*J. Intell. Comput. Health Inform. Vol. 4, No. 2, 2023*
ISSN: 2715-6923 e-ISSN: 2721-9186, pp.41~47 | DOI: 10.26714/jichi.v4i2.12769.

# Modelling of Dengue Hemorrhagic Fever Disease in Semarang City Using Generalized Poisson Regression Model

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Article histroy :
Received: 30 JUL 2023
Accepted: 06 SEP 2023
Avalaible online: 30 SEP 2023

*Research article*

**Abstract:** Dengue Hemorrhagic Fever (DHF) is an infectious disease that can be life-threatening within a relatively short period of time and can be fatal if not promptly treated. DHF in Indonesia ranks second as a dangerous seasonal disease. DHF remains a serious issue in the Central Java Province, particularly in Semarang City. The cases of DHF can be modeled using a Poisson regression model due to the characteristics of DHF cases, which involve count data with small occurrence probabilities. The Poisson regression model assumes equality between the mean and variance (equidispersion). However, the application of the Poisson regression model often encounters violations of the assumption of excessive variance (overdispersion), which necessitates addressing the violation, and one possible approach is to use the Generalized Poisson Regression model. Based on the analysis results, the Generalized Poisson Regression model could handle the overdispersion because the ratio of Pearson Chi-Square by degrees of freedom was 0.976, approaching a value of 1. It has also been proven to be more suitable for evaluating factors influencing the number of DHF cases, as it has a lower AIC value compared to Poisson models, with a value of 123.64. The variables that were found to have an impact on DHF cases in Semarang City based on the Generalized Poisson Regression model are the number of larval habitats ($X_1$), the number of hospitals ($X_2$), population density ($X_3$), and the number of healthcare workers ($X_4$).

**Keywords:** DENGUE HEMORRHAGIC FEVER; GENERALIZED POISSON REGRESSION; POISSON REGRESSION



## 1. Introduction

Dengue Hemorrhagic Fever (DHF) is an infectious disease that can have fatal consequences within a relatively short period of time, potentially claiming the lives of those affected if not promptly addressed (Mubarak & Budiantara, 2012). In Indonesia, DHF ranks second as a dangerous seasonal disease. The Aedes aegypti mosquito tends to transmit the dengue virus in places that contain stagnant water, such as bathtubs, flower pots, and glasses. As a result, the mosquito population tends to increase during the rainy season. Currently, the transmission of DHF is becoming more prevalent due to various contributing factors. The signs and symptoms of DHF are characterized by the sudden onset of fever within a range of 2 to 7 days, accompanied by symptoms such as headache, joint pain (myalgia), muscle pain (arthralgia), and skin rash (Sari, 2016).

In Indonesia, there were a total of 65,602 cases of DHF in 2018, resulting in 467 deaths. According to the Semarang City Health Department, DHF cases increased in 2019 after a decline from 2016 to 2018, indicating that DHF remains a serious issue in Central Java, affecting 35 districts/cities. As a result, it has become a significant problem that requires attention. Tembalang Sub-district is one area in Semarang City where Dengue Hemorrhagic Fever (DHF) is highly prevalent. In 2019, Tembalang Sub-district had the highest number of DHF cases with an incidence rate (IR) of 68.22 per 100,000 population. On the other hand, Tugu Sub-district had the lowest number of DHF cases in Semarang City in 2019, with an IR of 8.96 per 100,000 population (Alfiyanti & Siwiendrayanti, 2021).

According to the epidemiological triangle model, the role of humans as hosts and Aedes aegypti mosquitoes as disease vectors is among the factors that influence the emergence of DHF. It is increasingly clear that the environment affects individual health in terms of social, economic, and especially community behavior. Factors such as mosquito breeding sites, increased population mobility, population density, and improved transportation facilities are significant contributors to the spread of the disease (Islam, Kabir & Talukder, 2020; Yadav et al., 2021). The Poisson regression method can be used to analyze count data with a Poisson-distributed response variable or to examine relatively rare events. Therefore, Poisson regression is employed to identify which components contribute to the increase in the number of DHF cases in Semarang City (Sandra, Sofro, Suhartono, Martini & Hadisaputro, 2019).

Regression analysis is a statistical technique intended to show the relationship between a response variable (Y) and the predictor variable (X). If the analysis involves only one predictor variable, simple linear regression is used, but if two or more predictor variables are included, multiple linear regression is used (Muhammad Bangkit Riksa Utama & Hajarisman, 2021). Poisson regression itself has certain assumptions that need to be met, namely, that the dependent variable has the same mean and variance; otherwise, overdispersion occurs (Sabtika, Prahutama, & Yasin, 2021). If overdispersion occurs, it can be addressed using alternative models such as Generalized Poisson regression (Haris & Arum, 2022).

Previously, (Sari, 2016) used Poisson regression model to conduct a study on DHF. The objective of the research was to determine how various factors, such as the number of larval habitats, healthcare workers, population density, and fogging usage, correlate with the number of DHF cases in Bantul Regency. (Mubarak & Budiantara, 2012) also conducted a study on DHF, focusing on modeling the deaths of DHF patients in East Java. According to this research, the percentage of healthcare facilities, percentage of healthcare workers, and larval habitat index are some of the variables that influence DHF. (Aulele, 2012) also conducted a Poisson regression study unrelated to DHF. The research discussed the modeling of Infant Mortality in Maluku Province in 2010 using Poisson regression.

The researchers are focused on identifying the factors that influence DHF in Semarang City using the Generalized Poisson regression model. The results of this study are expected to provide guidance for the government in formulating policies related to vector control and efforts to reduce DHF cases in Semarang City.

## 2. Study Literatures

### 2.1 Hemorrhagic fever

The Aedes aegypti mosquito inhabits various locations in Southeast Asia, particularly in tropical and subtropical regions. They typically reside in dark and humid places such as beds, bathrooms, toilets, and stagnant water (Sandra et al., 2019). Dengue Fever is one of the infectious diseases caused by the dengue virus, which is transmitted by the Aedes aegypti mosquito. As a result, the population of Aedes aegypti mosquitoes tends to increase during the rainy season. With approximately 2.5 to 3 billion people at risk of contracting Dengue Fever, the disease has become a significant global problem. The primary vector for this disease is the Aedes aegypti mosquito. While the disease initially predominantly occurred in urban areas, it has now also started to affect rural areas. Approximately 50 to 100 million cases occur each year, with 500,000 cases requiring hospitalization. The disease has an average death rate of around 5% in a cyclical pattern, meaning that deaths reoccur periodically (Septiani, Sundari & Indrawan, 2022).

Dengue Hemorrhagic Fever (DHF) is an infectious disease that can be fatal if not promptly treated. Symptoms of DHF include sudden fever lasting 2 to 7 days, accompanied by headache, joint pain (myalgia), muscle pain (arthralgia), and skin rash. DHF is caused by the dengue virus, which is transmitted by the Aedes aegypti mosquito. It is one of the most dangerous seasonal diseases in Indonesia due to various influencing factors. These factors include human and environmental factors, such as increased transportation, population density, and the presence of locations conducive to mosquito breeding (Sari, 2016).

### 2.2 Poisson regression

Discrete data were included in nonlinear regression models. The utilization of the Poisson distribution forms the basis of Poisson regression. It is a regression model that can be applied to data with a response variable that has a discrete and non-normal distribution, particularly when the distribution follows the Poisson distribution. Since the Poisson random variable takes on non-negative integer values, the Poisson distribution provides a realistic model for various types of random events (Cahyandari, 2014).

The dependent variable used in Poisson regression models is typically a count or frequency, representing the number of occurrences or events within a specific period or area (Chen, Liu, Xiao, Xu & Long, 2020; Ibeji, Zewotir, North, & Amusa, 2020). It is suitable for analyzing data where the outcome of interest is a discrete and non-negative count, such as the number of disease cases, accidents, or customer visits. The Poisson regression model is designed to model the relationship between the predictor variables and the expected count or rate of the dependent variable (Fuad, Kudus & Sunendiari, 2018).

Assuming that the values $y_i$, where $i = 1, 2, \ldots, n$, represent the number of events that occur in a given period, with the parameter value μ representing the parameter of the Poisson distribution. The variable $y$ is a random variable that follows a Poisson distribution with the probability mass function by Eq. (1).

$$P(y;\mu) = \frac{e^{-\mu}\mu^{y}}{y!};\ y = 0,1,2, \ldots \text{ dan } \mu > 0 \tag{1}$$

with μ representing the average number of events in a specific interval, the expectation (mean) and variance of the Poisson distribution can be calculated by Eq. (2) (Haris & Arum, 2022).

$$E[y] = Var\,[y] = \mu \tag{2}$$

The Poisson regression model can be expressed by Eq.

(3).

$$y_i = \mu_i + \varepsilon_i = \exp(\boldsymbol{x}_i'\boldsymbol{\beta}) + \varepsilon_i;\ y_i = 1, 2, 3, \ldots \quad (3)$$

With $\mu_i$ representing the mean value of the number of events, the probability of an event $y_i$ occurring can be expressed in Eq. (4).

$$P(y_i|\boldsymbol{\beta}) = \frac{e^{-[\exp(x_i'\boldsymbol{\beta})]}[\exp(x_i'\boldsymbol{\beta})]^{y_i}}{y_i!};\quad y_i = 1,2,3,\ldots,\ i = 1,2,3,\ldots \quad (4)$$

The Poisson regression model is a nonlinear regression model, which means that the estimation of its coefficient parameters involves iteration using the Newton-Raphson method (Prahutama, Ispriyanti & Warsito, 2020).

### 2.3 Overdispersion

The Poisson regression modeling assumes equidispersion, which means that the mean and variance of the response variable are equal. However, in several studies, violations of this assumption in Poisson regression are often encountered, such as when the variance exceeds the mean (Var ($y_i$) > E ($y_i$)), which is known as overdispersion (Ismail & Jemain, 2007). Overdispersion can arise due to unaccounted sources of variation in the data or the presence of explanatory factors not included in the model. It can also occur due to outliers in the data, errors in modeling interactions, or erroneous assumptions about the link function (Hilbe, 2011).

Poisson regression modeling with data containing overdispersion can lead to underestimated standard errors, resulting in inaccurate decisions regarding the significance of the regression parameters (Haris & Arum, 2022). The presence of overdispersion can be assessed by comparing the deviance with its degrees of freedom. If the ratio of these values is greater than one, it indicates that the model is experiencing overdispersion. The Deviance equation is formulated in Eq. (5).

$$D = 2\sum_{i=1}^{n}\left\{y_i ln\left(\frac{y_i}{\widehat{\mu_i}}\right) - (y_i - \widehat{\mu_i})\right\} \quad (5)$$

### 2.4 Generalized poisson regression

The Generalized Poisson Regression distribution is an extension of the Poisson distribution that is useful for modeling count data with issues of overdispersion or underdispersion. Let $Y$ be the response variable that follows a Generalized Poisson distribution, and its probability distribution function can be defined by Eq. (6).

$$P(y;\mu,\phi) = \left(\frac{\mu}{1+\phi\mu}\right)^{y}\frac{(1+\phi y)^{y-1}}{y!}\exp\left[\frac{-\mu(1+\phi y)}{1+\phi\mu}\right];\quad y = 0,1,2,\ldots \quad (6)$$

with a mean value $\mu$ and a variance of $\mu(1+\phi\mu)^2$ (Irawati & Purhadi, 2012; Prahutama, Sudarno, Suparti, & Mukid, 2017; Yulianingsih, Sukarsa, & Suciptawati, 2012).

### 2.5 Akaike's information criterion

The selection of the best model among Poisson Regression and Generalized Poisson Regression can be done using the AIC value. AIC is formulated in Eq. (7)

$$AIC = -2(L - k) \quad (7)$$

With $L$ being the log likelihood model and k being the number of parameters in the model. The best model is determined by the model that has the smallest AIC value (Prahutama et al., 2017).

## 3. Methodology

### 3.1 Data acquisition

This study involves all individuals in the city of Semarang who have experienced Dengue Hemorrhagic Fever (DHF). However, only the sample of DHF cases in the year 2019 is used for this study. The data was obtained from the Semarang Health Office, which recorded the number of DHF cases in that year. The variables used in the study are described in Table 1.

Table 1. Research Variable

| VARIABEL | DESCRIPTION |
|---|---|
| Respond ($Y$) | The total number of dengue fever (DBD) cases in Semarang City in 2019 based on district |
| Predictor ($X_1$) | The Larval Free Index (LFI) is the ratio of the number of houses with negative larvae compared to the number of houses inspected |
| Predictor ($X_2$) | The total number of hospitals operating in Semarang City in 2019 by district |
| Predictor ($X_3$) | The comparison of population size divided by the area is known as population density |
| Predictor ($X_4$) | The individuals working in the healthcare field, specifically those responsible for preventing cases of DBD (Doctors, Midwives, Jumantik) in Semarang City per district in the year 2019 |
| Predictor ($X_5$) | The total number of health centers (puskesmas) in each district of Semarang City in the year 2019 |

The procedure used to process secondary data and generate optimal relationship patterns for Dengue Hemorrhagic Fever (DHF) cases in Semarang City through Poisson regression analysis typically involves the following steps:

1. Perform data exploration to understand the characteristics of the response and predictor variables across districts in Semarang City.
2. Identify and address the assumption violation of multicollinearity among the predictor variables.
3. Conduct assessment for overdispersion violation in the Poisson regression model.

4. Modelling data using Generalized Poisson regression.
5. Select the best model based on the AIC (Akaike Information Criterion) value.
6. Interpret the best model and create a clustering map based on the significant factors that influence the response variable.

## 4. Results and Discussion

Geographically, the city of Semarang is located between the southern latitude line of 6°50' - 7°10' and the eastern longitude lines of 109°35' - 110°50'. This city is bordered by Demak Regency to the east, Kendal Regency to the west, and Semarang Regency to the south. The Java Sea is located to the north. The area of Semarang is 373.70 km2, or 37,366,836 hectares, with 16 districts and 117 subdistricts. The air temperature in Semarang ranges from 20 to 30 degrees Celsius, with an average temperature of around 27 degrees Celsius. (Semarang City Government, 2023). The geographical conditions mentioned above make the residents of Semarang City vulnerable to dengue fever (DHF) virus exposure. The number of DHF cases in Semarang City is presented in Fig. 1.

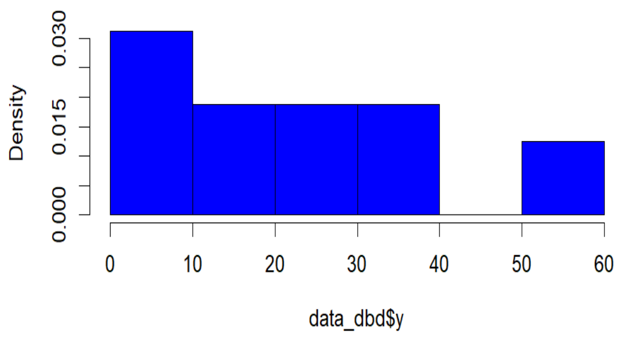


Fig 1. Histogram plot of DHF cases in Semarang City, 2019.

The above Fig. 1 shows a histogram plot of dengue fever cases in Semarang City in 2019. The plot demonstrates a non-symmetric shape, indicating that the number of dengue fever cases in Semarang City in 2019 deviates from a normal distribution. Subsequently, modeling factors influencing the number of dengue fever cases in Semarang City was conducted using a Poisson distribution approach.

### 4.1 Multicollinearity test

The factors used for model development should satisfy the assumption of no multicollinearity. The criteria used to test multicollinearity are the Pearson correlation coefficient and the Variance Inflation Factor (VIF). The relationship or correlation can be observed through the Pearson correlation coefficient. A higher correlation value indicates a stronger relationship between the two variables. The explanatory variables themselves are considered independent variables if they have a VIF value less than 10 [14]. The correlation values between the independent variables are presented in Fig. 2.

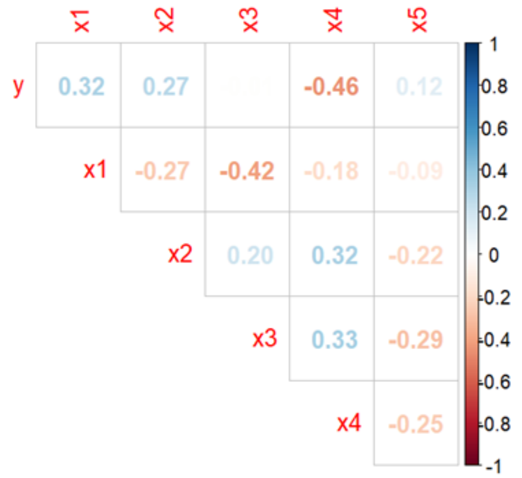


Fig 2. The correlation values between the independent variables.

The cross-correlation between the variables, as observed from Fig. 2, yields correlation values overall less than 0.5. This indicates a condition of independence among the independent variables used for modeling. The next examination is conducted by observing the VIF values of each independent variable. The VIF values are presented in Table 2.

Table 2. The VIF values of each independent variable

| INDICATOR | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ |
|---|---|---|---|---|---|
| VIF | 1.35 | 1.16 | 1.35 | 1.07 | 1.45 |

Based on the VIF values of each independent variable in Table 2, all values are less than 10. Therefore, all independent variables will be included in the modeling process.

### 4.2 Poisson regression model

The data on the number of dengue fever cases in Semarang City in 2019 is derived from a sample with a very low probability of occurrence. Therefore, to determine the factors that influence the number of dengue fever cases in Semarang City during that year, a Poisson regression model were used with maximum likelihood estimation (MLE) of regression parameters and the Newton-Raphson iteration. The estimated parameter results of the Poisson regression model for the number of dengue fever cases in Semarang City, along with the influencing factors, are presented in Table 3.

Table 3. The estimated parameter results of the Poisson regression model

| PARAMETER | ESTIMATE | Z VALUE | Pr(>\|z\|) |
|---|---|---|---|
| (Intercept) | 10.94 | -4.461 | 0.00000815 |
| $X_1$ | 13.94 | 5.573 | 0.000000025 |
| $X_2$ | 38.4 | 6.598 | 0.0000000000416 |
| $X_3$ | 0.00005676 | 3.891 | 0.0000999 |
| $X_4$ | -0.03845 | -6.155 | 0.000000000752 |
| $X_5$ | 0.1946 | 3.551 | 0.000383 |

The modeling of the DHF case count data in Semarang City involving 5 explanatory variables using a Poisson regression model based on the estimated parameter results concludes that all explanatory variables are statistically significant at the 5% significance level and affect the response variable. The equation for the Poisson regression model based on the estimated parameter results is as follows.

$$\hat{\mu} = exp\,(10.94 + 0.1394\,X_1 + 0.3840\,X_2 + 0.00005676\,X_3 - 0.03845\,X_4 + 0.01946\,X_5$$

The Poisson regression model generated will be further evaluated regarding violations of the assumptions of equal mean and variance (equidispersion). Information on the evaluation of the equidispersion assumption is presented in Table 4.

Table 4. The deviance value in a Poisson model

| CRITERIA | DEGREES OF FREEDOM | VALUE |
|---|---|---|
| Deviance | 10 | 58.493 |

The assumption of equidispersion is assessed by dividing the deviance by its degrees of freedom. Table 4 shows a deviance ratio of 5.849. A ratio value greater than 1 indicates a violation of the assumption of overdispersion in the Poisson regression model. The issue of overdispersion that arises in Poisson regression will be addressed by using Generalized Poisson regression.

### 4.3 Generalized poisson regression

According to several studies, the Generalized Poisson regression model has been shown to be better at handling overdispersion compared to the conventional Poisson regression model. Additionally, this model can handle cases of underdispersion, where the data's variation is smaller than expected by the Poisson model. Thus, the Generalized Poisson regression model can also handle cases of underdispersion, where the data's variation is smaller than expected by the Poisson model. The estimated parameter results of the Generalized Poisson Regression model are presented in Table 5.

Table 5. The estimated parameter results of the Generalized Poisson regression model

| PARAMETER | ESTIMATE | Z VALUE | Pr(>\|z\| |
|---|---|---|---|
| (Intercept 1) | -11,02 | NA | NA |
| (Intercept 2) | 0,2766 | 0,935 | 0,349766 |
| $X_1$ | 0,1395 | 2,975 | 0,002933 |
| $X_2$ | 0,4187 | 3,858 | 0,000114 |
| $X_3$ | 0,00005712 | 2,072 | 0,03825 |
| $X_4$ | -0,03698 | -3,379 | 0,000727 |
| $X_5$ | 0,201 | 1,951 | 0,051084 |
| Theta | -54,8178 | | |
| *Deviance* | | | |
| Pearson $\chi^2$ | 24,4036 | | |
| Df | 25 | | |

The estimation of the parameters of the Generalized Poisson regression model based on Table 5 leads to the conclusion that the Generalized Poisson regression model can address the issue of overdispersion in Poisson regression models. This is demonstrated by the Pearson Chi-Square by degrees of freedom ratio, which is 0,976 approaching a value of 1. The explanatory variables that significantly affect the response variable at a significance level of 0.05 are the percentage of larval breeding sites ($X_1$), the number of hospitals ($X_2$), population density ($X_3$), and the number of healthcare workers ($X_4$). The equation for the Generalized Poisson regression model based on the estimated parameters is as follows:

$$\hat{\mu} = exp\,(11.02 + 0.1395\,X_1 + 0.4187\,X_2 + 0.00005712\,X_3 - 0.03698\,X_4$$

The Generalized Poisson Regression model indicates that a 1% increase in the percentage of larval breeding sites ($X_1$) leads to an expected increase in the number of dengue fever cases in Semarang City by a factor of exp(0.1395) = 1.1497, assuming other variables are held constant. This suggests that reducing the larval breeding sites in Semarang City can contribute to a decrease in dengue fever cases.

Furthermore, the coefficient for the number of hospitals ($X_2$) is 0.4187, indicating that a 1% increase in the number of hospitals leads to an expected increase in the number of dengue fever cases in Semarang City by a factor of exp(0.4187) = 1.5199, assuming other variables are held constant.

The coefficient for population density ($X_3$) is 0.00005712, indicating that a 1% increase in population density leads to an expected increase in the number of dengue fever cases in Semarang City by a factor of exp(0.00005712) = 1.000057122, assuming other variables are held constant. This suggests that population density has a minimal impact on the number of dengue fever cases.

The coefficient for the number of healthcare workers ($X_4$) is 0.03698, indicating that a 1% increase in the number of healthcare workers leads to an expected decrease in the number of dengue fever cases in Semarang City by a factor of exp(0.03698) = 1.1037672, assuming other variables are held constant. This suggests that an increase in the number of healthcare workers can contribute to a decrease in dengue fever cases.

### 4.3 Best model evaluation

To determine the best model among a set of models, the Akaike Information Criterion (AIC) can be used. A lower AIC value indicates a better model quality. The AIC values for the two models are presented in Table 6.

Table 6. The AIC values for the two models

| MODEL | AIC |
|---|---|
| Poisson regression model | 145.03 |
| Generalized Poisson regression model | 123.64 |

Based on the consideration of the smallest AIC value, the best model is determined. Table 6 shows that the Generalized Poisson regression model has the smallest AIC value of 123.6355 compared to the Poisson regression model. Therefore, the Generalized Poisson regression model is the best model for modeling the number of dengue fever cases in Semarang City in 2019.

## 5. Conclusion

The investigation into factors influencing Dengue Hemorrhagic Fever (DHF) cases in Semarang City has provided crucial insights through rigorous statistical analysis. The study initially employed a Poisson regression model to scrutinize DHF cases, yet encountered overdispersion issues. Consequently, the Generalized Poisson Regression emerged as an alternative model effectively addressing this concern, evidenced by a Pearson Chi-Square with degrees of freedom ratio close to 1 (0.976).

The findings underscore the significance of several key factors in influencing DHF cases within Semarang City. Notably, the percentage of larval breeding sites ($X_1$), the number of hospitals ($X_2$), population density ($X_3$), and the number of healthcare workers ($X_4$) were identified as influential determinants impacting DHF cases in this area.

The Generalized Poisson Regression model revealed compelling associations between these factors and the incidence of DHF. For instance, an increase in the percentage of larval breeding sites was linked to a corresponding rise in DHF cases. Conversely, a higher count of healthcare workers correlated with a decrease in reported DHF instances.

Furthermore, the study validated the efficacy of the Generalized Poisson Regression model over the conventional Poisson regression approach. This was substantiated by the superior performance of the former, as indicated by a significantly lower Akaike Information Criterion (AIC) value.

In essence, this research presents a robust methodology and statistical model, providing valuable insights into the factors driving DHF cases in Semarang City. The identified influential variables can serve as critical guidelines for policymakers and health authorities in formulating targeted strategies for DHF prevention and control within the region.

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