JUSTEK : JURNAL SAINS DAN TEKNOLOGI
http://journal.ummat.ac.id/index.php/justek
ISSN 2620-5475
Vol. 9, No. 2, June 2026, Hal. 172-181

Application of Mosquito Net Control in a New Dynamics of Dengue

Nilwan Andiraja[1]
[1]Program Studi Matematika, UIN Sultan Syarif Kasim Riau, Indonesia
[1]nilwanandiraja@uin-suska.ac.id

ARTICLE INFO

Article History:

Received : 05-05-2026
Revised : 09-06-2026
Accepted : 09-06-2026
Online : 18-06-2026

Keywords:
Mosquito Net;
Optimal Control;
Pontryagin;
Sweep.

ABSTRACT

This study discusses the application of mosquito net control in the SIR-UV model for the spread of dengue fever. The study has a specific objective to analyze the effectiveness of mosquito net control on the vulnerable human population to reduce the number of people infected with dengue fever. This research begins by forming a new SIR-UV mathematical model (state equation) with mosquito net control in the class of vulnerable human population and creating a new objective function to minimize the population of humans infected with dengue fever. Next, using Pontryagin's principle, the Hamiltonian function was formed. From the Hamiltonian function, the costate equation and the optimal control for the use of mosquito nets were obtained. The next step is to change the state equation and the costate equation using the 4th order Runge-Kutta method. Then a numerical simulation is performed, with the forward sweep method determining the solution to the state equation, and the backward sweep method for solving the costate equation. Numerical simulations will be conducted to observe the effects of control on the class of human population infected. The numerical simulations will use some data from previous research so that the simulation results can be compared with the previous research findings. The simulation results show that the use of mosquito nets on the vulnerable human population class can reduce the population of humans infected with dengue fever, where from the initial time of day 0, the graph of infected humans immediately drops below 20 days and continues to approach zero until day 100. It has same results for mosquitoes infected, which decreased immediately from the start continued to approach zero until days 100. In contrast, without control, there is a spike in the number of infected humans at the beginning and will approach zero by day 80 and it took until day 60 for the mosquitoes infected population with dengue virus to approach 0. Therefore, the use of mosquito nets on the vulnerable human population can reduce the number of humans infected with dengue fever and, of course, contribute to minimizing the spread of dengue fever.

A. INTRODUCTION

Dengue fever, Indonesian called DBD, is a disease caused by the dengue virus, which is transmitted through the bite of the female Aedes aegypti mosquito. Symptoms of dengue fever typically include sudden high fever, muscle and joint pain, severe headache, and mild bleeding such as nosebleeds or bleeding gums, if not treated quickly and appropriately, dengue fever can cause serious complications such as dengue shock syndrome, which can lead to death (Ali, Obaid, & Alabsi, 2025; Gholami, Gachpazan, & Erfanian, 2025; Jamal et al., 2025; Murugesan, Thiruvengadam, Roy, Pulikkottil, & Paluru, 2022). Dengue fever also always announced as a huge health problem in Indonesia.

Therefore, research is needed to prevent the spread of DBD so that it does not spread by reducing the number of individuals infected with DBD. This study found that DBD can be eliminated over a long period of time through vaccination (He et al., 2026) or using the zone clustering (Yaqin et al., 2025), but the DBD will expand when population move to other populations (Matías-pérez et al., 2025). Other research by using mathematical models, for instance, the SEIHR-VW model, (Norramandhany & Tjahjana, 2025), SEITR-SI, (Tagne et al., 2025). Another study discusses co-infection of Malaria and DBD using the mathematical model; (Raj et al., 2024). The SIR-UV model for the dengue fever spread has also been conducted by examining the level of public awareness of the existence of dengue fever. (Aldila et al., 2023). These studies have generally modeled the spread of dengue fever mathematically with various efforts to prevent its spread, but none have used control to discuss the effectiveness of these efforts.

Furthermore, research combining mathematical models and control systems has been conducted in the following studies. Research using the model of SIR-SIR-SI with the use of vaccination control (Chamnan et al., 2021). the SIR-SI with treatment control (Meher et al., 2025; Syifana et al., 2026). Other research using the Adaptive control model has also been conducted (Dayap & Rabajante, 2025; Sa'adah et al., 2025). Furthermore, with the SI-SEIS-IR using several controls, such as larvicides, fumigation, vaccination, and isolation (Vellappandi et al., 2024). The mathematical model of SEAIRQV-SEI with the application of mosquito bite prevention controls (Abidemi et al., 2024). Next, the SPIR-SI with mosquito spraying control, mosquito net use control, and mosquito repellent clothing control (Brito da Cruz et al., 2024). Furthermore, the SEITR-SEI with mosquito spraying control and larvicide distribution (Pandey et al., 2024). Next, using the SEIRD-SI model with control of treatment and mosquito nets (Yoda et al., 2024), and SVEIR-SEI model with fuzzy mosquito net control and vaccination (Islam et al., 2025). These studies combine mathematical models and optimal control. The outcomes of this research is using the control more effectively than without control.

Based on this research, it can be seen that one way to control and reduce human infection with dengue fever is using the mosquito nets. According to WHO data from 2007, the use of mosquito nets in South Africa has been proven effective in reducing cases of mosquito-borne diseases (Tagne et al., 2025). Therefore, this research develops a new mathematical model by modifying previous research (Aldila et al., 2023). The new mathematical model is formed by incorporating a new control, namely the use of mosquito nets. Thus, this research aims to develop a new mathematical model and a new objective function to minimize the population of humans infected with dengue fever. Then, using the Pontryagin principle, this research aims to obtain the optimal control of mosquito net usage. Next, numerical simulations were conducted using the forward-backward sweep method and the 4th-order Runge-Kutta method. This numerical simulation was conducted with the aim of obtaining a comparison of the results of the infected human population after control and without control. Thus, the results of this research are expected to provide the right strategy in a joint effort to reduce the number of people infected with dengue fever (the number of people infected with dengue fever) in Jakarta so that the transmission of dengue fever can be minimized.

B. METHODS

This research uses the quantitative research. The initial stage of it is to form a new mathematical model of the transmission of dengue fever. The new mathematical model in this research is a modification of the previous mathematical model developed by (Aldila et al., 2023), namely

$$\frac{dS(t)}{dt}=\Lambda_h-\beta_h(1+\alpha I)S(t)V(t)+\delta R(t)-\mu_h S(t) \tag{1a}$$

$$\frac{dI(t)}{dt}=\beta_h(1+\alpha I)S(t)V(t)-\gamma I(t)-\mu_h I(t) \tag{1b}$$

$$\frac{dR(t)}{dt}=\gamma I(t)-\delta R(t)-\mu_h R(t) \tag{1c}$$

$$\frac{dU(t)}{dt}=\Lambda_v-\beta_v(1+\alpha I)U(t)I(t)-\mu_v U(t) \tag{1d}$$

$$\frac{dV(t)}{dt}=\beta_v(1+\alpha I)U(t)I(t)-\mu_v V(t) \tag{1e}$$

With, population of susceptible individuals at time t ($S(t)$), population of infected individuals at time t ($I(t)$), population of treated patients at time t ($R(t)$), population of susceptible mosquitoes at time t ($U(t)$) , many infected mosquitoes within a certain period of time ($V(t)$), human birth rate (Λ_h), mosquito birth rate (Λ_v), human dengue fever infection rate (β_h), level of *dengue* virus infection in mosquitoes (β_v) , human ignorance factor regarding dengue fever (α) , recovery rate (γ), level of immunity decline (δ), human natural mortality rate (μ_h), and mosquito natural mortality rate (μ_v).

Furthermore, according to (Aldila et al., 2023), the assumptions that apply to the model in equations (1a)-(1e) are population of individual is divided into $S(t)$, $I(t)$, $R(t)$, and population of mosquito is divided into two classes: $U(t), V(t)$. There is no recovery process in the mosquito population. Susceptible human will infections to dengue fever infection because they are bitten by mosquitoes infected with the dengue virus. The DBD infection rate will increase if the population of individuals infected with DBD also increases.

Based on equations (1a)-(1e), the first step is to modify the model by replacing the level of individual indifference to dengue fever in the susceptible class ($S(t)$), denoted by $(1+\alpha I)$, with a control measure, denoted by $(1-\psi(t))$ based on (Abidemi et al., 2024; Yoda et al., 2024). After forming the state equation, an objective function is formed, which is to reduce the number of individuals infected with dengue fever. The next step, based on the *state* equation and objective function, is to form a Hamiltonian function based on Pontryagin's principle. Based on the Hamiltonian function, a *costate* equation is then formed. The next step is to partially differentiate the Hamiltonian function with respect to the control $\psi(t)$ to obtain the optimal use of mosquito nets $\psi^*(t)$.

The next step is using the forward-backward sweep method, solutions will be sought for the state equation with a forward sweep and a backward sweep for solutions to the costate equation (Kebedow et al., 2025). Then, the numerical equations were formed using the 4th order Runge-Kutta method for the state equation and costate equation. In these numerical simulations, several data sets obtained from previous studies were used (Aldila et al., 2023; Rahman et al., 2025) because after numerical simulations, we will compare the result with control and result without control which is found in previous research (Aldila et al., 2023). The steps of the numerical simulation performed are as follows (Bahaa & Qamlo, 2025; Bijalwan & Muñoz, 2026):

Step 1 : An initial guess is taken for the value of $\psi^*(t)$ for $t \in [0, T_f]$.

Step 2: The initial value of $\psi^*(t)$ from Step 1 is used in the state equation, then a forward sweep is performed for the system of state equations using a fourth-order Runge-Kutta scheme.

Step 3 : Using the costate boundary value $\lambda(T_f) = 0$ and the control value $\psi^*(t)$ and the state equation value from step 2, a backward sweep is solved for the costate equation using a 4th order Runge-Kutta scheme.

Step 4 : Repeat the iteration step by updating the state and costate values by entering the state and costate values.

After performing numerical simulations, graphs of the results for all classes will be obtained. All graphs of the results will be interpreted to see whether the use of mosquito nets is useful to reduce the population infected and preventing the spread of DBD. These results also aim to determine whether the use of mosquito nets is more effective than without mosquito nets in preventing the spread of dengue fever.

C. RESULT AND DISCUSSION

1. Research Results

Based on equations (1a)-(1e), they will be modified by adding the control $\psi(t)$. Thus, the state equation is obtained,

$$\frac{dS(t)}{dt} = \Lambda_h - \beta_h(1-\psi(t))S(t)V(t) + \delta R(t) - \mu_h S(t) \tag{2a}$$

$$\frac{dI(t)}{dt} = \beta_h(1-\psi(t))S(t)V(t) - \gamma I(t) - \mu_h I(t) \tag{2b}$$

$$\frac{dR(t)}{dt} = \gamma I(t) - \delta R(t) - \mu_h R(t) \tag{2c}$$

$$\frac{dU(t)}{dt} = \Lambda_v - \beta_v(1-\psi(t))U(t)I(t) - \mu_v U(t) \tag{2d}$$

$$\frac{dV(t)}{dt} = \beta_v(1-\psi(t))U(t)I(t) - \mu_v V(t) \tag{2e}$$

Next, the objective function is formed,

$$J = \int_{t_0}^{t_f} \left(c_1 I(t) + c_2 \psi(t)^2 \right) dt \tag{3}$$

Where c_1 and c_2 are important parameter values for the objective function.

Next, based on the equations (2a)-(2e) and (3), by using Pontryagin's principle, the Hamiltonian function is formed as follows:

$$\begin{aligned} H = &\left(c_1 I(t) + c_2\psi(t)^2\right) + \lambda_S\left(\Lambda_h - \beta_h(1-\psi(t))S(t)V(t) + \delta R(t) - \mu_h S(t)\right) \\ &+\lambda_I\left(\beta_h(1+\alpha I)S(t)V(t) - \gamma I(t) - \mu_h I(t)\right) + \lambda_R\left(\gamma I(t) - \delta R(t) - \mu_h R(t)\right) \\ &+\lambda_U\left(\Lambda_v - \beta_v(1+\alpha I)U(t)I(t) - \mu_v U(t)\right) \\ &+\lambda_v\left(\beta_v(1+\alpha I)U(t)I(t) - \mu_v V(t)\right) \end{aligned} \tag{4}$$

Next, based on Equation (4), the costate equations will be formed.

$$\frac{\partial H}{\partial S(t)} = -\left(-\lambda_S\beta_h V(t) + \lambda_S\beta_h\psi(t)V(t) - \lambda_S\mu_h + \lambda_I\beta_h V(t) - \lambda_I\beta_h\psi(t)V(t)\right) \quad (5a)$$

$$\frac{\partial H}{\partial I(t)} = -(c_1 - \gamma\lambda_I - \mu_h\lambda_I + \gamma\lambda_R - \beta_v U(t)\lambda_U + \beta_v\psi(t)U(t)\lambda_U + \beta_v U(t)\lambda_V$$
$$-\beta_v\psi(t)U(t)\lambda_V \quad (5b)$$

$$\frac{\partial H}{\partial R(t)} = -\left(\delta\lambda_S - \delta\lambda_R - \mu_h\lambda_R\right) = -\delta\lambda_S + \delta\lambda_R + \mu_h\lambda_R \quad (5c)$$

$$\frac{\partial H}{\partial U(t)} = -\left(-\lambda_U\beta_v I(t) + \lambda_U\beta_v\psi(t)I(t) - \lambda_U\mu_v - \lambda_V\beta_v I(t) - \lambda_V\beta_v\psi(t)I(t)\right) \quad (5d)$$

$$\frac{\partial H}{\partial V(t)} = -\left(-\lambda_S\beta_h S(t) + \lambda_S\beta_h\psi(t)S(t) + \lambda_I\beta_h S(t) - \lambda_I\beta_h\psi(t)S(t) - \lambda_V\mu_v\right) \quad (5e)$$

The next step is to determine the optimal control for mosquito net usage from the Hamiltonian function in Equation (4) by $\frac{\partial H}{\partial\psi(t)} = 0$. Thus, we obtain

$$\psi^*(t) = \frac{-(\lambda_S - \lambda_I)\beta_h S(t)V(t) - (\lambda_U - \lambda_V)\beta_v U(t)I(t)}{2c_2} \quad (6)$$

with the control constraints set as follows $0 \le \psi^*(t) \le 1$, then Equation (6) can be reformed as follows:

$$\psi^*(t) = \min\left(1, max\left(0, \frac{-(\lambda_S - \lambda_I)\beta_h S(t)V(t) - (\lambda_U - \lambda_V)\beta_v U(t)I(t)}{2c_2}\right)\right) \quad (7)$$

Equation (7) is the optimal control of mosquito net usage to decrease the population of individuals infected with dengue fever and simultaneously prevent the spread of dengue fever.

2. Numerical Simulation

Numerical simulations were performed using several data obtained from previous studies (Aldila et al., 2023; Rahman et al., 2025). These data can be seen in Table 1 and Table 2.

Table 1. Parameter Values

Parameters	Value	Parameters	Value
$I(0)$	50	β_h	0.0025
$R(0)$	109	γ	0.25
$N(t)$	1000	δ	0.027

With $S(t) = N(t) - I(t) - R(t)$ (Aldila et al., 2023), then $S(t) = 841$. Meanwhile, other parameter values are assumed and provided in Table 2 below.

Table 2. Additional Parameter Values

Parameters	Value	Parameters	Value
Λ_h	0.01	β_v	0.001
Λ_v	0.2	$U(0)$	1000
μ_h	0.01	$V(0)$	100
μ_v	0.02		

Using the data from Table 1 and Table 2, numerical simulations were performed starting from step 1 to step 4 as described in the research method section. The numerical simulation steps were performed starting from day 0 to day 100.

The simulation results based on these steps have produced graphs for all classes, $S(t)$, $I(t)$, $R(t)$, $U(t)$, and $V(t)$. The results $S(t)$ class can be seen in Figure 1. Figure 1 shows that with mosquito net use, since time 20, the number of individuals susceptible to mosquito bites decreased to zero. Conversely, without mosquito net control, the number of vulnerable individuals increased from the 40th day and continued to increase until the 100th day.

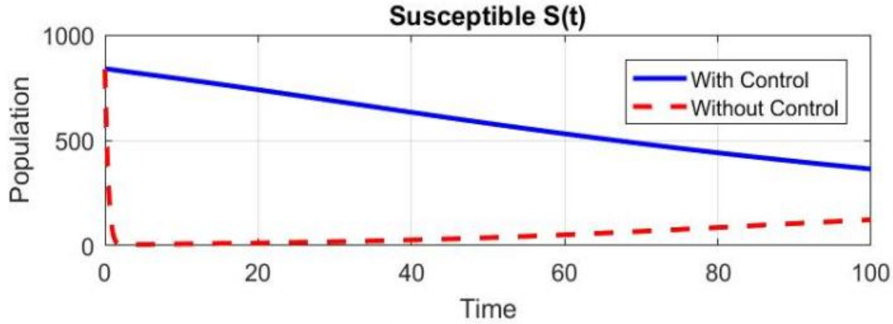

Figure 1. Susceptible class graph

Next, the graph showing the results of $I(t)$ is presented in Figure 2. Based on the results graph, by using mosquito net, class of $I(t)$ decrease immediately to zero from day 0 continues until day 100. Different results are seen without control, where there is an increase the population of people infected with dengue fever at the beginning and a gradual decrease, approaching zero from day 80.

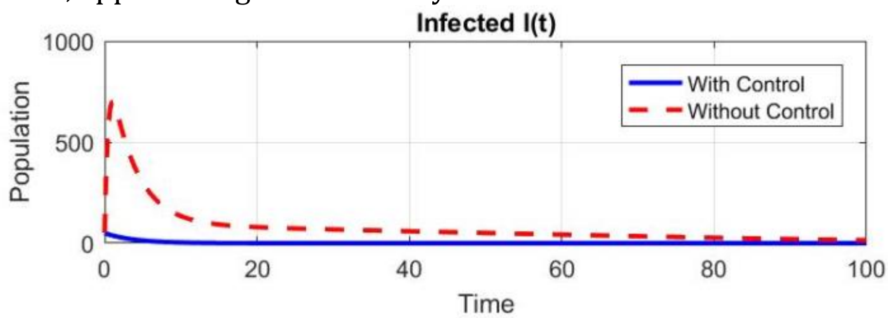

Figure 2. Infected class graph

The results graph for $R(t)$ from dengue fever is shown in Figure 3. It can be seen that the use of mosquito nets is more effective than not using them. The results graph $R(t)$ with mosquito net control is lower because, since the infected class graph, only a few individuals were infected with dengue fever. Meanwhile, without control, the recovery graph is higher because, since the dengue fever infected class, many individuals were infected with dengue fever, so there were also many individuals who recovered.

Next, for the *dengue* virus-susceptible mosquito class, the results graph is shown in Figure 4. The figure depict the results graph with and without control. It is known that initially, Aedes aegypti mosquitoes were not infected by the virus. Therefore, with the use of mosquito nets as a control measure for humans, the entire mosquito population is considered to be carriers of the *dengue* virus.

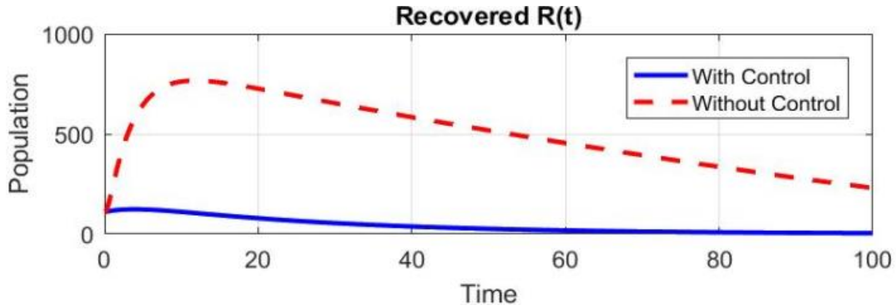

Figure 3. Recovered class graph

This means that at the beginning, the susceptible mosquito population was considered susceptible to the *dengue* virus. However, because the use of mosquito nets can prevent mosquitoes from biting humans infected with the dengue virus, the graph for the susceptible mosquito class also decreases over time. The graph results for susceptible mosquitoes without control from the beginning are lower because, from the start, without the use of mosquito nets, humans assumed that Aedes mosquitoes did not carry the *dengue* virus.

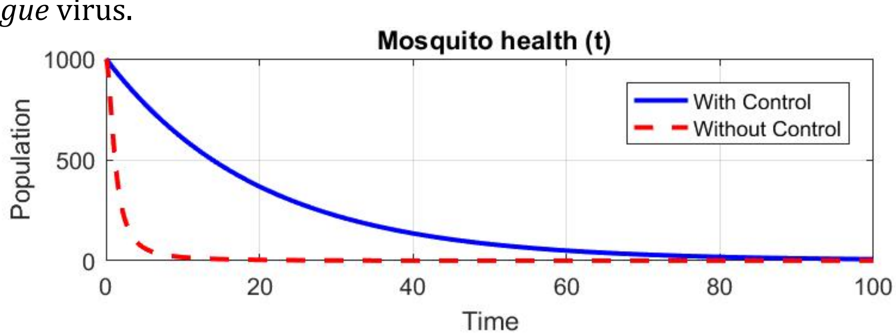

Figure 4. Susceptible mosquito graph

The results graph in Figure 5 is the results graph for mosquitoes infected with the *dengue* virus. Figure 5 shows that with the use of mosquito nets in humans, the infected mosquito population is very small from the start and continues to approach zero until day 100. This is because the use of mosquito nets on humans protects mosquitoes from biting individuals infected dengue fever. Thus, mosquitoes will not be infected with the virus and this virus will not be multiplied in the mosquito's body after biting, and these mosquitoes will not transmit the virus to other humans through biting. It is known that Aedes aegypti mosquitoes are the primary carriers and agents in the spread of the *dengue* virus.

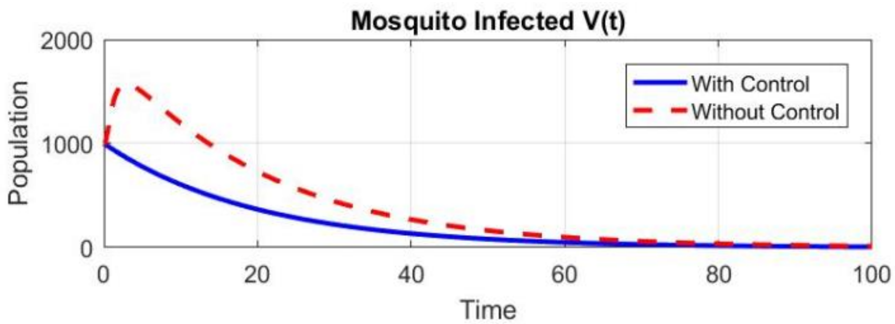

Figure 5. Graph of infected mosquitoes

The graph of mosquitoes infected with the *dengue* virus shows different results when there is no mosquito net control for humans. It can be seen that the mosquito population graph increases sharply at the beginning, because Aedes aegypti mosquitoes can easily bite any human. Therefore, the chance of these mosquitoes biting individuals who are already infected with dengue fever is also very high because there is no protection for humans from mosquito bites. Furthermore, over time, as the infected human population graph in Figure 2 also decreases, the mosquitoes infected population with dengue virus will also decrease over time.

3. Discussion

Based on the results of numerical simulation that can see in Figures 1 to 5, it can obtain conclusion that the use of mosquito nets, denoted by $\psi\ (t)$, has succeeded in significantly reducing the humans infected population by dengue fever and at the same time reducing the mosquitoes infected population with the *dengue* virus. According to Figure 2, it can be seen that from the beginning of time 0, the individuals infected population with dengue fever immediately decreased in less than 20 days without any increase, and continued to approach zero until day 100. The same thing happened to mosquitoes infected with the dengue virus. As shown in graph 5, the mosquito population also immediately declined and approached zero by day 100. This means that there were almost no mosquitoes infected with the dengue virus, which would certainly reduce the spread of dengue fever.

These results are in line with previous studies that the use of mosquito nets can reduce the population of humans infected with disease or prevent disease transmission and simultaneously control the spread of a disease caused by mosquito bites. Research by (Abidemi et al., 2024) shows that mosquito net control can minimize cases of human dengue fever infection better than other control methods. Another study supporting these findings is the research by (Brito da Cruz et al., 2024), which also shows that mosquito net control is more effective than mosquito spraying and mosquito-repellent clothing, as mosquito nets can more effectively reduce the number of individuals infected with dengue fever. The same is true for the results of this study with the previous research (Yoda et al., 2024) that the use of mosquito nets can reduce cases of individuals infected with dengue fever. Meanwhile, the results of (Islam et al., 2025) show that the use of mosquito nets can quickly and significantly reduce cases of Aedes aegypti mosquito bites on humans and will certainly reduce the number of individuals infected with dengue fever.

Meanwhile, based on the study (Aldila et al., 2023), it is known that reducing human negligence through media campaigns can provide opportunities to suppress dengue fever infection cases in individuals. Although dengue fever outbreaks still occur, their effects can be reduced. Thus, it can be concluded that reducing individual negligence is not sufficient to prevent the transmission of dengue fever, as there is still a possibility of outbreaks occurring. However, this study shows that the use of mosquito nets offers hope that the spread of dengue fever can be minimized.

Although the use of mosquito nets offers hope for reducing the population infected with dengue fever, the use of mosquito nets also has limitations and weaknesses. Mosquito nets can only be used over beds and will only protect humans while they sleep. However, when humans are active elsewhere, probability humans are being bitten by mosquitoes remains. Then, using a mosquito net only prevents but does not kill the source of mosquitoes, and its use is considered less practical and prone to tearing.

D. CONCLUSION AND SUGGESTIONS

A new SIR-UV mathematical model and a new objective function have been provided in this study to examine the effectiveness of mosquito net use $(\psi^*(t))$ with the aim of reducing the population of individuals infected with dengue fever and, of course, controlling or minimizing the spread of dengue fever. Using Pontryagin's principle, the optimal control variable was obtained in Equation (7). Furthermore, The results of the numerical simulation show that class $I(t)$ and $V(t)$ from time $t=0$ until day 20 $(t=20)$ decreased and continue to approach zero until day 100 $(t=100)$, and for $t<20$ has same decreased immediately from the start of the simulation $t=0$ and continued to approach zero until $t=100$. Compared to without control, there was an increase in cases for both $I(t)$ and $V(t)$ at the beginning of the period. Although, finally, both class $I(t)$ and $V(t)$ continue to approach zero for respectively day 80 and day 60. Therefore, based on these results, it can be concluded that the implementation of $\psi^*(t)$ in the $S(t)$ class offers hope that cases of dengue fever infection in $I(t)$ and $V(t)$ can be significantly reduced, and the spread of dengue fever can be contained.

Eventually, this research can be expanded the scope of case study location or can be expanded the mathematical model by adding one or more class in human population. For example, the treatment class can be added for new mathematical model for dengue fever disease and also can be used various data from other location. Next, this research has not yet examined the sensitivity analysis for the new model with the addition of control. Therefore, the next research can be added the sensitivity analysis for this new control mathematical model.

REFERENCES

Abidemi, A., Fatmawati, & Peter, O. J. (2024). An optimal control model for dengue dynamics with asymptomatic, isolation, and vigilant compartments. *Decision Analytics Journal*, *10*(June 2023). https://doi.org/10.1016/j.dajour.2024.100413

Aldila, D., Aulia Puspadani, C., & Rusin, R. (2023). Mathematical analysis of the impact of community ignorance on the population dynamics of dengue. *Frontiers in Applied Mathematics and Statistics*, *9*. https://doi.org/10.3389/fams.2023.1094971

Ali, W. A. M., Obaid, J. M. A. S., & Alabsi, L. N. (2025). *Dengue Fever Knowledge and Awareness Among University Students in Taiz Governorate , Yemen : A Cross - Sectional Study*. https://doi.org/10.1002/hsr2.71112

Bahaa, G. M., & Qamlo, A. H. (2025). *Optimal control of coupled fractional dynamical systems using Caputo – Fabrizio derivatives and Forward – Backward Sweep Method*. *4*.

Bijalwan, N. A. N. R. A., & Muñoz, A. R. J. J. (2026). *On the Convergence of Conjugate Gradient and GMRES Algorithms in the Forward Backward Sweep Method for Optimal Control*. 498–510. https://doi.org/10.1002/oca.70072

Brito da Cruz, A. M. C., Rodrigues, H. S., & Monteiro, M. T. T. (2024). Assessing Multiple Personal Protections For Dengue: An Optimal Control Approach. *AIP Conference Proceedings*, *3094*(1), 1–5. https://doi.org/10.1063/5.0210642

Chamnan, A., Pongsumpun, P., Tang, I. M., & Wongvanich, N. (2021). Optimal control of dengue transmission with vaccination. *Mathematics*, *9*(15), 1–33. https://doi.org/10.3390/math9151833

Dayap, J. A., & Rabajante, J. F. (2025). *Mathematical Model of Dengue Transmission Dynamics with Adaptive Human Behavior*. *8*(1), 93–109. https://doi.org/10.5614/cbms.2025.8.1.7

Gholami, H., Gachpazan, M., & Erfanian, M. (2025). Mathematical modeling and dynamic analysis of dengue fever: examining economic and psychological impacts and forecasting disease trends through 2030—a case study of Nepal. *Scientific Reports*, *15*.

He, S., Fan, D., Guo, Y., Guan, Y., Sheng, Z., Gao, N., & An, J. (2026). Virologica Sinica Current status of dengue fever epidemics and vaccine development. *Virologica Sinica*, *41*(1), 1–9.

https://doi.org/10.1016/j.virs.2026.01.001

Islam, S., Islam, M. S., & Kamrujjaman, M. (2025). Effectiveness of bed nets and media awareness in dengue control: A fuzzy analysis. *Results in Control and Optimization*, *20*. https://doi.org/10.1016/j.rico.2025.100593

Jamal, M. K., Sanaei, B., Naderi, M., Past, V., Hashemi, S., & Abadi, A. (2025). Investigating the recent outbreak of dengue fever in Iran : a systematic review. *The Egyptian Journal of Internal Medicine*. https://doi.org/10.1186/s43162-025-00411-2

Kebedow, K. G., Cheru, S. L., & Ega, T. T. (2025). *Optimal Control Strategies in a Diseased Prey – Predator Model With Holling Type-II Dynamics*. *2025*. https://doi.org/10.1155/jama/5535536

Matías-pérez, D., Guerra-martínez, A., Hernández-bautista, E., Pérez-santiago, A. D., Antonio-cruz, A. L., & García-montalvo, I. A. (2025). *Impact of migratory flows and socio-environmental factors on dengue epidemiology in Oaxaca , Mexico*. (July), 1–7. https://doi.org/10.3389/fsoc.2025.1617789

Meher, R., Nikan, O., & Al-saedi, A. A. (2025). *Numerical study on fractional order nonlinear SIR-SI model for dengue fever epidemics*. 1–17.

Murugesan, R., Thiruvengadam, K., Roy, A., Pulikkottil, S., & Paluru, V. (2022). *Respiratory symptoms : a significant factor to be considered in dengue infection*. https://doi.org/10.3855/jidc.19539

Norramandhany, N. A., & Tjahjana, R. H. (2025). *Local Stability Analysis of Mathematic Model SEIHR-VW on Dengue Haemorrhagic Fever*. *11*(2), 38–47.

Pandey, H. R., Phaijoo, G. R., & Gurung, D. B. (2024). Dengue dynamics in Nepal: A Caputo fractional model with optimal control strategies. *Heliyon*, *10*(13), e33822. https://doi.org/10.1016/j.heliyon.2024.e33822

Rahman, N. S., Fatahillah, H. A., & Aldila, D. (2025). Analysis of the Occurrence of Periodic Solutions from the Mathematical Model of the Spread of Dengue Hemorrhagic Fever with Non-Standard Infection Rates. *Jurnal Matematika Integratif*, *21*(1), 1–14. https://doi.org/10.24198/jmi.v21.n1.60353.1-14

Raj, M. P., Venkatesh, A., Kumar, K. A., & Manivel, M. (2024). Mathematical Modeling of The Co-infection Dynamic of Dengue adn Malaria Using Delay Differential Equations. *Advanced Theory and Simualtion*, *8*(2).

S1995820X26000076. (n.d.).

Sa'adah, A., Sari, D. K., Sinaga, R. Y., & Sitorus, H. C. K. (2025). Controlling the spread of dengue disease using adaptive sliding mode control. *AIP Conference Proceedings*, *3302*(1), 40001. https://doi.org/10.1063/5.0263146

Syifana, K. N., Chasnah, A., Himayati, A. I. A., & Nursani, I. I. (2026). Spread of dengue fever in Jepara regency with SIR model. *AIP Conference Proceedings*, *3411*(1), 40003. https://doi.org/10.1063/5.0321868

Tagne, C. S. D., Kouamo, M. F. M., Tchouakui, M., Muhammad, A., Mugenzi, L. J. L., Tatchou-nebangwa, N. M. T., Thiomela, R. F., Gadji, M., Wondji, M. J., Hearn, J., Desire, M. H., Ibrahim, S. S., & Wondji, C. S. (2025). A single mutation G454A in the P450 CYP9K1 drives pyrethroid resistance in the major malaria vector Anopheles funestus reducing bed net efficacy. *GENETICS*, *229*(1), 1–16. https://doi.org/10.1093/genetics/iyae181

Vellappandi, M., Govindaraj, V., Kumar, P., & Nisar, K. S. (2024). An Optimal Control Problem for Dengue Fever Model Using Caputo Fractional Derivatives. *Progress in Fractional Differentiation and Applications*, *10*(1), 1–13. https://doi.org/10.18576/pfda/100101

Yaqin, M. I. A., Agustin, A. D., Taufik, M., Taufiqurrochman, M., & Artiono, R. (2025). Analysis of dengue fever disease spread zone mapping in East Java Province using K-means clustering. *AIP Conference Proceedings*, *3316*(1), 80006. https://doi.org/10.1063/5.0290025

Yoda, Y., Ouedraogo, H., Ouedraogo, D., & Guiro, A. (2024). Mathematical analysis and optimal control of Dengue fever epidemic model. *Advances in Continuous and Discrete Models*, *2024*(1). https://doi.org/10.1186/s13662-024-03805-8