



## Model Analysis and Numerical Simulation of the Ebola Epidemic

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### ABSTRACT

The Ebola virus, a highly dangerous infectious disease, is transmitted to humans through contact with both domestic and wild animals, which serve as carriers, and subsequently propagates through close interpersonal interactions. This research introduces an SEIR model that incorporates a vaccination parameter to scrutinize the transmission dynamics and stability patterns of the virus within the human population under different vaccination strategies. The Laplace-Adomian decomposition method was employed to solve the epidemic model, with Maple 18 software facilitating the execution of numerical simulations. These simulations provide in-depth insights into how each population state responds to vaccination initiatives. We present the results of these simulations graphically and engage in extensive discussions, offering valuable decision-making guides for policymakers.

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### INTRODUCTION

Ebola virus disease (EVD) has acquired prominent attention among researchers for several decades. This is because it is important to know in detail about a life-threatening virus and, moreover, to know how the disease escalates. Scientists think people are initially infected with the Ebola virus through contact with an infected animal, such as a fruit bat or nonhuman primate. This is called a spillover event. After that, the virus spreads from person to person, potentially affecting a large number of people. The virus spreads through direct contact (such as through broken skin or mucous membranes in the eyes, nose, or mouth). A solution can be offered by mathematical or statistical models to understand the harmfulness of the disease. Thus, S, E, I, and R are the variables for the epidemic model. Compartment-to-compartment transmission flow of the Ebola virus in the SEIR model (Adams, B, 2016). Control of outbreaks requires coordinated medical services and community engagement (Ayoola et al, 2021). This includes rapid

detection, contact tracing of those who have been exposed, quick access to laboratory services, care for those infected, and proper disposal of the dead through cremation or burial (Rachah and Torres, 2015). Samples of body fluids and tissues from people with the disease should be handled with special caution (Baize et al, 2021). Prevention includes limiting the spread of disease from infected animals to humans by handling potentially infected bush meat only while wearing protective clothing and by thoroughly cooking bush meat before eating it. It also includes wearing proper protective clothing and washing hands when around a person with the disease. An Ebola vaccine was approved in the United States in December 2019. While there is no approved treatment for Ebola as of 2019, two treatments (atoltivimab, maftivimab, odesivimab and ansuvimab) are associated with improved outcomes. Supportive efforts also improve outcomes. This includes either oral rehydration therapy (drinking slightly sweetened and salty water) or giving intravenous fluids as

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well as treating symptoms. Atoltivimab/maftivimab/odesivimab (Inmazeb) was approved for medical use in the United States in October 2020 for the treatment of infections caused by Zaire ebolavirus (Ebenezer et al, 2016). The disease was first identified in 1976 in two simultaneous outbreaks: one in Nzara (a town in South Sudan) and the other in Yambuku (the Democratic Republic of the Congo), a village near the Ebola River from which the disease takes its name. EVD outbreaks occur intermittently in tropical regions of sub-Saharan Africa. From 1976 to 2012, the World Health Organization reported 24 outbreaks involving 2,387 cases and 1,590 deaths. The largest outbreak to date was the epidemic in West Africa, which occurred from December 2013 to January 2016, with 28,646 cases and 11,323 deaths. It was declared no longer an emergency on March 29, 2016. Other outbreaks in Africa began in the Democratic Republic of the Congo in May 2017 and 2018 (WHO, 2020). In July 2019, the World Health Organization declared the Congo Ebola outbreak a world health emergency (Heesterbeek and Diekmann, 2019). To gain a better knowledge of the disease's transmission dynamics and control, many models have been developed and studied using various methodologies. These studies include the following: Peter et al. (2018, 2020, 2021b), Ojo et al. (2018, 2021, 2022c), Abioye et al. (2018, 2021), Ojo and Goufo (2021, 2022b), Ayoola et al. (2021).

Simulation is considered a useful approach for controlling and eradicating diseases. Various numerical methods have been successfully applied to simulate the dynamics of epidemic models. For example, authors in

$\varphi(s) = \int_0^{\infty} e^{-st} \varphi(t) dt$  which satisfies the following properties:

- i. derivative of a function  $\varphi(t)$  with order  $\eta$  given by

$$L[\varphi^{(\eta)}(t)] = s^{\eta} L[\varphi(t)] - s^{\eta-1} \varphi(0) - s^{\eta-2} \varphi'(0) - s^{\eta-3} \varphi''(0) \dots$$

- ii. inverse transform of function  $\frac{\varphi(s)}{s}$  given by  $L^{-1} \frac{\varphi(s)}{s} = \int_0^t \varphi(t) dt$

(Yunus et al 2022) applied the Laplace Adomian decomposition method to analyze and numerically simulate a mathematical model of measles with non-integer time fractional derivatives which provide results that yield eradicating insights. Also, researchers in (Kolawole et al, 2023) carried out the simulation of different control strategies, such as vaccination and treatment, on a proposed epidemic model. In a result provided by (Alaje et al 2023), a modified numerical technique introduced by (He, 1999) was applied to solve and numerically simulate the transmission of wave in media using different models and the accuracy of the results was proved as it converged to the exact solution. Also, (Alaje et al 2021) applied this same numerical method to obtain the solution of viscoelasticity problems modelled using integro-differential equations and the results equally demonstrated good convergence.

Given the documented effectiveness of vaccination in mitigating Ebola transmission (Jefferey, 2012) our study aims to assess its impact using a proposed mathematical model (Model 1). We introduced a factor that accounts for the rate of vaccinated individuals, such that the model assumes reduced susceptibility among the vaccinated population. Subsequently, we carried out different simulations on the model variables using epidemiological data on Ebola acquired from relevant literature, and our results provide relevant information on the disease trends in different vaccination settings.

**Definition 1:** Laplace transform

The Laplace transform of a function  $\varphi(t)$  is the integral function  $\varphi(s)$  given by

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**Definition 2:** Adomian Polynomial

The Adomian polynomials introduced by Adomian (1981) denoted by  $A_0, A_1, \dots, A_n$ , consist in the decomposition of the unknown

$$A_n = \frac{1}{n} \frac{d^n}{d\lambda^n} \left[ G(t) \sum_{j=0}^n y_j \lambda^j \right]_{\lambda=0}$$

**METHODS**

**Laplace-Adomian decomposition method**

This section discusses the process for solving

$$\frac{d^n y(t)}{dt^n} = f(t, y(t)) \tag{1}$$

where  $y(t)$  is the unknown function,  $n$  is a positive integer representing the order of the ODE, and  $f(t, y(t))$  is a given nonlinear

$$s^n y(s) - s^{n-1} y(0) - s^{n-2} y'(0) \dots y^{(n-1)}(0) = F(s) \tag{2}$$

Where  $F(s) = L(f(t, y(t)))$  and the initial conditions are applied such that

$$y(s) = \frac{1}{s^n} (F(s) + L(s)) \tag{3}$$

Where  $L(s)$  are the linear terms obtained after evaluating (2) using the initial conditions such that

$$y(t) = L^{-1} \left[ \frac{1}{s^n} (F(s) + L(s)) \right] = L^{-1} \left[ \frac{1}{s^n} (F(s)) \right] + L^{-1} \left[ \frac{1}{s^n} (L(s)) \right] \tag{4}$$

Such that the inverse Laplace transforms of the linear term  $L^{-1} \left[ \frac{1}{s^n} (L(s)) \right] = y_0(t)$

$$y(t) = y_0(t) + L^{-1} \left[ \frac{1}{s^n} (F(s)) \right] \tag{5}$$

where  $y_0(t)$  is the initial approximation. Subsequently, the unknown terms can be represented by infinite series terms given by:

$$y(t) = \sum_n^{\infty} y_n(t) \tag{6}$$

the nonlinear term  $F(s)$  can be expressed as a sum of Adomian polynomials given by:

$$F(s) = A_0(s) + A_1(s) + A_2(s) + \dots + A_k(s) = \sum_{n=0}^k A_n(s) \tag{7}$$

$$\text{Where } A_n(s) = \frac{1}{n} \frac{d^n}{d\lambda^n} \left[ G(s) \sum_{j=0}^n y_j \lambda^j \right]_{\lambda=0} \tag{8}$$

function  $y(t)$  whose series can be expressed as

$$y(t) = y_0 + y_1 + y_2 + \dots + y_n \text{ given as:}$$

the differential equation in this research using the Laplace-Adomian decomposition method.

Consider a general form of a nonlinear ordinary differential equation (ODE) given by:

function.

We initiated the process by applying the Laplace transform to both sides of the equation:

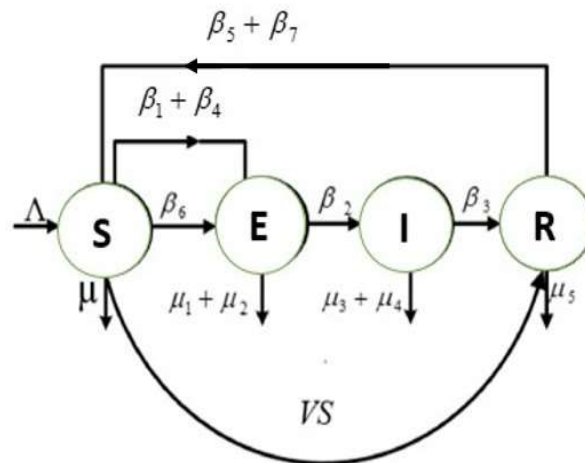
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Such that (5) yields:

$$\sum_n^{\infty} y_{n+1}(t) = y_0(t) + L^{-1} \left[ \frac{1}{s^n} \sum_{n=0}^k \left( \frac{1}{n} \frac{d^n}{d\lambda^n} \left[ G(s) \sum_{j=0}^n y_j \lambda^j \right] \right) \right] \quad (9)$$

And each  $y_n(t)$  for  $n = 1, 2, 3, \dots$  are computed for such that the approximate solution is given by  $y(t) = y_0(t) + y_1(t) + y_2(t) \dots$

### 3. The mathematical model



**Figure 1:** Schematic diagram of the proposed model.

The proposed model dynamics is given by:

$$\begin{aligned} \frac{dS}{dt} &= \lambda - \mu S - (\beta_1 + \beta_4 + \beta_6)SE - (\beta_5 + \beta_7)SI - \nu S \\ \frac{dE}{dt} &= (\beta_1 + \beta_4 + \beta_6)SE - \beta_2 EI - (\mu_1 + \mu_2)E \\ \frac{dI}{dt} &= \beta_2 EI + (\beta_5 + \beta_7)SI - (\beta_3 + \mu_3 + \mu_4)I \\ \frac{dR}{dt} &= \beta_3 I - \mu_5 R + \nu S \end{aligned} \quad (10)$$

Subject to  $S(0) = m_0 \quad E(0) = e_0 \quad I(0) = i_0 \quad R(0) = r_0$

Table 1: Model parameters, description, and numerical data

Notation	Parameter	Value	Source
$\lambda$	Rate of increase (recruitment rate) of susceptible humans	0.6321	(Heesterbeek, &

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			Diekmann, 2019).
$\mu$	Natural mortality rate of susceptible humans	0.9704	(Heesterbeek, & Diekmann, 2019).
$\beta_1$	Rate of infection from susceptible to exposed humans	0.2877	Assumed
$\beta_2$	Rate of infection from exposed to infected humans	0.7613	Assumed
$\beta_3$	Rate of infection from infected to recovered humans	0.4389	WHO, 2020
$\beta_4$	Rate of infection due to wild animals from susceptible to exposed humans	0.1234	Assumed
$\beta_5$	Rate of infection due to wild animals from susceptible to infected humans	0.2431	Assumed
$\beta_6$	Rate of infection due to domestic animals from susceptible to exposed humans	0.4000	Assumed
$\beta_7$	Rate of infection due to domestic animals from susceptible to infected humans	0.3000	Assumed
$\mu_1$	Natural mortality rate of exposed humans	0.0432	(Heesterbeek, & Diekmann, 2019).
$\mu_2$	Disease-induced mortality rate of exposed humans	0.02006	Yunus et al, 2022
$\mu_3$	Natural mortality rate of infected humans	0.0656	WHO, 2020
$\mu_4$	Disease-induced mortality rate of infected humans	0.09764	Kolawole et al 2023
$\mu_5$	Natural mortality rate of recovered humans	0.6704	(Heesterbeek, & Diekmann, 2019).
$V$	Rate of vaccination	0.2-1.0	-

**Analytical solution by Laplace Adomian Decomposition Method:**

The Laplace Adomian decomposition method [2] shall be applied to obtain the solution  $SE = A, SI = B, VS = C, EI = D$ .

of (1). We initiate the technique by first taking the Laplace transform of both sides of (1) using definition 1. Also, the nonlinear terms are represented by:

$$L(S(t)) = \frac{m_o}{s} + \frac{\lambda}{s^2} - (v + \mu) \frac{L(S)}{s} - (\beta_1 + \beta_4 + \beta_6) \frac{L(A)}{s} - (\beta_5 + \beta_7) \frac{L(B)}{s} + \frac{v}{s} L(S(t))$$

$$L(E(t)) = \frac{e_0}{s} + (\beta_1 + \beta_4 + \beta_6) \frac{L(A)}{s} - \beta_2 \frac{L(D)}{s} - (\mu_1 + \mu_2) \frac{L(E)}{s}$$

$$L(I(t)) = \frac{i_0}{s} + \frac{\beta_2}{s} L(D) + \frac{(\beta_5 + \beta_7)}{s} L(B) - (\beta_3 + \mu_3 + \mu_4) \frac{L(I)}{s} \tag{11}$$

$$L(R(t)) = \frac{r_o}{s} + \frac{\beta_3}{s} L(I) - \frac{\mu_5}{s} L(R) + \frac{v}{s} L(S)$$

We aim to obtain the solution of each class in form of Taylor's series

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$$\begin{aligned}
 S(t) &= \sum_0^\infty S_n(t), \quad E(t) = \sum_0^\infty E_n(t), \quad I(t) = \sum_0^\infty I_n(t), \quad R(t) = \sum_0^\infty R_n(t), \\
 L\left[\sum_{n=0}^\infty S_n(t)\right] &= \frac{m_0}{s} + \frac{\lambda}{s^2} - \frac{(v+\mu)}{s} L\left[\sum_{n=0}^\infty S_n(t)\right] - \\
 &\frac{(\beta_1 + \beta_4 + \beta_6)}{s} L\left[\sum_{n=0}^\infty A_n\right] - \frac{(\beta_5 + \beta_7)}{s} L\left[\sum_{n=0}^\infty B_n\right] + \frac{v}{s} L\left[\sum_{n=0}^\infty S_n(t)\right] \\
 L\left[\sum_{n=0}^\infty E_n(t)\right] &= \frac{e_0}{s} + \frac{(\beta_1 + \beta_4 + \beta_6)}{s} L\left[\sum_{n=0}^\infty A_n\right] - \frac{\beta_2}{s} L\left[\sum_{n=0}^\infty D_n\right] - \frac{(\mu_1 + \mu_2)}{s} L\left[\sum_{n=0}^\infty E_n(t)\right] \\
 (12) \\
 L\left[\sum_{n=0}^\infty I_n(t)\right] &= \frac{i_0}{s} + \frac{\beta_2}{s} L\left[\sum_{n=0}^\infty D_n\right] + \frac{(\beta_5 + \beta_7)}{s} L\left[\sum_{n=0}^\infty B_n\right] - \frac{(\beta_3 + \mu_3 + \mu_4)}{s} L\left[\sum_{n=0}^\infty I_n(t)\right] \\
 L\left[\sum_{n=0}^\infty R_n(t)\right] &= \frac{r_0}{s} + \frac{\beta_3}{s} L\left[\sum_{n=0}^\infty I_n(t)\right] - \frac{\mu_5}{s} L\left[\sum_{n=0}^\infty R_n(t)\right] + \frac{v}{s} L\left[\sum_{n=0}^\infty S_n(t)\right]
 \end{aligned}$$

Following definition (2), the Adomian polynomial for non-linear terms are obtained as:

$$\begin{aligned}
 A &= SE, & B &= SI, & D &= EI, \\
 A_0 &= S_0 E_0 & B_0 &= S_0 I_0 & D_0 &= E_0 I_0 \\
 A_1 &= S_0 E_1 + S_1 E_0 & B_1 &= S_0 I_1 + S_1 I_0 & D_1 &= E_0 I_1 + E_1 I_0 \\
 A_2 &= S_0 E_2 + S_1 E_1 + S_2 E_0 & B_2 &= S_0 I_2 + S_1 I_1 + S_2 I_0 & D_2 &= D_0 I_2 + D_1 I_1 + D_2 I_0
 \end{aligned} \tag{13}$$

Evaluating (3) using these Adomian polynomials yields:

$$\begin{aligned}
 L[S_0 + S_1 + S_2] &= \frac{m_0}{s} + \frac{\lambda}{s^2} - \frac{(v+\mu)}{s} L(S_0 + S_1 + S_2) - \frac{(\beta_1 + \beta_4 + \beta_6)}{s} L(A_0 + A_1 + A_2) \\
 &\frac{(\beta_5 + \beta_7) L(S_0 + S_1 + S_2) - \frac{v}{s} L(S_0 + S_1 + S_2)}{s}
 \end{aligned} \tag{14}$$

$$L[E_0 + E_1 + E_2] = \frac{e_0}{s} + \frac{(\beta_1 + \beta_4 + \beta_6)}{s} L(A_0 + A_1 + A_2) - \frac{\beta_2}{s} L(D_0 + D_1 + D_2) - \frac{(\mu_1 + \mu_2)}{s} L(E_0 + E_1 + E_2) \tag{15}$$

$$L[I_0 + I_1 + I_2] = \frac{i_0}{s} + \frac{\beta_2}{s} L(D_0 + D_1 + D_2) + \frac{(\beta_5 + \beta_7)}{s} L(B_0 + B_1 + B_2) - \frac{(\beta_3 + \mu_3 + \mu_4)}{s} L[I_0 + I_1 + I_2] \tag{16}$$

$$L[R_0 + R_1 + R_2] = \frac{r_0}{s} + \frac{\beta_3}{s} L(I_0 + I_1 + I_2) - \frac{\mu_5}{s} L(R_0 + R_1 + R_2) + \frac{v}{s} (S_0 + S_1 + S_2) \tag{17}$$

Matching the two sides of (14)-(17) and subsequently taking the inverse Laplace transform yields the initial approximations:

$$S_0(t) = m_0 + \lambda t, \quad E_0(t) = e_0, \quad I_0(t) = i_0, \quad R_0(t) = r_0 \tag{18}$$

Similarly at  $n = 1$ , the first approximations is obtained by

$$L(S_1(t)) = -\frac{(-\nu + \mu)}{s} L(S_0) - \frac{(\beta_1 + \beta_4 + \beta_6)}{s} L(A_0) - \frac{(\beta_5 + \beta_7)}{s} L(B_0) - \frac{\nu}{s} L(S_0(t)) \quad (19)$$

$$L(E_1(t)) = \frac{(\beta_1 + \beta_4 + \beta_6)}{s} L(A_0) - \frac{(\beta_2)}{s} L(D_0) - \frac{(\mu_4 + \mu_2)}{s} L(E_0) \quad (20)$$

$$L(I_1(t)) = \frac{(\beta_2)}{s} L(D_0) - \frac{(\beta_5 + \beta_7)}{s} L(B_0) - \frac{(\beta_3 + \mu_3 + \mu_4)}{s} L(I_0) \quad (21)$$

$$L(R_1(t)) = \frac{(\beta_3)}{s} L(I_0) - \frac{\mu_5}{s} L(R_0) - \frac{(\nu)}{s} L(S_0(t)) \quad (22)$$

Evaluating (19) to (22) using the Adomian polynomials (13) and the initial approximations (18) yields:

$$L(S_1(t)) = -\frac{(-\nu + \mu)}{s} L(m_0 + \lambda t) - \frac{(\beta_1 + \beta_4 + \beta_6)}{s} L((m_0 + \lambda t)e_0) - \frac{(\beta_5 + \beta_7)}{s} L((m_0 + \lambda t)i_0) - \frac{\nu}{s} L((m_0 + \lambda t)) \quad (23)$$

$$L(E_1(t)) = \frac{(\beta_1 + \beta_4 + \beta_6)}{s} L((m_0 + \lambda t)e_0) - \frac{(\beta_2)}{s} L(e_{j_0}) - \frac{(\mu_4 + \mu_2)}{s} L(e_0) \quad (24)$$

$$L(I_1(t)) = \frac{(\beta_2)}{s} L(e_{j_0}) - \frac{(\beta_5 + \beta_7)}{s} L((m_0 + \lambda t)i_0) - \frac{(\beta_3 + \mu_3 + \mu_4)}{s} L(i_0) \quad (25)$$

$$L(R_1(t)) = \frac{(\beta_3)}{s} L(i_0) - \frac{\mu_5}{s} L(r_0) - \frac{(\nu)}{s} L((m_0 + \lambda t)) \quad (26)$$

Applying inverse Laplace transform to equations (23) to (26) yields:

$$S(t) = L^{-1} \left[ -\frac{(-\nu + \mu)}{s} L(m_0 + \lambda t) - \frac{(\beta_1 + \beta_4 + \beta_6)}{s} L((m_0 + \lambda t)e_0) - \frac{(\beta_5 + \beta_7)}{s} L((m_0 + \lambda t)i_0) - \frac{\nu}{s} L((m_0 + \lambda t)) \right] \quad (27)$$

$$E(t) = L^{-1} \left[ \frac{(\beta_1 + \beta_4 + \beta_6)}{s} L((m_0 + \lambda t)e_0) - \frac{(\beta_2)}{s} L(e_{j_0}) - \frac{(\mu_4 + \mu_2)}{s} L(e_0) \right] \quad (28)$$

$$I_1(t) = L^{-1} \left[ \frac{(\beta_2)}{s} L(e_{j_0}) - \frac{(\beta_5 + \beta_7)}{s} L((m_0 + \lambda t)i_0) - \frac{(\beta_3 + \mu_3 + \mu_4)}{s} L(i_0) \right] \quad (29)$$

$$R(t) = L^{-1} \left[ \frac{(\beta_3)}{s} L(i_0) - \frac{\mu_5}{s} L(r_0) - \frac{(\nu)}{s} L((m_0 + \lambda t)) \right] \quad (30)$$

Such that the following results are obtained:

$$S_1(t) = (\nu m_0 + \mu m_0 - \beta_1 m_0 e_0 - \beta_4 m_0 - \beta_6 m_0 e_0 - \beta_5 m_0 i_0 - \beta_4 m_0 - \beta_7 m_0 e_0) t + (\nu \lambda + \mu \lambda - e_0 \beta_1 \lambda - e_0 \beta_6 \lambda - i_0 \beta_5 \lambda - i_0 \beta_7 \lambda) \frac{t^2}{2}$$

$$e_1(t) = (-e_0 \mu_2 + e_0 \beta_1 m_0 - \beta_2 e_0 i_0 + \beta_4 e_0 m_0 + \beta_4 e_0 m_0 - e_0 \mu_0) t + (e_0 \beta_1 \lambda + e_0 \beta_3 \lambda + e_0 \beta_6 \lambda) \frac{t^2}{2}$$

$$i_1(t) = (\beta_2 e_0 i_0 + \beta_5 m_0 i_0 + \beta_7 m_0 i_0 - \beta_5 i_0 - \mu_3 i_0 - \mu_4 i_0) t + (i_0 \beta_7 \lambda + i_0 \beta_5 \lambda) \frac{t^2}{2}$$

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$$R_1(t) = (\beta_3 i_0 - \mu_5 r_0 + \nu m_0)t + (\nu \lambda) \frac{t^2}{2}$$

Subsequent iterations can be computed in the same manner such that the iterative results of each class are obtained as:

$$S(t) = m_0 + \lambda t + (\nu m_0 + \mu m_0 - \beta_1 m_0 e_0 - \beta_4 m_0 - \beta_6 m_0 e_0 - \beta_5 m_0 i_0 - \beta_4 m_0 - \beta_7 m_0 e_0)t + (\nu \lambda + \mu \lambda - e_0 \beta_1 \lambda - e_0 \beta_6 \lambda - i_0 \beta_5 \lambda - i_0 \beta_7 \lambda) \frac{t^2}{2}$$

$$E(t) = e_0 + (-e_0 \mu_2 + e_0 \beta_1 m_0 - \beta_2 e_0 i_0 + \beta_4 e_0 m_0 + \beta_4 e_0 m_0 - e_0 \mu_0)t + (e_0 \beta_1 \lambda + e_0 \beta_3 \lambda + e_0 \beta_6 \lambda) \frac{t^2}{2}$$

$$I(t) = i_0 + (\beta_2 e_0 i_0 + \beta_5 m_0 i_0 + \beta_7 m_0 i_0 - \beta_5 i_0 - \mu_3 i_0 - \mu_4 i_0)t + (i_0 \beta_7 \lambda + i_0 \beta_5 \lambda) \frac{t^2}{2}$$

$$R(t) = r_0 + (\beta_3 i_0 - \mu_5 r_0 + \nu m_0)t + (\nu \lambda) \frac{t^2}{2}$$

These results are evaluated using the predefined parameter values on Table 3 and numerical simulation follows.

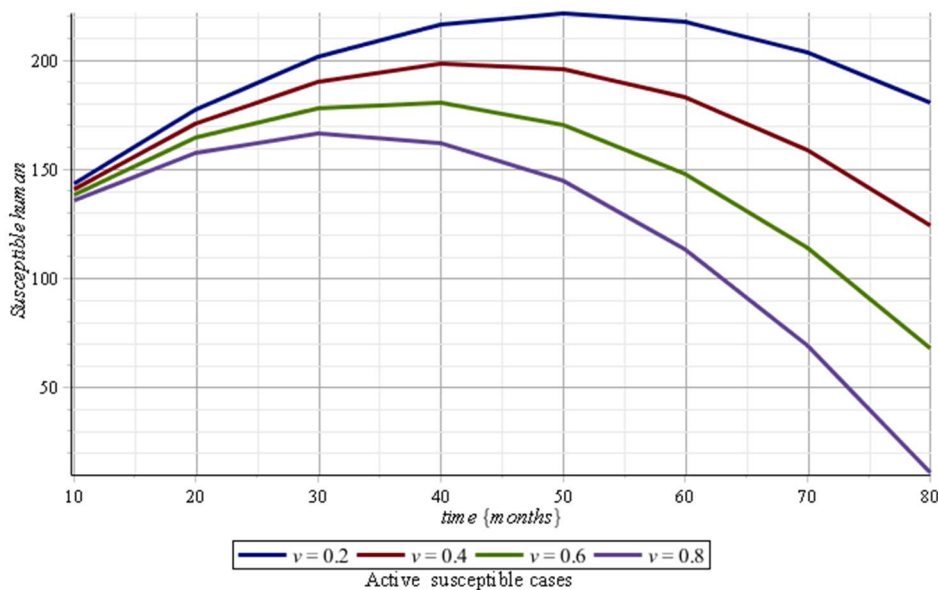


Figure 2: Plot of Susceptible population against vaccination rates



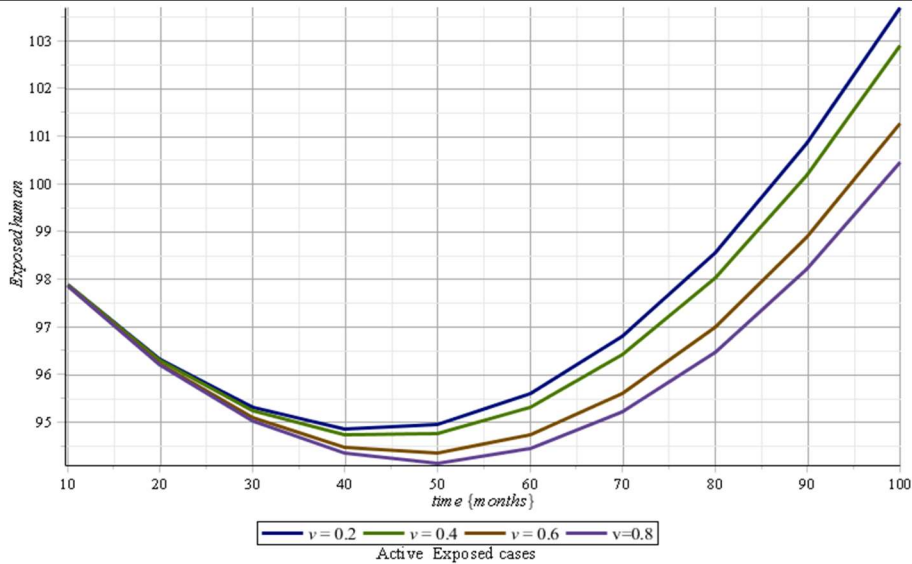


Figure 3: Plot of exposed population against vaccination rates

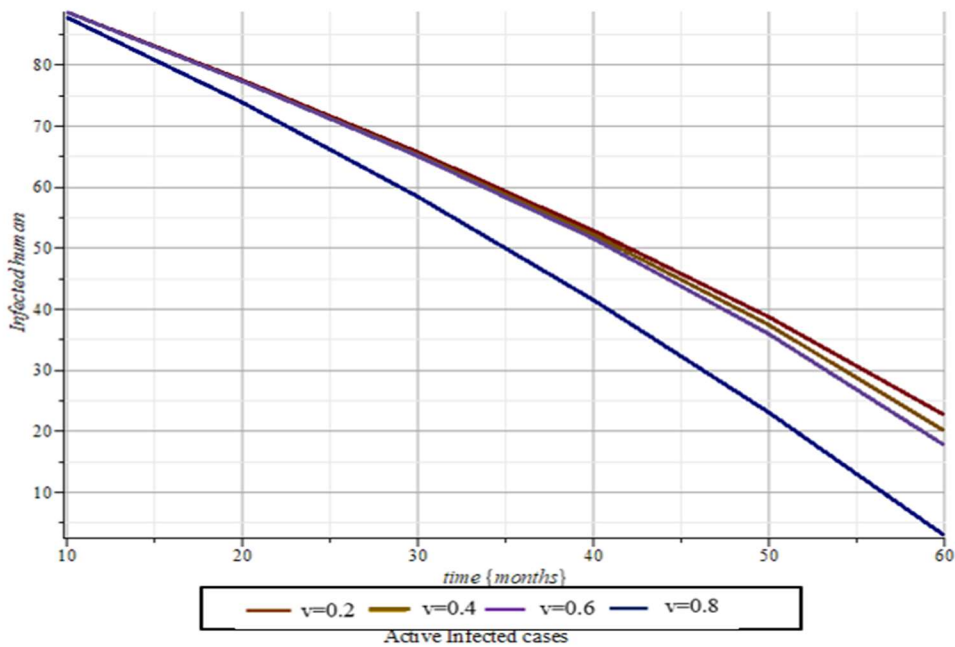


Figure 4: Plot of Infected population against vaccination rates

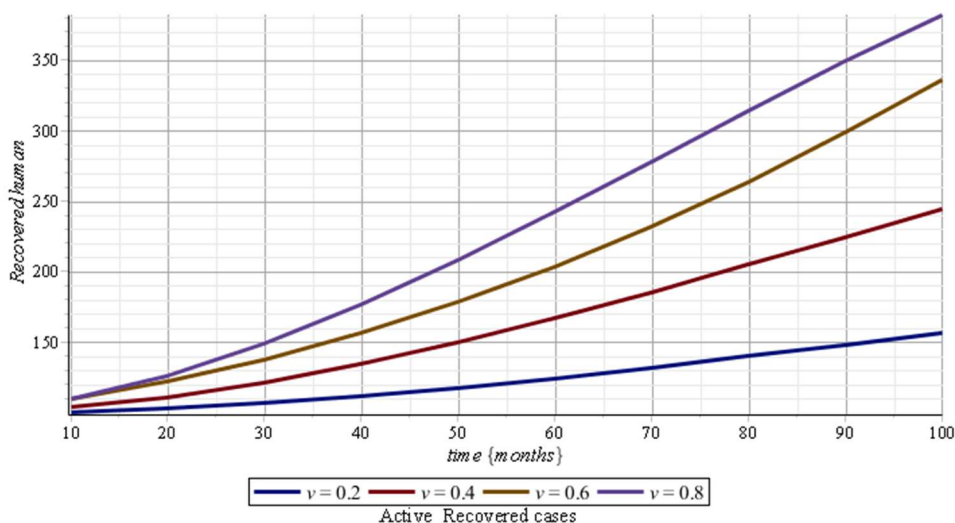


Figure 5: Plot of Recovered population against vaccination rates

## DISCUSSION

The Ebola pandemic has been a major public health concern, and numerical simulation and mathematical modeling have proved crucial in comprehending and controlling the disease's spread. Mathematical/Statistical models have been used in several studies to examine the dynamics of Ebola virus disease (EVD) transmission and the potential effects of intervention (Chowell et al 2014; Takaizda et al 2017; Velásquez et al 2015; Jiang et al 2017; Li et al 2017; Viboud et al 2018). These models have provided useful information about how the disease spreads and how well the control measures work. Numerical simulations have also been used to forecast the progression of the Ebola epidemic and evaluate the efficacy of interventions. With controlled data and epidemiological conditions, the RAPIDD Ebola forecasting challenge offered a chance to evaluate model performance (Viboud et al., 2018). The challenge involved synthesizing data and evaluating individual model outputs and ensemble predictions. The results showed that data accuracy and availability significantly improved the accuracy of the predictions, but challenges with uncontrolled outbreaks and data reporting noise posed difficulties for the models

(Viboud et al., 2018).

To help with decision-making and resource allocation for the Ebola outbreak response, optimal control measures have been investigated. In order to create the best eradication strategies and assess the impacts of the spread of the disease, mathematical models have been utilized (Jiang et al., 2017). Additionally, vaccination strategies have been considered in mathematical models to analyze their effectiveness in controlling the transmission of Ebola (Rachah & Torres, 2015).

Maple 18 software was used to examine a model of Ebola virus disease via numerical simulation by applying results generated through the Laplace-Adomian Decomposition Method. Consequently, our findings are discussed as follows:

In Figure 2, we observed a distinctive trend when the susceptible population was plotted against vaccination rates. Initially, the curve starts at a high point for low vaccination rates, indicative of a substantial number of susceptible individuals. As vaccination rates increase, this curve progressively descends. Eventually, it levels off as the vaccination rate approaches 100%, signifying near-complete immunity within the population. Furthermore, the

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simulation results presented in Figure 3 revealed a significant reduction in the exposed population with increasing vaccination rates. This outcome underscores the effectiveness of vaccination in mitigating the transmission and dissemination of the infectious agent responsible for the disease's propagation in the system. In Figure 4, the simulation results depict a marked decline in the infected population as vaccination rates rise. This suggests that achieving a substantial level of vaccination can lead to herd immunity, inhibiting the pathogen's spread within the system. Consequently, a lower number of individuals may contract the infection. Figure 5 further strengthens this fact as it demonstrated that the recovered population experienced a dramatic increase as vaccination rates increased. This underscores that vaccination can be instrumental in averting Ebola outbreaks by limiting the overall prevalence of the virus in a population. Hence, when a significant portion of the population is vaccinated, herd immunity is achieved and this extends protection even to those who are not vaccinated, as the virus's spread is impeded by

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