# Application of Product-Limit and Nelson-Aalen Methods in Health Insurance for Estimating Mean and Variance of Infected Duration of Dengue Fiver

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## Abstract

In health insurance knowing the length of the patient contracting a disease is important, due to the handling and maintenance costs. This paper analyzed the mean and variance estimator duration contracted dengue fever based on data on the number of cases of dengue fever in the Bandung city in January-April 2017. A person suffering from dengue fever symptoms is called Dengue Suspect. This Suspect has 2 opportunities, namely the chance of recovery or positive chance of contracting dengue fever. Opportunities suspect dengue fever to healt was analyzed by using survival model. The standard estimate in survival function was proposed by Kaplan and Meier in 1958, called Product-Limit Estimator. While the probability of suspected dengue fever to be positive contracted dengue is analyzed by using cumulative hazard function based on Nelson-Aalen estimator. Based on the survival function it is found that the time of suspect dengue fever to heal continues to decrease, while suspect dengue fever to become positive contracted dengue fever continues to increase based on cumulative hazard function. From the calculation results obtained average duration of dengue fever is for 8 days after suspect dengue fever, with variance 0.0758. Based on the average estimator and this variance can be used as consideration in the treatment planning and maintenance cost.

## Keywords:
Survival model, Kaplan-Meier, Product-Limit, Nelson-Aalen, dengue fever

## 1. Introduction
Cases of Dengue Fever in Bandung increased. Until December 2016, Bandung Health Department recorded as many as 3,389 cases of dengue fever that occurred throughout Bandung. Efforts from the start of the precautionary measures to the treatment of dengue patients have been done by the government. Treatment of patients generally financing is done through health insurance program (Sukono et al., 2017.a; 2017.b). The problem that often arises is the budget reserved is not sufficient, because one of them is not known exactly how long the patient contracted dengue fever will be treated until healed (Camerron and Trivedi, 2005; Hanif et al., 2015).

To find the solution of the problem, Hanif et al. (2015), conducted an analysis of dengue patients associated with liver dysfunction using survival models. While Kenah (2011), performs endemic data analysis using nonparametric survival model. Meanwhile, Guibert & Planchet (2014), and also Mesike et al. (2012), undertook a nonparametric inference analysis of transition probabilities based on an integral estimator with the Aalen-Johansen model for semi-competing risk data applied to LCT insurance company. Furthermore, Christensen and Kallestrup-Lamb (2012), analyzed the relationship between health insurance coverage and survival of cervical cancer patients.

In 2016, dengue is an Extraordinary Events in the city of Bandung, because of the many positive patients contracted dengue fever since suspected of suffering from dengue fever symptoms. These problems can be analyzed and solved by applying survival model. Based on the above description, this paper discusses the nonparametric model approach of survival function and cumulative hazard function by using Product-Limit and Nelson-Aalen estimators to obtain the average and variance duration of dengue fever in Bandung in January-April 2017. The goal is to get an estimate of the duration of action services for patients with dengue fever.

## 2. Research Method

This section discusses nonparametric estimation methods for data on the number of dengue cases. The discussion covers from: estimation of survival function, estimation of cumulative hazard function, confidential interval for survival models, and estimation of residual life mean**.**

### 2.1 Estimation of Survival Function

The standard estimate of survival functions was proposed by Kaplan and Meier in 1958, called Product-Limit estimators. Defined by Klein & Moeschberger (1997) andYen & Kassim (2013), suppose $X$ random variable time dengue fever outbreak, $x_i$ the duration of the contract dengue fever in individuals $i$, and $n$ the number of data observations. Suppose that the incidence of dengue occurs at different times $D$, that is $t_1 < t_2 < ... < t_D$, and at the time of the incident $t_i$ there $d_i$ events. Suppose, too $Y_i$ states the number of individuals at risk of contracting dengue fever $t_i$. The esstimator of survival function $\hat{S}(x)$ is expressed as follows:

$$\hat{S}(x) = \begin{cases} 1 & , x < x_i \\ \prod_{x_i \le x}\left[1 - \frac{d_i}{Y_i}\right] & , x_i \le x \end{cases} \tag{1}$$

From equation (1) , the estimator of variance of the Product-Limit Adjuster $\hat{\sigma}_S^2(x)$ is expressed as follows:

$$\hat{\sigma}_S^2(x) = \hat{V}\left[\hat{S}(x)\right] = \hat{S}(x)^2 \sum_{x_i \le x} \frac{d_i}{Y_i(Y_i - d_i)} \tag{2}$$

Thus, the standard error of the Product-Limit estimator $\hat{\sigma}_S(x)$ is:

$$\hat{\sigma}_S(x) = \left\{\hat{V}\left[\hat{S}(x)\right]\right\}^{1/2} \tag{3}$$

The Product-Limit estimate gives the right result in estimating survival function for right sensor data.

### 2.2 Estimation of Cumulative Hazard Function

Other estimates of average cumulative hazards that have small sample sizes are better than estimates based on Product-Limit estimators, first proposed by Nelson in 1972 in the context of reliability and then reiterated by Aalen in 1978b. The cumulative hazard function based on the Nelson-Aalen estimator is defined (Klein and Moeschberger, 1997; Rich et al.,2010). Using notations in Section 2.1, The cumulative hazard function based on the Nelson-Aalen estimator is defined as follows:

$$\hat{H}(x) = \begin{cases} 0 & , x \le x_i \\ \sum_{x_i \le x} \frac{d_i}{Y_i} & , x_i \le x \end{cases} \tag{4}$$

While the variance of the Nelson-Aalen estimator is:

$$\sigma_H^2(x) = \sum_{x_i \le x} \frac{d_i}{Y_i^2} \tag{5}$$

### 2.3 Confidential Interval for Survival Models

For $Z_{1-\alpha/2}$ percentile of standard normal distribution, with confidence level $\alpha$ %, the confidence interval given for the survival function according to Borgan and Liestøl in 1990 was (Willem, 2014; Karnon et al., 2009):

– *Linear*

$$\hat{S}(x_0) - Z_{1-\alpha/2}\sigma_S(x_0)\hat{S}(x_0) \le S(x_0) \le \hat{S}(x_0) + Z_{1-\alpha/2}\sigma_S(x_0)\hat{S}(x_0) \tag{6}$$

– *Transformation-Log*

$$\left[\hat{S}(x_0)^{1/\theta}, \hat{S}(x_0)^{\theta}\right],$$

where

$$\theta = \exp\left\{\frac{Z_{1-\alpha/2}\sigma_S(x_0)}{\ln\left[\hat{S}(x_0)\right]}\right\} \tag{7}$$

– *The arcsin square root transformation*

$$\sin^2\left\{\min\left[\frac{\pi}{2}, \arcsin\left(\hat{S}(x_0)^{1/2}\right) - 0.5Z_{1-\alpha/2}\sigma(x_0)\left(\frac{\hat{S}(x_0)}{1-\hat{S}(x_0)}\right)^{1/2}\right]\right\} \le S(x_0) \le \sin^2\left\{\min\left[\frac{\pi}{2}, \arcsin\left(\hat{S}(x_0)^{1/2}\right) + 0.5Z_{1-\alpha/2}\sigma(x_0)\left(\frac{\hat{S}(x_0)}{1-\hat{S}(x_0)}\right)^{1/2}\right]\right\} \tag{8}$$

### 2.4 Estimation of Residual Life Mean

Estimated mean values are limited to intervals $[0,\tau]$, with $\tau$ is the longest observation time, given by (Nasir and Zaidi, 2009; Klein and Moeschberger, 1997):

$$\hat{\mu}_\tau = \int_0^\tau \hat{S}(x)dx \tag{9}$$

While the variance is:

$$\hat{\sigma}_{\mu_\tau}^2(x) = \hat{V}[\hat{\mu}_\tau] = \sum_{i=1}^{D}\left[\int_{x_i}^{\tau}\hat{S}(x)dx\right]^2 \frac{d_i}{Y_i(Y_i - d_i)} \tag{10}$$

Thus, the standard error is:

$$\hat{\sigma}_{\mu_\tau}(x) = \left\{\hat{V}[\hat{\mu}_\tau]\right\}^{1/2} \tag{11}$$

## 3. Result and Discussion

In the results and discussion section, a discussion of object data, survival estimation, and estimated hazard function. Therefore, the discussion begins with the object data problem as follows.

### 3.1 Object Data

In this section we will estimate the survival function and cumulative hazard function for the duration of dengue fever based on data on the number of dengue cases in Bandung in January-April 2017.

Suppose $x_i$ is the duration of the patient contracted dengue fever, $d_i$ is the number of patients who are positively infected with dengue, and $Y_i$ is the number of patients at risk of contracting dengue fever. Data on the number of dmam cases in Bandung in January-April 2017 can be seen in Table 1 follows:

Table 1. Number of dengue cases in Bandung from January to April 2016

| Times ($x_i$) | Number of Cases DB ($d_i$) | Number of Infection Risk DB ($Y_I$) |
|---|---|---|
| 0 | 1 | 1000 |
| 1 | 19 | 999 |
| 2 | 83 | 872 |
| 3 | 67 | 735 |
| 4 | 90 | 618 |
| 5 | 76 | 505 |
| 6 | 66 | 405 |
| 7 | 53 | 325 |
| 8 | 44 | 263 |
| 9 | 46 | 204 |
| 10 | 25 | 153 |
| 11 | 24 | 125 |
| 12 | 19 | 99 |
| 13 | 16 | 78 |
| 14 | 8 | 61 |
| 15 | 11 | 51 |
| 16 | 5 | 40 |
| 17 | 3 | 35 |
| 18 | 3 | 32 |
| 19 | 1 | 29 |
| 20 | 3 | 26 |
| 21 | 2 | 23 |
| 23 | 2 | 21 |
| 30 | 4 | 19 |
| 31 | 1 | 15 |
| 32 | 4 | 13 |
| 33 | 3 | 9 |
| 34 | 1 | 6 |
| 36 | 1 | 5 |
| 42 | 2 | 4 |
| 45 | 1 | 2 |
| 49 | 1 | 1 |

Then we will calculate $\hat{S}(x)$ using equation (1). The next step calculates the variance of $\hat{S}(x)$ using equation (2). The calculation results $\hat{S}(x)$ and $\hat{V}\left[\hat{S}(x)\right]$ for $x_i \le x$ can be seen in Table 2 below:

Table 2. Calculation Results $\hat{S}(x)$ and $\hat{V}\left[\hat{S}(x)\right]$

| Time Event | Estimator *Product-Limit* | Variance | Standard *Error* |
|---|---|---|---|
| $0 \le x < 1$ | 0.9990 | 0.000001 | 0.0010 |
| $1 \le x < 2$ | 0.9800 | 0.000020 | 0.0044 |
| $2 \le x < 3$ | 0.8867 | 0.000111 | 0.0105 |
| $3 \le x < 4$ | 0.8059 | 0.000180 | 0.0134 |
| $4 \le x < 5$ | 0.6885 | 0.000262 | 0.0162 |
| $5 \le x < 6$ | 0.5849 | 0.000309 | 0.0176 |
| $6 \le x < 7$ | 0.4896 | 0.000332 | 0.0182 |
| $7 \le x < 8$ | 0.4097 | 0.000333 | 0.0183 |
| $8 \le x < 9$ | 0.3412 | 0.000320 | 0.0179 |
| $9 \le x < 10$ | 0.2643 | 0.000292 | 0.0171 |
| $10 \le x < 11$ | 0.2211 | 0.000266 | 0.0163 |
| $11 \le x < 12$ | 0.1786 | 0.000235 | 0.0153 |
| $12 \le x < 13$ | 0.1444 | 0.000203 | 0.0143 |
| $13 \le x < 14$ | 0.1147 | 0.000172 | 0.0131 |
| $14 \le x < 15$ | 0.0997 | 0.000154 | 0.0124 |

| | | | |
|---|---|---|---|
| $15 \le x < 16$ | 0.0782 | 0.000128 | 0.0113 |
| $16 \le x < 17$ | 0.0684 | 0.000115 | 0.0107 |
| $17 \le x < 18$ | 0.0626 | 0.000106 | 0.0103 |
| $18 \le x < 19$ | 0.0567 | 0.000098 | 0.0099 |
| $19 \le x < 20$ | 0.0547 | 0.000095 | 0.0097 |
| $20 \le x < 21$ | 0.0484 | 0.000086 | 0.0093 |
| $21 \le x < 23$ | 0.0442 | 0.000080 | 0.0089 |
| $23 \le x < 30$ | 0.0400 | 0.000073 | 0.0086 |
| $30 \le x < 31$ | 0.0316 | 0.000060 | 0.0077 |
| $31 \le x < 32$ | 0.0295 | 0.000056 | 0.0075 |
| $32 \le x < 33$ | 0.0204 | 0.000041 | 0.0064 |
| $33 \le x < 34$ | 0.0136 | 0.000029 | 0.0053 |
| $34 \le x < 36$ | 0.0113 | 0.000024 | 0.0049 |
| $36 \le x < 42$ | 0.0091 | 0.000020 | 0.0044 |
| $42 \le x < 45$ | 0.0045 | 0.000010 | 0.0032 |
| $45 \le x < 49$ | 0.0023 | 0.000005 | 0.0023 |

From Table 2 the plot of the survival function can be seen in Figure 1 bellow:

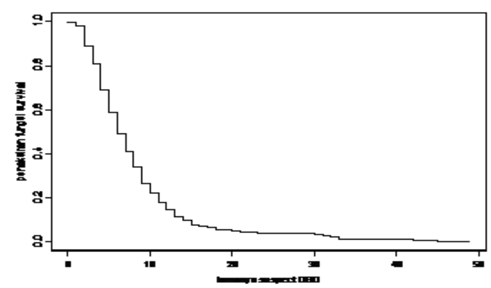

Figure 1. Plot of Survival Function

the time of suspecte patients from Table 2 and Figure 1, it can be seen that the survival function continues to decline, meaning that continues to decline until it becomes positive for dengue fever.

Then we will calculate $\hat{H}(x)$ using equation (4). The next step calculates the variance of $\hat{H}(x)$ using equation (5). The calculation results $\hat{H}(x)$ and $\sigma_H{}^2(x)$ for $x_i \le x$ can be seen in Table 3 below:

Table 3. Calculation Results $\hat{H}(x)$ and $\sigma_H^2(x)$

| Time Event | Estimator *Nelson-Aalen* | Variance | Standard *Error* |
|---|---|---|---|
| $0 \le x < 1$ | 0.0010 | 0.000001 | 0.0010 |
| $1 \le x < 2$ | 0.0200 | 0.000020 | 0.0045 |
| $2 \le x < 3$ | 0.1152 | 0.000129 | 0.0114 |
| $3 \le x < 4$ | 0.2064 | 0.000253 | 0.0159 |
| $4 \le x < 5$ | 0.3520 | 0.000489 | 0.0221 |
| $5 \le x < 6$ | 0.5025 | 0.000787 | 0.0281 |
| $6 \le x < 7$ | 0.6654 | 0.001189 | 0.0345 |
| $7 \le x < 8$ | 0.8285 | 0.001691 | 0.0411 |
| $8 \le x < 9$ | 0.9958 | 0.002327 | 0.0482 |
| $9 \le x < 10$ | 1.2213 | 0.003432 | 0.0586 |
| $10 \le x < 11$ | 1.3847 | 0.004500 | 0.0671 |
| $11 \le x < 12$ | 1.5767 | 0.006036 | 0.0777 |
| $12 \le x < 13$ | 1.7686 | 0.007975 | 0.0893 |
| $13 \le x < 14$ | 1.9738 | 0.010605 | 0.1030 |
| $14 \le x < 15$ | 2.1049 | 0.012755 | 0.1129 |
| $15 \le x < 16$ | 2.3206 | 0.016984 | 0.1303 |

| | | | |
|---|---|---|---|
| $16 \le x < 17$ | 2.4456 | 0.020109 | 0.1418 |
| $17 \le x < 18$ | 2.5313 | 0.022558 | 0.1502 |
| $18 \le x < 19$ | 2.6251 | 0.025488 | 0.1596 |
| $19 \le x < 20$ | 2.6595 | 0.026677 | 0.1633 |
| $20 \le x < 21$ | 2.7749 | 0.031115 | 0.1764 |
| $21 \le x < 23$ | 2.8619 | 0.034895 | 0.1868 |
| $23 \le x < 30$ | 2.9571 | 0.039430 | 0.1986 |
| $30 \le x < 31$ | 3.1676 | 0.050511 | 0.2247 |
| $31 \le x < 32$ | 3.2343 | 0.054955 | 0.2344 |
| $32 \le x < 33$ | 3.5420 | 0.078624 | 0.2804 |
| $33 \le x < 34$ | 3.8753 | 0.115661 | 0.3401 |
| $34 \le x < 36$ | 4.0420 | 0.143439 | 0.3787 |
| $36 \le x < 42$ | 4.2420 | 0.183439 | 0.4283 |
| $42 \le x < 45$ | 4.7420 | 0.308439 | 0.5554 |
| $45 \le x < 49$ | 5.2420 | 0.558439 | 0.7473 |

From Table 3 the plot of the cumulative hazard function can be seen in Figure 2:

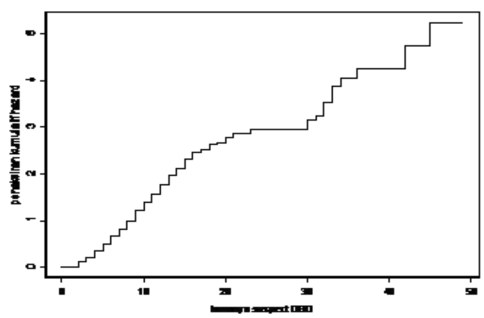

Figure 2. Plot Cumulative hazard function

From Table 3 and Figure 2, it can be seen that the cumulative hazard function continues to increase, meaning that the time of positive patients contracting dengue fever continues to increase.

Then we will calculate the confidence interval based on the value of survival estimation for the duration of the patient with dengue as shown in Table 2. If within 1 week (7 days), the survival function is worth $S(7) = 0.4896$ and variance $0.0182^2$, then:

$$\sigma_S^2(7) = (0.0182/0.4896)^2 = 0.0372^2 .$$

The linear confluence interval of 95% in the first week, based on (6) is:

$$0.4896 \pm 1.96 \times 0.0372 \times 0.4896 = (0.4539, 0.5253)$$

The next step is based on (7), the log conversion transform confidence interval in the first week we obtain:

$$\theta = \exp\left[\frac{1.96 \times 0.0372}{\ln(0.4896)}\right] = 0.9029 .$$

So the interval is:

$$\left(0.4896^{1/0.9029}, 0.4896^{0.9029}\right) = (0.4534, 0.5248).$$

The confound interval of 95% arcsin square root transformation in the first week, based on (8), is $(0.4890, 0.4902)$.

Estimating the average length of contracting dengue fever based on data on the number of dengue cases in the city in January-April 2017 is obtained by calculating $\hat{\mu}_\tau$ using equation (6), with $\tau$ as the longest observation time, which is 49 days, then obtained:

$$\hat{\mu}_\tau = \int_0^{49} \hat{S}(x)dx = 8.1407$$

The next step is to calculate $\hat{V}\left(\hat{\mu}_{\tau}\right)$ using equation (7), for $\tau$ = 49, obtained $\hat{V}\left(\hat{\mu}_{49}\right)$ = 0.0758. From the above calculation results obtained average duration of positive patients contracted dengue fever is after 8 days experiencing symptoms of dengue fever.

## 4. Conclusions

The Product-Limit estimator can be applied to estimate the survival function and cumulative hazard function in calculating the average duration of dengue fever in the city of Bandung from January to April 2016. In addition, the Nelson-Aalen Appraiser can also be applied to estimate the cumulative hazard function. Estimated survival function and cumulative hazard function is obtained by entering data on the number of dmam cases of bloody, so that the calculation results obtained the average duration of dengue fever in the city of Bandung in January to April 2016 is 8 days.

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