Healthcare Analytics Group Project

Epidemic Modeling:

***Question 1: Conditions under which the disease will spread, i.e., :***

To determine the conditions for the spread of a disease, we first need to calculate the rate of change of the infectious compartment, which depends on two factors:

the rate of individuals moving from the infected compartment to the infectious compartment, and the rate of recovery for infectious individuals.

The disease will spread in the population when the number of infectious individuals is increasing over time, which is achieved when the rate of movement to the infectious compartment is greater than the recovery rate. In other words, **the disease can spread when the transmission/infection rate is higher than the recovery rate**, meaning that the disease is spreading faster than people can recover from it. This condition results in an increasing number of infectious individuals during the epidemic.

***Questions 2: Describing the possible equilibrium states:***

In the SEIR model, an equilibrium state is a state where the number of individuals in each compartment (S, E, I, and R) remains constant over time. Mathematically, an equilibrium state is a solution to the differential equations where the time derivatives of all compartments are zero. There are two types of equilibrium states in the SEIR model: disease-free equilibrium (DFE) and endemic equilibrium (EE).

1. **Disease-free equilibrium**: a state where there are no infectious individuals in the population. Mathematically, the DFE is defined as the solution to the differential equations when the number of infectious individuals in the population (I) is equal to zero.

To find the equilibrium states, we need to set all four derivatives to zero and solve for the corresponding values of S, E, I, and R.

In finding the disease-free equilibrium, we assume that there is no transmission of the disease in the population. Therefore, the transmission rate, denoted by β is equal to 0. This implies that there is no contact between the susceptible and infectious compartments, and the disease cannot spread in the population.

Substituting β = 0 in the SEIR model differential equations, we obtain:

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From the above equations, we can see that the number of susceptible individuals (S) remains constant over time and is equal to the total population size (N). The number of exposed individuals (E), infected individuals (I), and recovered individuals (R) are all equal to zero, since the infection rate is zero. Therefore, the disease-free equilibrium for the SEIR model is given by**: S\* = N E\* = I\* = R\* = 0 where N is the total population size.**

1. Endemic Equilibrium (EE): The EE is a state where the disease is sustained in the population, with a non-zero number of infectious individuals. Mathematically, the EE is defined as the solution to the differential equations where the time derivatives of all compartments are zero, except for the infectious compartment (I), which is non-zero.

*In the first scenario, there is no outbreak at all. T*he disease-free equilibrium for the SEIR model is given by**: S\* = N E\* = I\* = R\* = 0 where N is the total population size.**

*There is another scenario,Endemic equilibria, at which the number of new infections and the number of recoveries are balanced, resulting in a steady state.*

*We need to find the values of S, E, I, and R that satisfy the equations when their derivatives are equal to zero. This means that we need to solve the following system of equations:  
-dS = 0*

*beta \* I \* S - theta \* E = 0*

*gamma \* I = 0*

*theta \* E - gamma \* I = 0*

*And the results are:*

*S\* = (gamma + theta) / beta*

*E\* = (gamma + theta) / beta \* (1 - (1 / R0))*

*I\* = (gamma + theta) / beta \* (1 / R0)*

*R\* = (gamma + theta) / beta \* (1 - (1 / R0))*

*Where Ro = beta/gamma\*So, is the basic reproduction number, defined as the average number of secondary infections that result from a single infected individual in a completely susceptible population.*

***Question 3 & 4: Please find attached the excel file along with the code.***