigration rate of the susceptible* is 3.56 per 1000 people per year. As for the *immigration rate of the exposed*, a study by Wilson (2014) has concluded that there is always a minimal rate of 3 exposed people per month taking international flight in West Africa. We also assume that there is an information delay among people travelling in West Africa. Initially they are still unaware of the Ebola outbreak; they still travel as usual. However, as they begin to learn about the growing number of Ebola cases and victims, they begin to reduce the frequency of travel. As such, we formulated our *immigration rate of the exposed* population to be a graphical function as shown in Fig. 4.3.a.

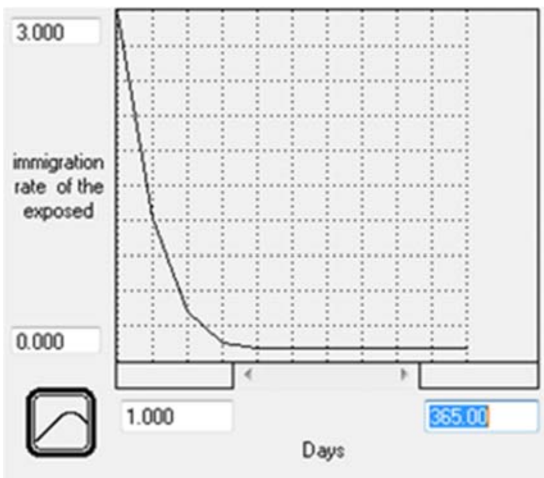

Figure 4.3.a

As for the emigration rate, our model splits the empirical emigration rate of 9.26 per 1000 people per year into two emigration flows: *emigration of the susceptible* population and the *emigration of the exposed population*. To split this, two ratios are introduced: the *susceptible to total population ratio* and the *exposed to total population ratio*. These two ratios are then multiplied to their corresponding emigration outflows, together with the empirical emigration rate, to arrive at the *emigration of the susceptible* outflow and the *emigration of the exposed* outflow.

4.4 Healthcare

To model the change in healthcare standard in the country, our model uses the *change in healthcare spending* of the government. As the situation of national health changes, the government respond by increasing or decreasing funds from its *national budget* to the healthcare spending. Thus, a new converter called *ratio of number of EVD cases to the total population* is introduced to reflect the situation of national health. This ratio is obtained by adding the total number of *infected*, *recovered but contagious*, *fully recovered*, and *deaths* and then dividing it with the *total population*. This ratio will then affect the *percentage of national budget for healthcare spending*. Therefore, as the number of EVD cases increases, the government will then increase the healthcare spending of the country from 4% to 10% of the *national budget* (United Nations, 2014). This increase in healthcare spending will then be divided with the *current healthcare spending* to obtain a new ratio called the *change in healthcare spending* of the government. This new ratio, which represent the change in Liberia's healthcare standard, will affect both the infection mechanism and survival of those EVD victims. As the ratio increases, there will be more healthcare workers, facilities, and better equipments to contain and control the *Infected* population. As a result, there will be a decrease in the *number of contacts that the infected makes per day*. Furthermore, this increase in healthcare standard will increase the chance of survival of the infected; the *recovery rate* will increase and the *death rate* will decrease. On top of that, better equipments will decrease the infection between the infected and the healthcare workers, thus reducing the *probability of transfer of EVD upon contact*. These various effects combine will counteract the *rate of infection* in the model.

4.5 Travel Restriction

In order to prevent the spread of the EVD, the government of Liberia has introduced travel restrictions. Besides preventing individuals coming in and going out from the country, the travel restriction also minimizes travels within the country. This policy will greatly reduce the inflows to and the outflows from both the *Susceptible* and *Exposed* population since people are unable to travel freely from one area to the others. In the model, *travel ban* will reduce those inflows and outflows to 0, as we are interested to compare the maximum impact of *travel ban* on the infection mechanism. Therefore, this policy will reduce the *number of contacts between the infected and susceptible populations per day* as there is no extra inflow to the *Exposed* population other than from the *Susceptible* population that have been exposed to EVD.

While the travel restriction policy does alleviate the spread of the EVD in the short run, it has negative repercussions in the long run. *Travel ban* severely disrupt the *international trade* of Liberia, deteriorating her economy. According to the World Bank report (Washington Post, 2014), Liberia's most important agricultural export, rubber, was badly affected. Rubber export is estimated to drop by 20%. Other agricultural and industrial export are severely disrupted as well. Economic disruption will ultimately deplete *national budget*, disabling them to increase their *healthcare spending*. Without sufficient resources in their healthcare sector, it is impossible to contain the Ebola virus disease in the long run.

5 Model Validation

After creating and formulating the model for the Ebola infection in Liberia, it is important to validate our model for the purpose of building up confidence for the result and analysis discussion in the next session.

5.1 Model Validation

During the initial stage of Ebola outbreak, the level of government's response was very minimum. The government does little to contain EVD since the number of people affected is very small. However, due to this unresponsiveness, the *total number of EVD cases* increases exponentially after some time. This triggers the government to take action to contain further spread of EVD in Liberia. The government responds by increasing the healthcare spending of the country. With increased standard of healthcare, the rate of infection will decrease, represented by a gradual change in the steepness of the *total number of EVD cases* curve starting from the 180th day. However, due to the imposition of the travel restriction, the international trade is greatly disrupted, decreasing the amount of national budget of the country. This will cripple the government's ability to contain the outbreak. This is reflected in the graph by the constant increase of the *total number of EVD cases.*

5.2 Model Verification

In running the model and plotting the graphs, we use Runge-Kutta 4 integration method with delta time (DT) of 0.125. To verify the model that has been constructed, it is necessary to run it with using different integration method and delta time (DT). To test our model robustness against the integration method, we fix the DT of the model to 0.125 and run our model using Euler's Method and Runge-Kutta 2 integration methods. It is found that all three different integration methods produce almost identical graphs. Moving on, to test our model robustness against the DT of the model, we fix integration method to Runge-Kutta 4 and run our model using three more DT values; they are 0.0625, 0.250, and 0.500. It is also found that all the 4 DT values yield almost identical graphs.

5.3 Sensitivity Analysis

Sensitivity analysis is necessary to identify the factors that greatly affect how the outbreak spreads. We have chosen the total number of death as our reference in the sensitivity analysis, as it is the most important information regarding the outcome of the outbreak after the study period. The result of our analysis shows that the top three most sensitive factors are the *probability of transfer upon contact*, the *number of contact an infected person makes per day* and the *number of contact a recovered but contagious person makes per day*. As such, any policies to contain the EVD outbreak should be directed to target these factors.

6 Results and Discussion

6.1 Base Case

In order to begin our analysis on the situation of Ebola Virus Disease (EVD) epidemic in Liberia, we will first establish a base case which models the current situation in Liberia that is where travel restriction is implemented.

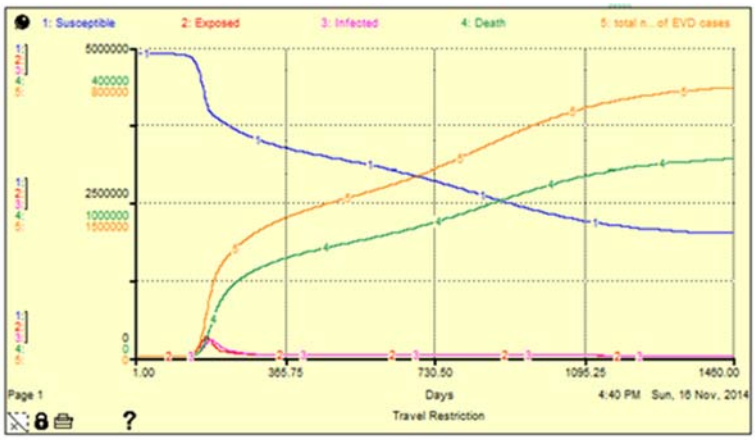

Figure 6.1.a

In Figure 6.1.a, it can be seen that if the travel restriction remains in place without any changes made to the system, the number of *Deaths* will reach around 1.3 millions throughout our duration of study of 4 years. This would deal a severe blow to Liberia, which has the population of 4.4 million people. Next, we will observe whether travel restriction is indeed just a symptomatic solution, which forms the crux of the shifting the burden archetype, by comparing this with the results when travel restriction is lifted.

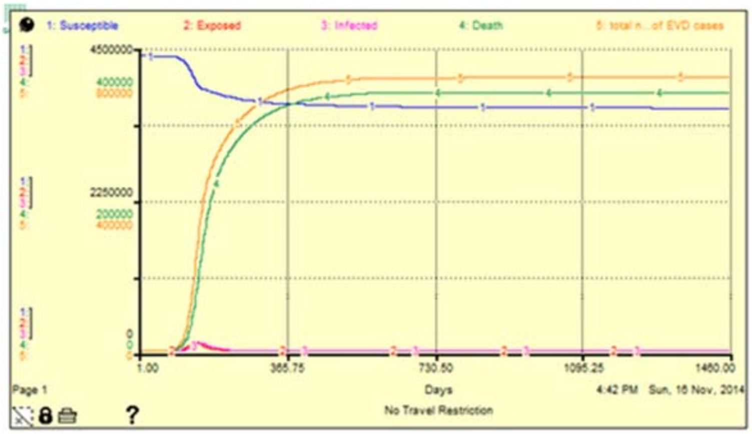

Figure 6.1.b

As can be seen from Figure 6.1.b, the number of deaths at the end of 4 years is around 340,000, which is less than the number of deaths in the case with travel restriction. This is because as travel restriction is implemented, the flow of goods and people between Liberia and its trading partners is affected thus decreasing Liberia's exports. This will result in less export income which will in turn reduce government revenue and jeopardize Liberia's ability to increase its healthcare spending. Consequently, in the long run, more people will be exposed to EVD due to lack of hospital facilities to quarantine those infected. More people will also die due to the lack of medical equipment to care for those infected.

Another proof of travel restriction being a symptomatic solution can be seen from the number of susceptible population in both graphs, which is negatively correlated with the number of EVD cases. The number of susceptible in the case with travel restriction only dips sharply on day 159 as shown in Figure 6.1.a. In contrast, this dip is observed earlier, on day 120, in Figure 6.1.b, which is the case without travel restriction. This means that initially the number of EVD cases in the travel restriction case is lower than if there is no travel restriction. Hence, the government might think that the travel restriction works in slowing down the increase in the number of EVD cases in Liberia. However, as has been shown in the previous paragraph, as time progresses, the travel restriction actually worsens the EVD epidemic instead of alleviating it.

6.2 Suggested Policies

6.2.1 Improving Government's Responsiveness

Currently, the Liberian government has not been successful in containing the Ebola Virus Disease (EVD) epidemic in the country. According to UN, Liberia will increase their health spending by 2.5 times, from 4% to 10% by 2015 (United Nations, 2014). However, in the face of the current EVD epidemic, the government should have been more responsive and increase their healthcare spending sooner in order to deal with the crisis more effectively.

Figure 6.2.1.a

Based on Liberia's vow to increase its healthcare spending by 2.5 times only in 2015, we assume that the government is not ready to quickly increase their spending. Therefore, as shown in Figure 6.2.1.a, we assume that the Liberian government will only increase its healthcare spending by 2.5 times once 16.7% of the population fall prey to EVD (total of *infected*, *death*, *recovered but contagious* and *fully recovered* populations). This might not be the most effective strategy as the quality of Liberia's healthcare system in its current state is still inadequate to manage the EVD outbreak. Furthermore, unlike Nigeria, Liberia is not very experienced in handling infectious disease outbreak. Hence, without a swift response from government to increase its healthcare spending, the current epidemic will grow worse and affect the country more severely. Thus, we will propose for the Liberian government to respond faster to the epidemic by increasing its healthcare spending immediately, especially as there is delay between the increase of spending and the effect to take place.

Under our proposal, the government should increase its healthcare spending by 2.5 times once 16.7% of the population becomes EVD cases as shown in Figure 6.2.1.b

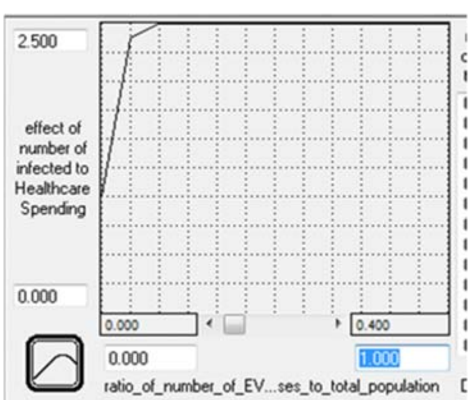

Figure 6.2.1.b

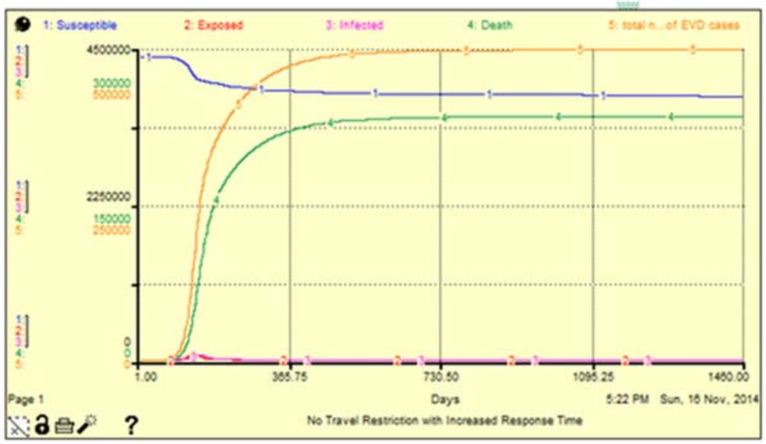

Figure 6.2.1.c

If the policy is implemented, there will only be 2 people being exposed every month and only 235,000 people dying at the end of 4 years, as shown in Figure 6.2.1.c. These figures are significantly lower than the figures under the base case, which shows that the epidemic should have been more successfully contained if the Liberian government has been more responsive in increasing its healthcare spending to deal with the epidemic. Hence, although the government has to divert their national budget away from other sectors such as economic sector in order to fund their healthcare sector, this move is necessary and useful for dealing with the prevalent EVD outbreak.

6.2.2 Contact Tracing

Due to the lack of healthcare spending, Liberia currently does not have contact tracing system. Contact tracing could save lives by diagnosing the people who might have entered the exposed population through contacts with the contagious population (*Infected* and *Recovered but Contagious*) such that they will receive early treatment for the disease. Those who develop the symptoms will be quarantined and treated, hence minimizing their chances of spreading the virus to others. Moreover, another round of contact tracing will also be done from the information provided by those people. Seeing how contact tracing is very useful in managing the spread of the disease in Nigeria (Sifferlin, 2014), we would like to propose for Liberia to put this system in place.

In our model, contact tracing system will help to decrease the *number of contacts with susceptible population*. After we have identified the potentially exposed individuals, we can quickly treat those who develop symptoms, i.e. those who enter the *Infected* population, and quarantine them, thus reducing the number of *Susceptible* that they come into contact with.

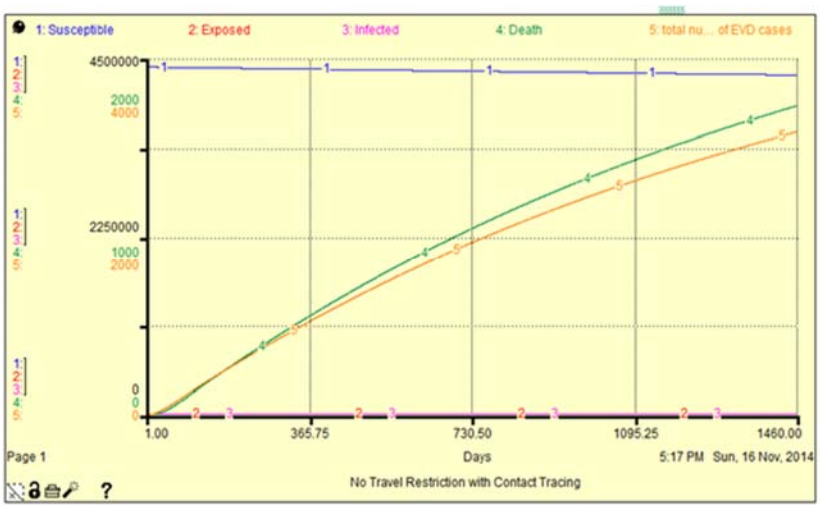

Figure 6.2.2 1

After contact tracing is implemented, there will only be 19 people being exposed every month and only 1,700 people dying at the end of 4 years, as shown in Figure 6.2.2. These figures are significantly lower than the figures under the base case, which shows that the epidemic should have been more successfully contained if the contact tracing system was put in place.

6.2.3 Education

One of the things that differentiate Nigeria, which was now Ebola-free, from Liberia, is the education that Nigeria gave to its citizens regarding the EVD itself. For example, in Nigeria some workers provided education about EVD to the citizens by going door-to-door (Sifferlin, 2014). If similar education were implemented in Liberia, the citizens would know about the symptoms of the EVD, the transmission mechanism, and the necessary measures required to minimize the chance of contracting the disease, for instance, by practicing high-level of hygiene and avoiding contact with the infected population. In our model, education will help to reduce the *probability of transfer upon contact*, and consequently decrease the *number of new exposed per day*.

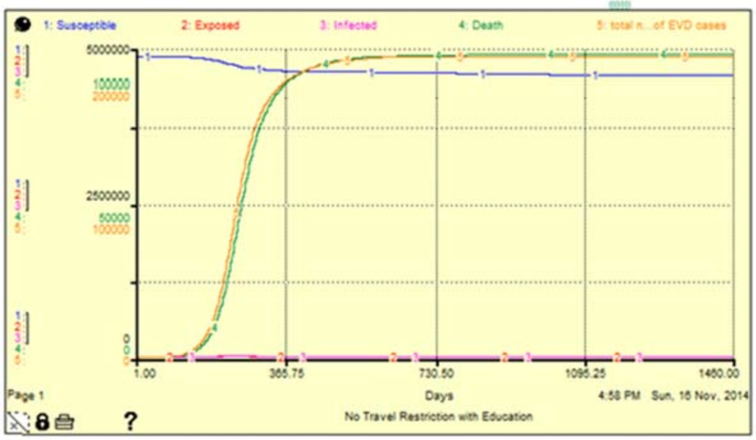

Figure 6.2.3

Similar to the other policies that we suggested, there are less people being exposed every month and less people dying at the end of 4 years compared to the base case. As shown in Figure 6.2.3, only 2 people are being exposed every month and only 98,000 people died at the end of 4 years. This shows that education on the public is also an effective method to manage the EVD outbreak.

6.2.4 Optimal Solution

While each of the policies has been shown to help in managing the EVD epidemic by reducing the number of people being *Exposed* every month and the number of *Deaths*, none of the policies is able to completely eradicate EVD from Liberia. Thus, to achieve our goal of rendering Liberia Ebola-free, we will try to see the effect of the 3 policies being implemented simultaneously.

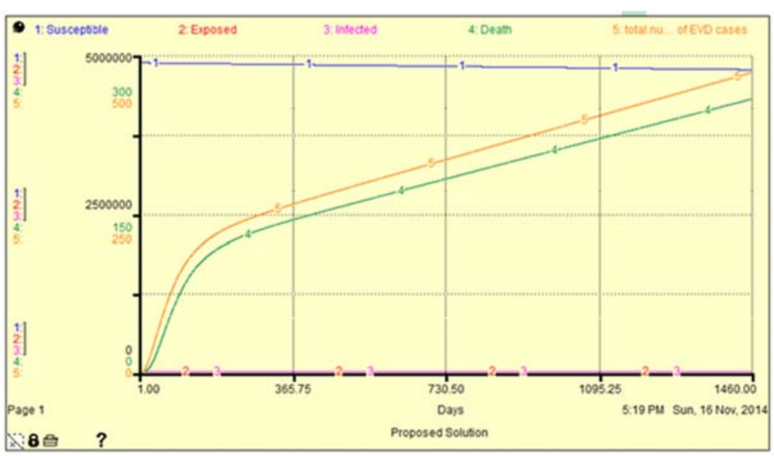

Figure 6.2.4

Implementing the 3 policies at the same time seem to produce better results than implementing any one of the policies alone. As seen in Figure 6.2.4, only 3 people are being exposed every month and 260 people died at the end of the study period.

However, even with the 3 policies being implemented together, we still did not manage to make Liberia Ebola-free as there is at least 3 people being exposed every month, which means that every month there will be at least 3 new cases entering the *Infected* population. It is important to note however, that this case does not come from the lack of treatment of the people getting infected in the country or failure in minimizing contacts between the contagious (*Infected* and *Recovered but Contagious*) and *Susceptible* population. Rather, the case comes from the inflow of immigrants to Liberia as travel ban has been lifted. Additionally, it is also very hard to detect an *Exposed* individual as they have yet to show symptoms, especially if the origin country of the immigrant does not implement the contact tracing system and prevents the individual from travelling.

7 Conclusion

In this report, we have looked into the Ebola Virus Disease (EVD) epidemic that currently plagues the country of Liberia. From the problem, we identified the "Shifting the Burden" archetype and used this archetype to explain Liberia's EVD epidemic. We have also discussed the model's validity and analyzed whether the prevalent travel restriction helps to alleviate or actually worsens the situation. Finally, after gaining insights on the current situation through simulations, we have suggested policies that the Liberian government might want to consider to contain the EVD epidemic more effectively and evaluated those policies based on their effectiveness, both when implemented individually or simultaneously.

From the results of our simulations, we have concluded that with proper management and implementation of the correct policies, the EVD outbreak in Liberia can be successfully contained. Of course, the success of these policies will depend on the commitment and political will of the Liberian government in solving this crisis despite the heavy cost that might be involved, as Liberia is a developing country with limited national budget. Help from the International Monetary Fund, United Nations and other countries can help to increase their healthcare budget.

Additionally, while the EVD outbreak can be contained, achieving a totally Ebola-free Liberia might not be very possible at the current moment due to the possible inflow of exposed individual from other countries. Thus, a concerted efforts from all countries is needed to truly eradicate EVD, such that no exposed individual from other countries can enter Liberia and further spreading the disease.

References

Boseley, S. (2014). Response to Ebola epidemic in West Africa too slow, say scientists. *The Guardian*. Retrieved 16 November 2014, from http://www.theguardian.com/world/2014/oct/24/ebola-epidemic-west-africa-lancet-infectious-diseases-liberia

Index Mundi (2011a). *Liberia - Literacy rate*. Retrieved 16 November 2014, from http://www.indexmundi.com/facts/liberia/literacy-rate

Index Mundi (2011b). *Liberia - Net migration rate - Historical Data Graphs per Year*. Retrieved 16 November 2014, from http://www.indexmundi.com/g/g.aspx?c=li&v=27

International Monetary Fund (2014), Liberia, *IMF Country Report No. 14/299*

Wilson, J. C. (2014). Ebola fears hit close to home. *CNN*. Retrieved 16 November 2014, from http://edition.cnn.com/2014/07/29/health/ebola-outbreak-american-dies/

Sifferlin, A. (2014). Nigeria Is Ebola-Free: Here's What They Did Right. *TIME*. Retrieved 16 November 2014, from http://time.com/3522984/ebola-nigeria-who/

United Nations (2014). *Liberia will increase health spending from 4% to 10% of the national budget and will ensure that by 2015*. Retrieved 16 November 2014, from http://sustainabledevelopment.un.org/index.php?page=view&type=1006&menu=1348&nr=1074

Washington Post (2014). *Ebola-stricken Liberia is descending into economic hell*. Retrieved 16 November 2014, from http://www.washingtonpost.com/news/morning-mix/wp/2014/09/30/hit-by-ebola-liberia-is-descending-into-economic-hell/

World Health Organization (2014a). *Ebola virus disease*. Retrieved 16 November 2014, from http://www.who.int/mediacentre/factsheets/fs103/en/

World Health Organization (2014b). *Ebola situation in Liberia: non-conventional interventions needed*. Retrieved 16 November 2014, from http://www.who.int/mediacentre/news/ebola/8-september-2014/en/

Center for Disease Control and Prevention (2014). *Ebola in Liberia - Warning - Level 3, Avoid Nonessential Travel - Travel Health Notices | Travelers' Health | CDC*. Retrieved 16 November 2014, from http://wwwnc.cdc.gov/travel/notices/warning/ebola-liberia