The Comparative Software Reliability Cost Model based on Generalized Goel-NHPP Model

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Abstract. In this study, reliability software cost model considering hazard function parameter based on life distribution from the process of software product testing was studied. The cost comparison problem of generalized Goel-Okumoto reliability growth model that is widely used in the field of reliability presented. For analysis of software cost model considering hazard function, in this research, software developers to identify software development cost some extent be able to help is considered.

Keywords: Cost Model, Generalized Goel-NHPP Model.

1 Introduction

In this field, enhanced non-homogenous Poisson Process model was presented by Gokhale and Trivedi [1]. Goel and Okumoto [2] proposed an exponential software reliability models. In this model, the total number of defects have S-shaped or exponential-shaped with a mean value function was used. Pham and Zhang [3] testing measured coverage, the stability of model, with software stability can be evaluated, presented. In addition, Shin and Kim [4] were studied about the comparative study of software optimal release time based on NHPP software reliability model using exponential and log shaped type for the perspective of learning effect.

In this paper, we generalize widely used in the field of software reliability and software development cost Goel-NHPP growth models proposed trust model for comparison.

2 Software development cost using Goel-NHPP reliability model
The generalized Goel-NHPP the software reliability models are widely used in software reliability field. The intensity and mean value function of the model is known, as follows: [5].

$$\lambda(t) = \theta \beta e^{\theta \beta c t} \exp\left(-\beta e^{\theta \beta c t}\right) \quad (\theta > 0, \beta > 0, c > 0), \quad m(t) = \theta \left(1 - \exp\left(-\beta e^{\theta \beta c t}\right)\right)$$ (1)

Note. $t \in (0, \infty)$, $\beta$ and $c$ refer to the shape parameter. In addition, using Eq. (1), the hazard function is derived as follows:

$$h(t) = \frac{\lambda(t)}{m(t)} = \beta c e^{\theta \beta c t}$$ (2)

The hazard functions for each model are summarized in Figure 1. If this Figure is the shape parameter $c = 1$, the basic model in this field, that is, Goel-Okumoto model can be. Thus, hazard function of Goel-Okumoto model is independent of the time $t$ as having a constant pattern. The case of shape parameter less than 1 ($c = 0.3$) have reduction pattern and greater than 1 ($c = 1.3$) shows a growth pattern.

Fig. 1. Hazard function of each model

The likelihood function, using Eq. (1), is as follows:

$$L_{\text{NHPP}}(x, \Theta) = \prod_{i=1}^{n} \exp\left(-\theta e^{\beta x_i} + \beta \sum_{j=1}^{n} x_j e^{-\beta x_j} - \theta (1 - e^{-\beta x_j})\right)$$ (3)

Note. $x = (x_1, x_2, x_3, \ldots, x_n)$, $\Theta$ is parameter space.

The log-likelihood function to maximum likelihood estimation (MLE) can be derived as follows using Eq. (3).

$$\ln L_{\text{NHPP}}(x, \Theta) = n \ln \theta + n \ln \beta + n \ln c + (c - 1) \sum_{i=1}^{n} \ln x_i - \beta \sum_{i=1}^{n} x_i e^{-\beta x_i} - \theta (1 - e^{-\beta x_j})$$ (4)

Using log-likelihood function from Eq. (4), $\hat{\theta}_{\text{MLE}}$ and $\hat{\beta}_{\text{MLE}}$ can be obtained as the solutions of the following equations.
Using Eq. (1), the reliability of the generalized Goel-NHPP model can be derived as follows:

\[
\hat{R}(t | x_n) = \exp\left[-\theta(1 - e^{-\beta t})^c + \hat{\theta}(1 - e^{-\beta t})^c \right]
\] (6)

4 Software failure data and cost analysis

The data set of software faults analyzed here was obtained from literature [6]. The result of parameter estimation has been summarized in Table 1.

<table>
<thead>
<tr>
<th>Shape Parameter</th>
<th>Maximum likelihood estimation (MLE)</th>
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<tbody>
<tr>
<td>(c = 0.3)</td>
<td>(\hat{\theta}<em>{MLE} = 59.2012) (\hat{\beta}</em>{MLE} = 2.601 \times 10^{-1})</td>
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<tr>
<td>(c = 1.0)</td>
<td>(\hat{\theta}<em>{MLE} = 33.4092) (\hat{\beta}</em>{MLE} = 3.089 \times 10^{-1})</td>
</tr>
<tr>
<td>(c = 1.3)</td>
<td>(\hat{\theta}<em>{MLE} = 30.1191) (\hat{\beta}</em>{MLE} = 2.756 \times 10^{-1})</td>
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Reliability of each model is summarized in Figure 2. In this Figure, the reliability of Goel-Okumoto model has a non-increasing pattern. However, if the shape parameter is greater than 1(\(c = 1.3\)), it can be seen that reliability is increased compared with the other comparison models. In this study, it is to analyze the cost curve by the following assumptions:

(Assuming) A, \(E_1 = 2S, C_2 = 0.98S, C_3 = 0.05S, C_4 = 5S, t' = 2\),

(Assuming) B, \(E_1 = 2S, C_2 = 0.98S, C_3 = 0.05S, C_4 = 5S, t' = 15\).
Software reliability growth model can estimate the cost of the optimal release time and testing software, so more efficient model is to be emitted can increase the benefit to reduce the cost of test software. Therefore, for the software release time side, case of the shape parameter is less than 1, in (Assumption) A, is faster than cases greater and Goel-Okumoto model as shown in Figure 3. However, from the cost side, case of greater than 1(shape parameter) is found to be relatively economical compared to other comparison models [7]. Other conditions are similar to the case after it is released, the operating system software and software in the time and a greater (Assumption) B which can maintain the shape parameter compared to the other is greater than 1, the software release time and compared to the other case appearing in cost efficiently as shown in Figure 4.

References