PROPOSAL REPORT

THE MATHEMATICAL MODELLING OF THE OUTBREAK OF EBOLA

NUR'ADNIN SYAZA BINTI ABD WAHAB 2013174909 CS2495A

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SUPERVISOR: PUAN ZATI IWANI ABDUL MANAF

Bachelor of Science (Hons.) Mathematics
Center of Mathematics Studies
Faculty of Computer and Mathematical Sciences

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1 INTRODUCTION

Ebola Virus Disease (EVD),is a viral infection that is caused by a virus of the family Filoviridae, genus Ebolavirus. The period of incubation of Ebola is between 2-21 days, and the period of infection is 4-10 days. Ebola can be transmit through direct contact with the blood, skin, or body fluids of an infected individual or animal. Ebola virus found to be remain in semen for a period up to three months. Since 1976, from the observation of the outbreaks of Ebola virus it cannot be transmit naturally through air, water, and foods like influenza or diarrhea disease. Common symptoms of Ebola virus which are typically start two days until three weeks and the symptoms are fever, malaise, myalgia, sore throat,chest pain, hiccups, red eyes, weakness, diarrhea, stomach pain, vomiting, dehydration, dry and hacking cough, and appetite loss. It is difficult to diagnose the Ebola virus because it is usually misdiagnosed as typhoid and malaria. The body will undergo severe blood loss and coagulation abnormalities as the infection of EVD spreading. If it is not treated and diagnosed, usually death can occur in the second week of the symptoms and it also usually caused by a massive blood loss.

The Ebola Virus Disease outbreak has been declared by the World Health Organisation on 23 March 2014, firstly occurred in Yambuku, Zaire and it surrounding areas in 1976. Then the virus outbreak continue to spread in large number which is latest in Guinea, Liberia and Sierra Leone. The largest outbreak of EVD is in West Africa, with 3944 cases reported in 5 September 2014 (World Health Organisation,2014). According to Bekoe (2015), from the first confirmed case recorded on 23 March 2014 which more than 18 months, at least 11,312 people have been reported died from the disease in six countries; Liberia, Sierra Leone, Guinea, Nigeria, Mali and US. The Ebola Virus Disease began in December, 2013 and it had killed a two years old boy in Guinea become the beginning of an outbreak that has killed for over 5000 people a year. This outbreak leaving hundreds of children becomes orphanages and thousands more are affected later.

Since the virus keep spreading through contacts and the mortality rate of 0.7 World Health Organisation (2014), it is needed to understand the patterns and epidemiology of the disease. By these condition, mathematical model of the outbreaks of Ebola virus can be helpful as it is a platform for understanding the behavior of a dynamical system. The objectives is to understand better the mathematical dynamics of a infected population when an outbreaks occurs. Another goal is to use mathematical modeling to examine and to analyze the viral dynamics of the Ebola virus. To model this outbreak, the systems of differential equations is used. To study the known data, several distinct models will be used and each model is different depends on the parameters acquired. From the differs a model that fits the data will be choose.

2 PROBLEM STATEMENT

Ebola Virus Disease (EVD), one of the deadliest human pathogens that is known currently and become the cause of the 2013-2015 Ebola epidemic in West Africa. According to the Center For Disease Control and Prevention (2015), total cases resulted is at least 23,014 cases and total deaths occurred as in 4 March 2015 is 9,840 deaths. Ebola virus is a bioterrorism in class A and level four biosafety agent. Therefore, the research of Ebola virus needs facilities with the highest level of containment, highly trained personnel and strict control on access.

Due to the threat poses by the virus to the rest of the world and the most recent outbreak in Western Africa, the research of the Ebola specific immune system and into how the Ebola virus interacts with the host has increase significantly. It has led to a new development into the effects of the immune system behaviour and into how the virus functions. A mathematical analysis is applied to a model for Ebola viral dynamics to achieve further understanding of the viral dynamics during the course of infection.

Furthermore, the effects of Ebola virus outbreak that has occurred in Sierra Leone, Guinea, Zaire and Liberia has present the application of the standard SIR model to understand the 2014 Ebola virus. The effectiveness of the intervention of terms will be able to control the epidemic of the outbreak of the virus.

3 OBJECTIVE

The purpose of this project are

1. To apply SIR model to predict the outbreaks of Ebola virus
2. To determine the effect of the initial number of infectives of the population

4 SIGNIFICANT OF THE PROJECT

The study of the outbreaks of Ebola virus by using mathematical model is to forecast the progression of the epidemic of Ebola Virus Disease (EVD). This uncontrollable virus has caused a lot of deaths not just adult but children.

The finding of this project will improve the control practice and the survival of the people especially the one who suffered the disease. Further understanding of the viral dynamics of Ebola virus will also control the number of dead individual in a population.

In addition, this study will also help me in understanding better about the disease and how it is actually spreads out in the population. This project either improving my knowledge in mathematics by applying mathematical model in the study.

5 SCOPE OF THE PROJECT

In the proposal study , I will only investigate the outbreaks of Ebola virus by applying the mathematical model. The data has been collected and it cover the area in the continent of Africa, on Sierra Leone that was recorded by (World Health Organisation, 2015). The calculation will be done by using dissolve tool of maple software.

6 DEFINITION OF TERMS AND CONCEPTS

The following are the definition of terms and concepts used in this project:

Epidemic	means a widespread occurrence of an infectious disease in a community at a particular time,synonyms with outbreak, plague, pandemic and epizootic
Eradication	The complete destruction of something
Filoviridae	A family threadlike RNA viruses that cause diseases in humans and nonhuman primates (monkeys and chimpanzees)
Pathogens	A bacterium,virus, or other microorganism that can cause disease
Semen	A viscid, whitish fluid that is produced in the male reproductive organs,containing sperm.
Myalgia	Pain in the muscles or muscular rheumatism
Hiccups	A quick, involuntary inhalation that follows a spasm of the diaphragma is suddenly checked by closure of the glottis, producing a relatively, short and sharp sounds.
Epidemiology	The branch of the medical science concerns with the transmission, occurrence and control of the epidemic disease
Diagnose	To determine the identity of the illnesses or disease by a medical examination

7 LITERATURE REVIEW

The SIR model was proposed by (Kermack et al., 1927) to explain the cases of the frequent rapid rise and fall of cases frequently observed in the epidemics such as the cholera epidemic in London (1865), the Great Plague in London (1665-1666) and the plague in Bombay (1906). The SIR model created for the number of infected people by a contagious illness in a closed population. The population size is assumed to be fixed, instantaneous infectious agent in incubation period and the length of the disease is same as the duration of infectivity. A completely homogenous population with no age, social structure or spatial is also assumed by the SIR model. There are three coupled nonlinear ordinary differential equations consisted in the model, which the S represent the number of susceptible people,R is the number of recovered people, I is the number of infected people,β is the rate of infection and γ is the rate of recovery.

According to Cenciarelli et al. (2015), it had investigate about the outbreak of the ebola virus disease in west Africa from 2013 until 2014. Based on the outbreak of the virus in West Africa an analysis was carried out on the epidemic spread and response of the Ebola virus. The Ebola virus epidemic burst in West Africa started in late of 2013. It has started in Guinea and continue to spread in several countries which are Liberia, Sierra Leone, Nigeria, Senegal and Mali. The geographical spread of the virus has followed to the large urban area. This condition has cause significant concern all over the world. The ability of reaching the far countries from endemic areas was mainly using fast transport. It was to induced several countries to issue health supervision and information documents for individuals that are coming or going to the area that was in risk. This paper had analyzed the geographical spread of the epidemics, by geographic area it also assessing the sequential appearance of cases considered the increase in mortality and cases to affected nations. The measures done by each international organization and government to contain the outbreak and the effectiveness were also evaluated.

Cited by Nsubuga et al. (2014), there are challenge of detecting and responding to the initial cluster of cases of outbreak. The staff who are undergone experiential training in the field of epidemiology and are working in a response system and a multi-disease surveillance that is adequately supported will know how to use the definition of case to identify cases suspect for viral hemorrhagic fevers. They will also know the need to transport and collect specimens safely to a laboratory to make initial diagnosis. In several countries, the epidemiology staff have different complimentary background training either as veterinary, medical or laboratory scientist. There are also the challenge of predicting the next outbreak in a country. In this paper, the recent outbreak of Ebola in West Africa had revealed three related public health systems and workforce challenge that has been addressed for enable the Africa to address the communicable and non communicable disease threats.

The current outbreak of Ebola virus in West Africa is the largest and most complex outbreak since the virus was discovered in 1976 which is firstly discovered. The Ebola virus continue affecting multiple countries in West Africa. Therefore, an epidemic model is impotant to optimize the eradication of Ebola. The epidemic model considered not only the spread of the Ebola virus but also the speed of manufacturing of the vaccine or drug for Ebola and possible feasible delivery system. From the existing data, a mathematical model of Ebola is parametrized.

In conclusion, the outbreak of Ebola is disastrous but under several methods the spreads of Ebola virus can be controlled. There are three approaches to optimize the eradication of Ebola which are the Vaccination intervention, Quarantine intervention and Delivery system optimization. By using a mathematical model apllying the SIR model it will also help to control the spread of the disease instead of increasing the potential of being survive from the disease in the future.

8 METHODOLOGY

In epidemiology the SIR model is used to calculate the amount of susceptible, infected, recovered people in a population. This model is a suitable one to use under the following assumptions:

1. Fixed population.
2. The person can leave the susceptible group only by being infected. A person can only leave the infected group by being recover from the disease. A person received immunity when the person has recovered once.
3. The probability of being infected are not affected by age,sex,social status and race.
4. Inherited immunity not exist.

8.1 APPLYING THE SIR MODEL

The SIR model are:

$$\frac{dS}{dt} = -\beta SI \tag{1}$$

$$\frac{dI}{dt} = \beta SI - \gamma I \tag{2}$$

$$\frac{dR}{dt} = \gamma I \tag{3}$$

At time t we will get;

$$S(t) + I(t) + R(t) = N(t) \tag{4}$$

where;

S : The number of susceptible individuals

I : The number of individuals infected

R : The number recovered individuals with total immunity

N : Total Population

β : The rate of infection

γ : The rate of recovery

8.2 DATA COLLECTION

The table below shows the number of infected and the total population in the West African country, Sierra Leone by the World Health Organization.

Table 8.1: Table of the population and infection cases

Country	**Case Definition**	**Number of Cases**	**Total Population**
Sierra Leone	Infected	8704	6453000

N = 6453000

I = 8704

R=0

Therefore, assigning the parameter value into the model, the number of susceptible individuals in the population is;

S = N - (R + I)

N = 6444296

8.3 PARAMETER VALUES

In order to calculate the rate of infection,β and the rate of recovery,γ it defined two more parameters:

$$\gamma = \frac{1}{D} \tag{5}$$

$$\beta = \frac{M}{S} \tag{6}$$

where;

D : Duration of disease for the recovered people

M : Mortality rate who die per day (7/10)

The World Health Organization has put the incubation period from 2 to 21 days. So that, the EVD could be estimated and it has a duration of D =10 .

Therefore, we get the value of $\gamma = 0.1$

In a meanwhile, the mortality rate (M) of the EVD had put by the WHO at 0.7. It means that the virus had killed seven patients out of 10 patients.

Therefore the value of β is;

$\beta = 1.086 \times 10^{-}7$

8.4 INITIAL NUMBERS OF INFECTIVES

The table below shows the percentage of infected, susceptible and recovered individuals

Table 8.2: Table of percentage of infected,susceptible, and recovered

Infected	**Susceptible**	**Recovered**
0.05	0.95	0.00
0.10	0.90	0.00
0.20	0.80	0.00
0.30	0.70	0.00

8.5 RESULTS AND DISCUSSION

The results will be interpret and a discussion will be made.

9 PROJECT BENEFIT

The project of modelling the outbreaks of Ebola virus certainly being investigate and analyzed for better future by improving the control practice for the survival of the infectious population.

10 PROJECT SCHEDULING

The project schedule for MAT530 and for MAT660 for the next coming semester is as follows.

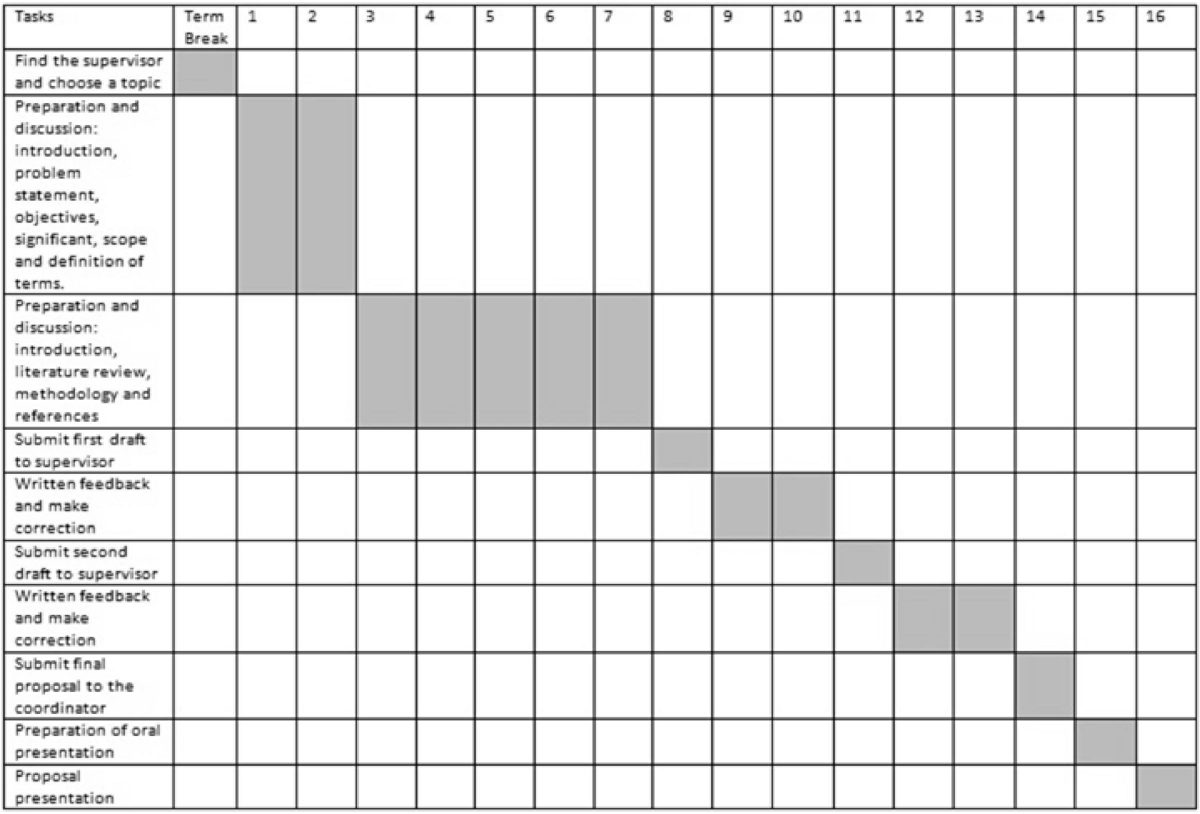

Figure 10.1: Project Schedule for MAT530

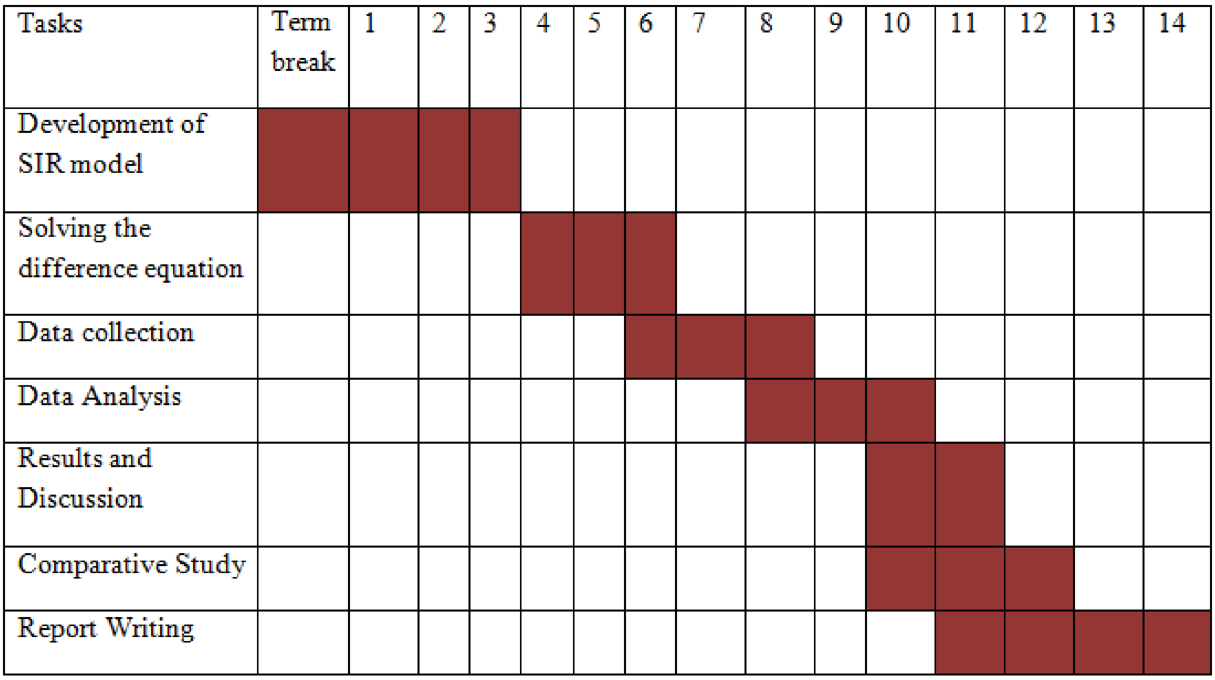

Figure 10.2: Project Schedule for MAT660 for next semester

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