# DEVELOPMENT OF EXCEL-BASED RELIABILITY MODEL FOR SYSTEMS WITH INCREASING/DECREASING FAILURE RATES

by

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# CERTIFICATION OF APPROVAL

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**By**

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**A project dissertation submitted to the**

**Mechanical Engineering Programme**

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**BACHELOR OF ENGINEERING (Hons.)**

**(MECHANICAL ENGINEERING)**

**Approved by,**

_____

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2013

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Hamdan Bin Patthi

## ABSTRACT

Reliability is the probability that a system, component, or device will perform without failure for a specified period of time under specified operating conditions. The objective of this project is to develop excel-based reliability model for systems with increasing and decreasing failure rates. There are several method used to perform the excel-based reliability model for systems such as the analytical method,. Crow-AMSAA method, Maximum Likelihood method and etc. Microsoft Excel is becoming more applied in the industry sector as it is the most familiar. After all the problems have been analyzed and defined, the available data gathered and model development must be conducted for further research. some more specific models was proposed which assume specific forms for the shape of the curve and the simpler models in most widespread use are based on an exponential 'learning curve'. The first, and well known of these is due to Duane. Plots or Crow/AMSAA Plots. The technique involves plotting most commonly cumulative failures Vs cumulative time on log-log scale with the resulting straight lines' slope indicating improving. Ways to solve reliability model for systems with increasing or decreasing failure rates is by focusing on the simulation, graphical and analytical method. Crow AMSAA is often used on systems when the usage is measured on a continuous scale. The main application is also for high reliability, huge number of trials and one-shot items. The Maximum likelihood estimation is a totally an analytic maximization procedure approach. It applies within every form of censored or multicensored data, and it is even possible to be used the technique across several stress cells and estimate acceleration model parameters at the same time as life distribution parameters. Lastly, Weibull distribution is the most popular statistical distribution among reliability engineers it can fit all other distribution by changing the parameters. Both Weibull++ Software and Excel Microsoft Software is used to compare the results obtained ( in Fig 4 and Fig 5). The results include the Plot Failure Vs Cumulative on log-log. The toolkit developed in Excel Microsoft Software can finally be used to predict future failures by estimating the parameters needed that can also be found the same parameters in the Weibull++ that can be a great achievement in software history.

# ACKNOWLEDGEMENT

All the success and praises to Allah who has  given the author all the strength and motivation needed to complete this brilliant project within the limited period of time. Special thanks also awarded by the author to his forever beloved Supervisor Dr. Masdi Bin Muhammad who had been the man behind all the spectacular success and endlessly gave him more than enough support that he could never repay needed in designing this project.

A happy and big thanks also to the graduate assistant and also to his colleagues in Universiti Teknologi PETRONAS (UTP) that gave him a lot of support and endless ideas which basically contributed to the development of the project.

Finally, special thanks and biggest gratitude  to the authors parents and also Universiti Teknologi PETRONAS (UTP) whom always will be loved and  engraved deeply in the heart of the author.

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLE

# CHAPTER 1

# INTRODUCTION

## 1.1     Background of Study

Reliability is the probability that a system, component, or device will perform without failure for a specified period of time under specified operating conditions. George E.Dieter, Linda C. Schmidt (2013).The importance of reduction of  the likelihood or frequency of failures must be focused by identify and make better improvements on the root cause of failure  and to find alternatives to handle failure that will occur and finally to make data analysis on the reliability data. If an effective reliability  system could be reached then reduction of the overall cost can be made efficiently.

There are some methods used to perform the development of excel-based reliability model for systems with increasing/decreasing failure rates using analytical methods such as Crow-AMSAA method and Maximum likelihood method. The Maximum likelihood estimation is a totally an analytic maximization procedure approach. It applies within every form of censored or multicensored data, and it is even possible to be used the technique across several stress cells and estimate acceleration model parameters at the same time as life distribution parameters. Moreover, MLE's and Likelihood Functions generally have very desirable large sample properties such that they becomes unbiased minimum variance estimators as the sample size increases, have approximate   normal distributions and approximate sample variances that can be calculated and used to generate confidence bounds. Likelihood functions can be used to test hypotheses about models and parameters which will be useful in making system modelling.

Crow-AMSAA method is often used on systems when the usage is measured on a continuous scale. The main application is also for high reliability, huge number of trials and one-shot items. The test programs are normally made on a phase by phase basis. The fundamental understanding is that the Crow-AMSAA model is intended for tracking the reliability within a test phase and not across test phases.

3 basic ways in which the pattern of failures can change with time for non-repairable items. The particular hazard rate may be decreasing, increasing or constant as shown in fig.1.1. For repairable items, the rate of occurance of failure can also vary with time. This particular pattern can also be illustrated using bathtub curves but with hazard rate plotted against age.
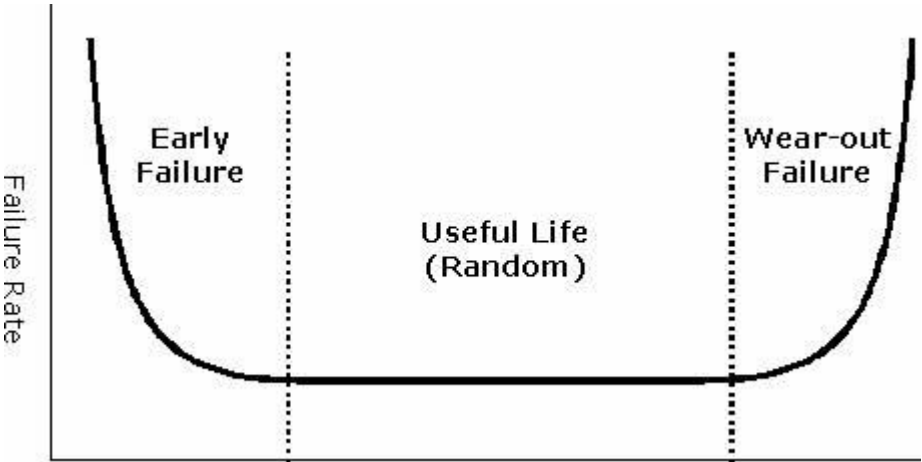


Fig.1 the bathtub curve

## 1.2    Problem statement

In order to develop a better solution for excel-based reliability model for systems with increasing or decreasing failure rates, Crow AMSAA method and maximum likelihood method are two of the best ways to perform  an easier and affordable system. A lot of surveys and analysis can be made to make sure reliability model for systems can detect failures efficiently.

Nowadays, there are a lot of software that can perform Crow AMSAA method such as WinSMITH Visual Software and ReliaSoft's RGA software, but most of these type of software is not easily accessible to any company. Thus, Microsoft Excel is becoming more popular in terms of usage nowadays because the software is applied widely in the industry sector as it is the most familiar software tool to almost every company in the world for its application. It can be used as a tool for performing multiples of simulation which saves costs which is easy for basic and advance learning.

Big part of the society expects better planning to achieve success and rejects abnormal $Risks in using unfamiliar software.

## 1.3    Objective

The objective of this project is to develop excel-based reliability model for systems with increasing and decreasing failure rates based on Crow-AMSAA method.

## 1.4    Scope of Study

The scope of study relates to the development of excel-based reliability model for systems with increasing and decreasing failure rates which uses the  Reliability theory by CROW AMSAA method. This research project will find the increasing and decreasing failure rates in the bathtub curves  that identifies whether there is an improvement or degradation by calculating the time interval for next failure of the reliability model system.  For this project, Microsoft Excel is used for data storage and computer simulation.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1     Reliability theory

George E.Dieter, Linda C. Schmidt (2013) stated that "Reliability is the probability that a system, component, or device will perform without failure for a specified period of time under specified operating conditions". The discipline of reliability engineering generally is a study of the causes, distribution and prediction of failure . If R(t) is the reliability with respect to time t, then F(t) is the unreliability(probability of failure) in the same time t. Since failure and nonfailure are mutually exclusive events,

$$R(t) + F(t) = 1 \tag{14.13}$$

The reliability theory statement is also agreed by Patrick (2012) "Reliability is the probability of an item will perform a required function without failure under stated conditions for a stated period of time" which shows that it is vital to prevent or to reduce the likelihood or frequency of failures, to identify and improve the cause of failure that usually occur, to find ways to handling with failure that will be occur and lastly to analyzing reliability data. If found the reliability of the system is very efficient then the overall cost will also be reduced. [13]

## 2.2     Reliability Growth models

John Davidson,(1994) said that some more specific models was proposed which assume specific forms for the shape of the curve and the simpler models in most widespread use are based on an exponential 'learning curve'. The first, and well known of these is due to Duane. It was derived empirically from observation of the reliability improvements patterns of a number of electronic and mechanical systems.[16] This is basically for the development of AMSAA model which can be differently express the basic logic model as Duane and other more advanced models.

The AMSAA model assumes that the failure are the results of a NHPP which shows that the number of failures in specified time intervals have a Poisson distribution but Failure Rate is not constant. The object of all these models os to quantify the rate of reduction of Failure Rate, and to predict the further development effort needed to meet specific targets.[16]

John Davidson,(1994) works was also agreed by Nigel Comerford(2005) technical papers which states that the Reliability Growth Plots have a variety of names, such as Duane Plots, Crow Plots or Crow/AMSAA Plots. The technique involves plotting most commonly cumulative failures Vs cumulative time on log-log scale with the resulting straight lines' slope indicating improving , deteriorating or constant reliability.[17] It is important to search for beta values with the basic conditions to show the trend of failure rate in graphical methods. This method which handles mixed failure modes can forecast future failures.

## 2.3    Methods of Excel-based reliability model for systems with increasing and decreasing failure rates.

Ways to solve reliability model for systems with increasing or decreasing failure rates is by focusing on the simulation, graphical and analytical method. The analytical approach which applies such mathematical models for formal modelling of systems had been used which enable analysis for future patterns of behaviours of the system. Nowadays, computer simulation had played the most important role of making simulation model because of the low cost ,accuracy and the validity of the simulation model. This make it easier for industry to do their projects that saves time, energy, costs and prevents higher risks without confronting expensive and dangerous experiments that needs lots of materials.

Crow AMSAA method will be the best to be used for making simulation on discrete system. The Crow-AMSAA model is designed for tracking the reliability within a test phase and not across test phases.

## 2.4    Crow-AMSAA and its application

Crow AMSAA is often used on systems when the usage is measured on a continuous scale. The main application is also for high reliability, huge number of trials and one-shot items. The test programs are normally made on a phase by phase basis. The fundamental understanding is that the Crow-AMSAA model is intended for tracking the reliability within a test phase and not across test phases. [1]Crow AMSAA method applies the working principles of finding the time between failure data (TBF) by creating the $\beta$ slope which is in the log summation of failure vs log summation of time graph. Slope $\beta$ is estimated by using maximum likelihood method. This is vital to detect for increasing or decreasing failure rates for reliability model for systems which will be calculated for predictions of every time interval for the next failure. Crow-AMSAA model is an empirical relationship which will further into equivalent to a non-homogeneous Poisson process (N.H.P.P.) model which will also involve a Weibull intensity function. Furthermore, the focus on the test phases which is within a reliability program can become equal or unequal length. Thus the Crow-AMSAA model is focusing on the calculations of the reliability growth which is within a specific phase.

In "Reliability Analysis for Complex, Repairable Systems" (1974), Dr. Larry H. Crow noted that the Duane model could be stochastically represented as a Weibull process, allowing for statistical procedures to be used in the application of this model in reliability growth. This statistical extension became what is known as the Crow-AMSAA (NHPP) model. This method was first developed at the U.S. Army Materiel Systems Analysis Activity (AMSAA). It is frequently used on systems when usage is measured on a continuous scale. It can also be applied for the analysis of one shot items when there is high reliability and large number of trials.

Test programs are generally conducted on a phase by phase basis. The Crow-AMSAA model is designed for tracking the reliability within a test phase and not across test phases. A development testing program may consist of several separate test phases. If corrective actions are introduced during a particular test phase then this type of testing and the associated data are appropriate for analysis by the Crow-AMSAA model. The

model analyzes the reliability growth progress within each test phase and can aid in determining the following:

- Reliability of the configuration currently on test
- Reliability of the configuration on test at the end of the test phase
- Expected reliability if the test time for the phase is extended
- Growth rate
- Confidence intervals
- Applicable goodness-of-fit tests

## 2.5    Parameter Estimation Using Maximum Likelihood

Another method that will be used besides Crow AMSAA is the Maximum likelihood method. The method starts by making estimation using mathematical expression of the Likelihood Function of a sample data. likelihood set of data is the probability of obtaining that particular set of data, which is given its chosen probability distributed model.

The Maximum likelihood estimation is a totally an analytic maximization procedure approach. It applies within every form of censored or multicensored data, and it is even possible to be used the technique across several stress cells and estimate acceleration model parameters at the same time as life distribution parameters. Moreover, MLE's and Likelihood Functions generally have very desirable large sample properties such that they becomes unbiased minimum variance estimators as the sample size increases, have approximate normal distributions and approximate sample variances that can be calculated and used to generate confidence bounds. Likelihood functions can be used to test hypotheses about models and parameters

The method of maximum likelihood provides a basis for many of the techniques and methods discussed in this course. The reasons are:

- The method has a good intuitive foundation. The underlying concept is that the best estimate of a parameter is that giving the highest probability that the observed set of measurements will be obtained.

- The least-squares method and various approaches to combining errors or calculating weighted averages, etc., can be derived or justified in terms of the maximum likelihood approach.

- The method is of sufficient generality that most problems are amenable to a straightforward application of this method, even in cases where other techniques become difficult. Inelegant but conceptually simple approaches often provide useful results where there is no easy alternative. [3]

## 2.6    Type of distribution

Crow-AMSAA method which uses incredible mathematical modelling and statistical capabilities in the Excel Microsoft Software, the data will be entered into each and every cell in the Excel based on the failure time distribution either it is lognormal, normal, weibull distribution or exponential.

The type of distribution that is used and familiar nowadays are the Normal or Gaussian distribution, which it is symmetric and the pattern occurs in many natural phenomena for example temperature, rain quantity and so much more, it define the mean o expected value and a standard variation to express the variation about the mean. While lognormal distribution is based on normal distribution although it is not symmetric, but it has range of shapes and it does not have normal distribution's disadvantage of extending below zero.

About the uniform distribution, all the values of chance of occurring and it simply defines the minimum and maximum. For exponential distribution, it show that the hazard rate constant. Lastly, Weibull distribution is the most popular statistical distribution among reliability engineers it can fit all other distribution by changing the parameters. [13]

Table 1: Excel expressions for time to failure for various distributions of interest in reliability

| Distribution | PDF or f(t) | Excel Expression for time to failure |
|---|---|---|
| Exponential | $\exp(-\lambda t)$ | - LN [RAND()] / $\lambda$<br>$\lambda$ = failure rate |
| Weibull | $\dfrac{\beta}{\alpha}\left(\dfrac{t}{\alpha}\right)^{\beta-1}\exp\left\{-\left(\dfrac{t}{\alpha}\right)^{\beta}\right\}$ | $\alpha\{$-LN(1-RAND())$\}$^(1/$\beta$)<br>$\alpha$ = scale parameter, $\beta$ = shape parameter |
| Normal | $\dfrac{1}{\sigma\sqrt{2\pi}}\exp\left\{-\dfrac{1}{2}\left(\dfrac{t-\mu}{\sigma}\right)^{2}\right\}$ | NORMINV(RAND(), $\mu$, $\sigma$)<br>$\mu$ = mean, $\sigma$ = variance |
| Uniform | 1/T | T x RAND()<br>T = max time |
| Lognormal | $\dfrac{1}{\sigma t\sqrt{2\pi}}\exp\left\{-\dfrac{1}{2}\left(\dfrac{\ln t-\mu}{\sigma}\right)^{2}\right\}$ | LOGINV(RAND(), $\mu$, $\sigma$)<br>$\mu$ = mean, $\sigma$ = variance |

# CHAPTER 3

# Methodology

## 3.1 Research Methodology

```
          ┌─────────────────────────────┐
          │       Tiltle selection      │
          └─────────────────────────────┘
                        │
          ┌─────────────────────────────┐
          │   Preliminary Research work │
          └─────────────────────────────┘
                        │
          ┌─────────────────────────────┐
          │      Problem definition     │
          └─────────────────────────────┘
                        │
          ┌─────────────────────────────┐
          │        Data gathering       │
          └─────────────────────────────┘
                        │
          ┌─────────────────────────────┐
          │      Literature review      │
          └─────────────────────────────┘
                        │
          ┌─────────────────────────────┐
          │         Data analysis       │
          └─────────────────────────────┘
                        │
          ┌─────────────────────────────┐
          │      Model development      │
          └─────────────────────────────┘
                        │
          ┌─────────────────────────────┐
          │       Model validation      │
          └─────────────────────────────┘
                        │
         No           ◇ Accepted ◇
                        │
                       Yes
          ┌─────────────────────────────┐
          │            Report           │
          └─────────────────────────────┘
```

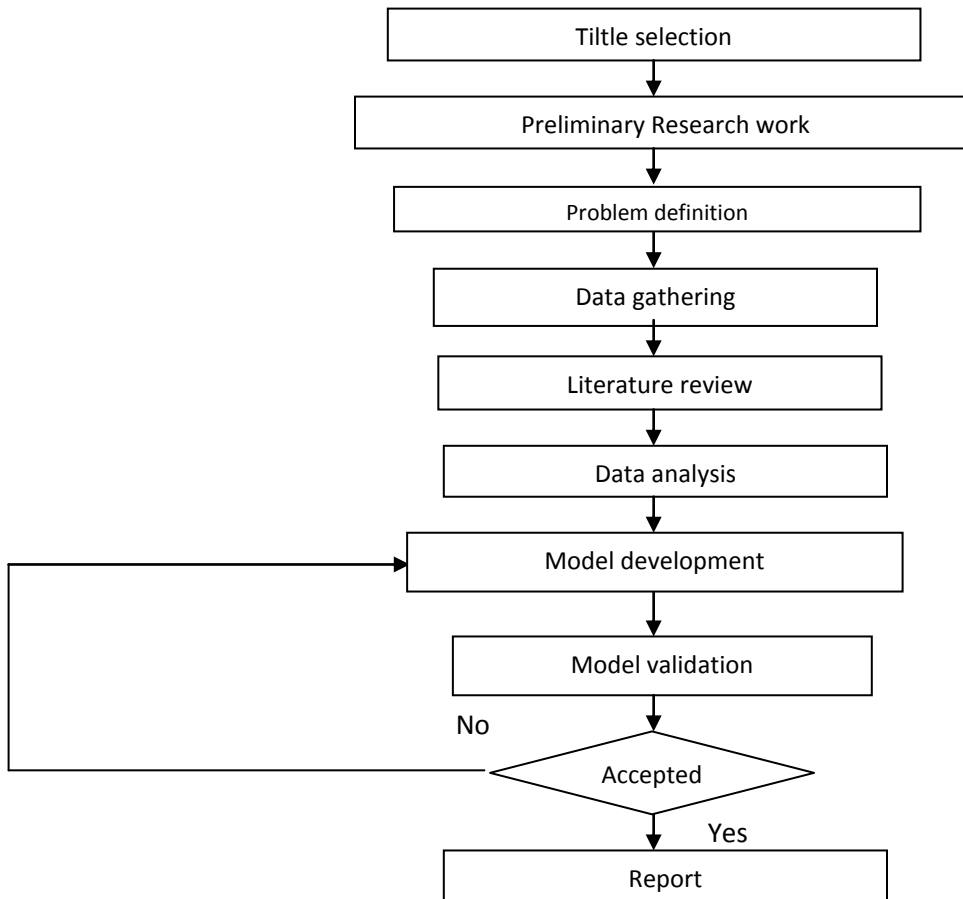*Fig 2 : Flowchart of research methodology*

### 3.1.1 Title Selection

Based on the titles that were given by the coordinator, the best title was selected from the 3 options for the students to choose in the E-Learning. The title chose was mostly based on today's scenario which includes solution to problems faced by the industry and also towards a better future to the society.

### 3.1.2 Preliminary Research Work

Understanding of the title selected was mostly made by reading from varies resources and also discussion from meeting's with the Supervisor in Charge. The supervisor also gives better perspective of explanation towards the better understanding of the project topic that will assist in helping to make future research. This includes the understanding of the method and research work involved that will help was done to advance with the work.

### 3.1.3 Problem Definition

The project focus was mostly related towards the usage of the method which is still usage involvement towards solving related problems for excel-based reliability model analysis systems. This is such that it can be used as an alternative for reliability analysis systems in the future.

### 3.1.4 Data Gathering

The search for references were made for the data gathering. Most reference were found by going to the library to find books, journals, articles related and meeting with the Supervisor for information based on previous research. For atleast 20 references were needed in different resources. This research data gathering will be included in the literature review for advance research in the future.

### 3.1.5 Literature Review

Literature review is gathered from the research data gathering from journals, news papers, books, internet, articles and etc.

### 3.1.6 Data Analysis

Data analysis is made to understand the data which is gathered to build strong ideas of the data gathered to make future research easier and efficiently.

### 3.1.7 Model Development

The development of model is made by deriving using the Crow-AMSAA method that will be used all the formula related to form the system using Excel Microsoft Software.

### 3.1.8 Model Validation

Based on computer simulation and analytical method, the results will show whether the model can be used or not into the new system.

### 3.1.9 Report

The report writing will be done as soon as the project starts until the end of the next semester.

## 3.2 Model Development Methodology

```
                    ┌──────────┐
                    │  Start   │
                    └────┬─────┘
                         │
              ┌──────────▼──────────┐
              │  Time to Failure Xn │
              └──────────┬──────────┘
                         │
              ┌──────────▼──────────┐
              │    Test for trend   │
              └──────────┬──────────┘
                         │
                    ◇ Trend ◇ ──No──► ┌─────────────────────┐
                         │             │ Distribution Fitting │
                        Yes            └──────────┬──────────┘
                         │                        │
 ┌───────────────────────────────┐    ┌──────────▼──────────┐
 │ Non-Homogeneous Poisson Process│    │  Estimate Parameter │
 │ (NHPP)                          │    └──────────┬──────────┘
 └───────────────┬────────────────┘               │
 ┌───────────────▼────────────────┐    ┌──────────▼──────────┐
 │ Plot Failure Vs Cumulative Time │    │ Reliability Prediction│
 │ on Log-log                      │    └──────────┬──────────┘
 └───────────────┬────────────────┘               │
 ┌───────────────▼────────────────┐               │
 │       Estimate λ and β          │               │
 └───────────────┬────────────────┘               │
 ┌───────────────▼────────────────┐               │
 │ Maximum Likelihood Estimation   │               │
 │ (MLE)                           │               │
 └───────────────┬────────────────┘               │
 ┌───────────────▼────────────────┐               │
 │     Prediction of Failure       │◄──────────────┘
 └───────────────┬────────────────┘
                 │
            ┌────▼─────┐
            │   End    │
            └──────────┘
```
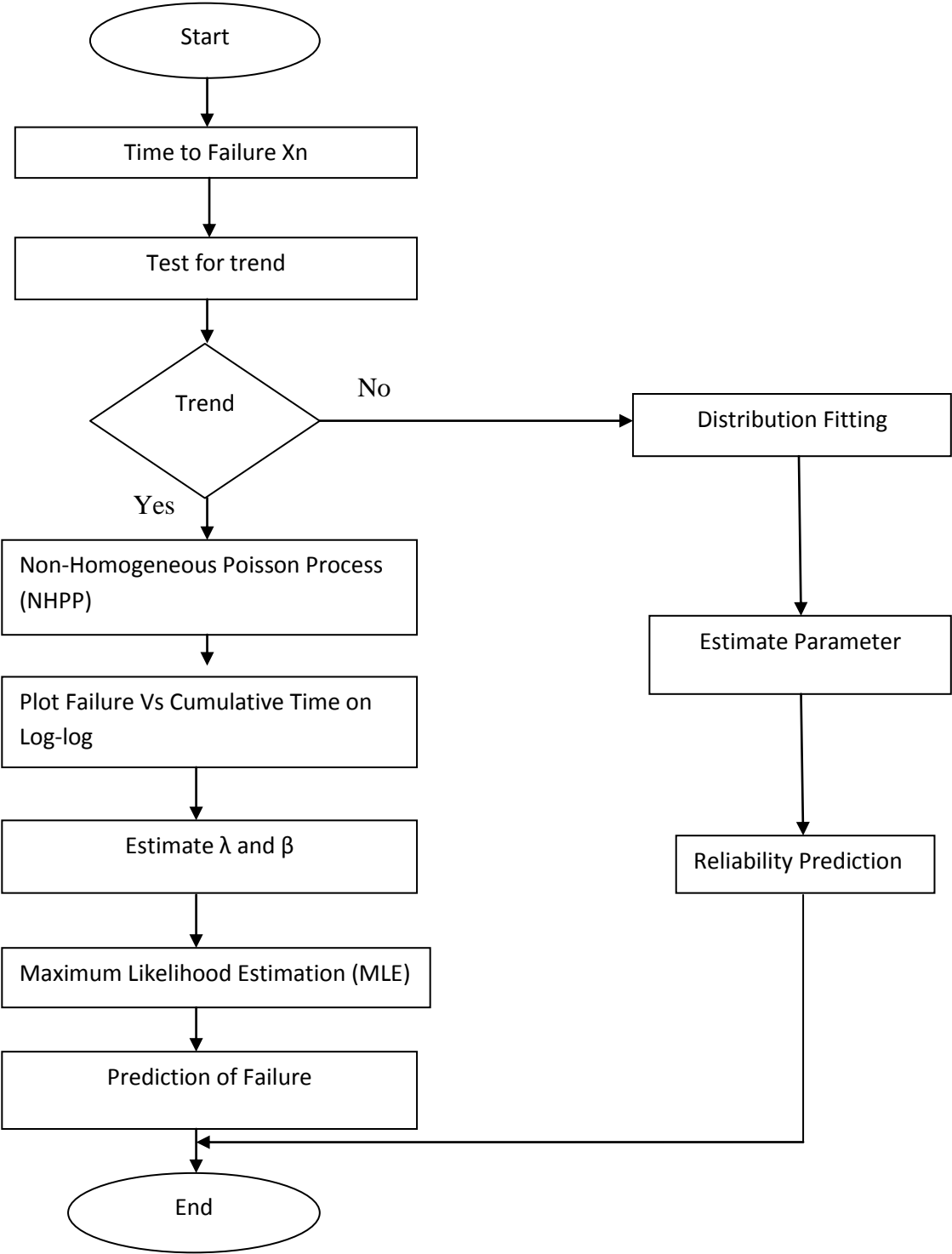
Fig 3.: Flowchart of model development

### 3.2.1. Time to failure Xn;

In this first part in the methodology, the cumulative time parameters for the time to failure is determined from the data set for the Crow/AMSAA Reliability Growth Plots. It is important to determine and receive the cumulative time to failure data so that it can be used for the test for trend.

### 3.2.2. Test for Trend

Test for trend is determined in this methodology by using 2 major methods which can determine whether the set of data is decreasing, increasing or even no trend in failure by making the Plot Failure vs Cumulative Time on log-log by using either the distributing fitting or Non-Homogeneous Poisson Process.

### 3.2.3.1  If Trend

### 3.2.3.1.1  NHPP

If there is a trend, the Prediction of Failure can be made through the Non-Homogeneous Poisson Process which mathematical models were involved. Such mathematical model used are the intensity function $\rho(t)$, the log of the cumulative failure events n(t), natural logarithms Lnn(t), the cumulative failure rate C(t), The $\lambda$ and $\beta$ values is gained from the Plot Failure Vs Cumulative Time on log-log.

### 3.2.3.1.2.  Plot Failure Vs Cumulative Time on log-log.

This Plot Failure Vs Cumulative Time on log-log is accomplished by using  Excel Microsoft Software. This step is made in the methodology so that it can be compared the results gained with the Weibull++ Software.

### 3.2.3.1.3.  Estimate $\lambda$ and $\beta$.

The values for $\lambda$ and $\beta$ can be determined from the Failure vs Cumulative Time on log-log plot. These values then can be included in the mathematical models to be used in the Crow-AMSAA method.

### 3.2.3.1.4. Maximum Likelihood Method

For futher developments, Maximum Likelihood Estimates is useful in determining lambda and beta from which p(t) and C(t) can be derived. This method is used with time and failure terminated data or interval and group data. It describes an unbiased method for determining the parameters suitable for use when the individual failure times are known. Paul Barringer investigated the accuracy of all three methods, Rank Regression,

MLE, and IEC, with IEC being the best bearing in mind it requires the failure times to be known. However it should be noted that at least 20 data points are required for any method to work.

\

### 3.2.3.1.5. Prediction of Failure

Prediction of failure can be finally made  as the last remaining step for the Crow-AMSAA method. From the calculations made in the NHPP, parameters and trend tests received from the Plot Failure Vs Cummulative Time on Log-log and MLE, the predictions of failure in the future is easier to analyze.

### 3.2.3.2.  If no Trend.

### 3.2.3.2.1.  Distribution Fitting

The distribution fitting involves the usage of Weibull++ software and exponential lognormal, where the plot Failure Vs cumulative time on log-log where the shape of the graph can be determined whether the data has a decreasing failure rate trend or increasing failure rate trend or even no trend.

### 3.2.3.2.2.  Estimate parameter

From the plot of failure vs cumulative time on log-log, the parameters can be estimated from the Weibull++ software for the $\lambda$ and $\beta$ values which is easy to analyze and important for the reliability prediction process.

### 3.2.3.2.3.  Reliability Prediction

From the values of the $\lambda$ and $\beta$ that had been estimated, the reliability prediction can be made from the trend test of the Plot Failure vs Cummulative time from the Weibull++ Software which shows all the needed parameters including $\lambda$ and $\beta$ values.
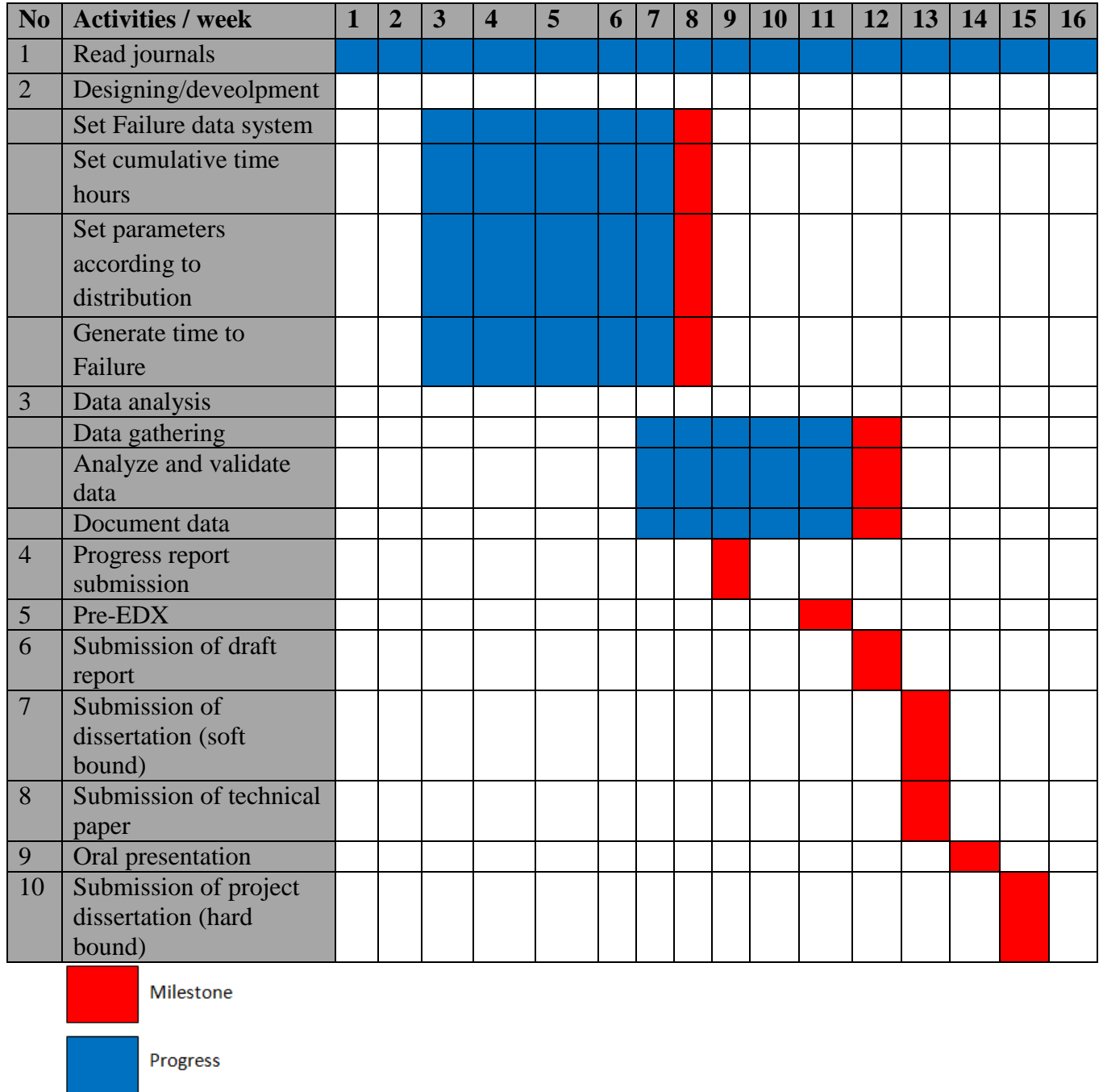
## 3.3 Gantt Chart FYP I

Fig 4 shows the the Gantt Chart used for FYP I (January 2013 – May 2013)

| No | Activities / week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Topic Selection | ▣ | ▮ | | | | | | | | | | | | | | |
| 2 | FYP Briefing | | | ▮ | | | | | | | | | | | | | |
| 3 | Basic Research | | | | ▣ | ▣ | | | | | | | | | | | |
| 4 | Extended Proposal Submission | | | ▣ | ▣ | ▣ | ▮ | | | | | | | | | | |
| 5 | Studies on Crow-AMSAA Method System | | | | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ |
| 6 | Maximum Likelihood Method | | | | | | | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ | ▣ |
| 7 | Proposal Defense | | | | | | | ▣ | ▣ | ▮ | | | | | | | |
| 8 | Oral Presentation | | | | | | | ▣ | ▣ | ▮ | | | | | | | |
| 9 | Studies on Excel user interface | | | | | | | | | | ▣ | ▣ | ▣ | ▣ | ▣ | | |
| 10 | Interim Draft Report Submission | | | | | | | | | | | ▣ | ▣ | ▣ | | | |
| 11 | Interim Report Submission | | | | | | | | | | | | | ▣ | ▮ | ▮ | ▮ |
| | | | | | | | | | | | | | | | | | |

▮ Milestone

▣ Progress
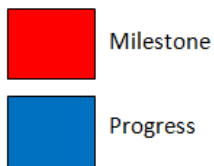
### 3.4 Gantt Chart FYP II

Fig 5 :shows the the Gantt Chart used for FYP II (May 2013 – September 2013)

| No | Activities / week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Read journals | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B |
| 2 | Designing/deveolpment | | | | | | | | | | | | | | | | |
| | Set Failure data system | | | B | B | B | B | B | R | | | | | | | | |
| | Set cumulative time hours | | | B | B | B | B | B | R | | | | | | | | |
| | Set parameters according to distribution | | | B | B | B | B | B | R | | | | | | | | |
| | Generate time to Failure | | | B | B | B | B | B | R | | | | | | | | |
| 3 | Data analysis | | | | | | | | | | | | | | | | |
| | Data gathering | | | | | | | B | B | B | B | B | R | | | | |
| | Analyze and validate data | | | | | | | B | B | B | B | B | R | | | | |
| | Document data | | | | | | | B | B | B | B | B | R | | | | |
| 4 | Progress report submission | | | | | | | | | R | | | | | | | |
| 5 | Pre-EDX | | | | | | | | | | | R | | | | | |
| 6 | Submission of draft report | | | | | | | | | | | | R | | | | |
| 7 | Submission of dissertation (soft bound) | | | | | | | | | | | | | R | | | |
| 8 | Submission of technical paper | | | | | | | | | | | | | R | | | |
| 9 | Oral presentation | | | | | | | | | | | | | | R | | |
| 10 | Submission of project dissertation (hard bound) | | | | | | | | | | | | | | | R | |

R — Milestone

B — Progress

24

# CHAPTER 4

# Result and Discussion

In this particular project, the results gained is by making a simulation using both Excel Microsoft software to be compared with the Weibull ++ software. The finding was absolutely magnificent as months of research and development the results had finally been awarded to this project. The simulation results were guided and gained by using sample sets of data used as follows[18] :

Table 2: observed times between failures of a system.

| Failure Date | Cumulative Time in Days | Failure Number | Failure Date | Cumulative Time in Days | Failure Number |
|---|---|---|---|---|---|
| 2/05/2003 | 4 | 1 | 16/08/2003 | 110 | 13 |
| 8/05/2003 | 10 | 2 | 25/08/2003 | 119 | 14 |
| 16/05/2003 | 18 | 3 | 30/08/2003 | 124 | 15 |
| 27/05/2003 | 29 | 4 | 2/09/2003 | 127 | 16 |
| 4/06/2003 | 37 | 5 | 14/09/2003 | 139 | 17 |
| 14/06/2003 | 47 | 6 | 28/09/2003 | 153 | 18 |
| 20/06/2003 | 53 | 7 | 11/10/2003 | 166 | 19 |
| 30/06/2003 | 63 | 8 | 25/10/2003 | 180 | 20 |
| 10/07/2003 | 73 | 9 | 5/11/2003 | 191 | 21 |
| 14/07/2003 | 77 | 10 | 20/11/2003 | 206 | 22 |
| 18/07/2003 | 81 | 11 | 4/12/2003 | 220 | 23 |
| 8/08/2003 | 102 | 12 | 20/12/2003 | 236 | 24 |

In this table 2 shows the failure data of a system that can be used to trace the time to next failure by using the Regression method and the MLE method which is used for the parameters estimation for $\beta$ and $\lambda$. This would be the most vital information as from these parameter of $\beta$ and $\lambda$, the reliability model from excel can be developed from this project can finally estimate time to failure  The results will also be compared with the

Weibull++ Software as the results obtained starts from Fig 5. The results include the Plot Failure Vs Cumulative on log-log.
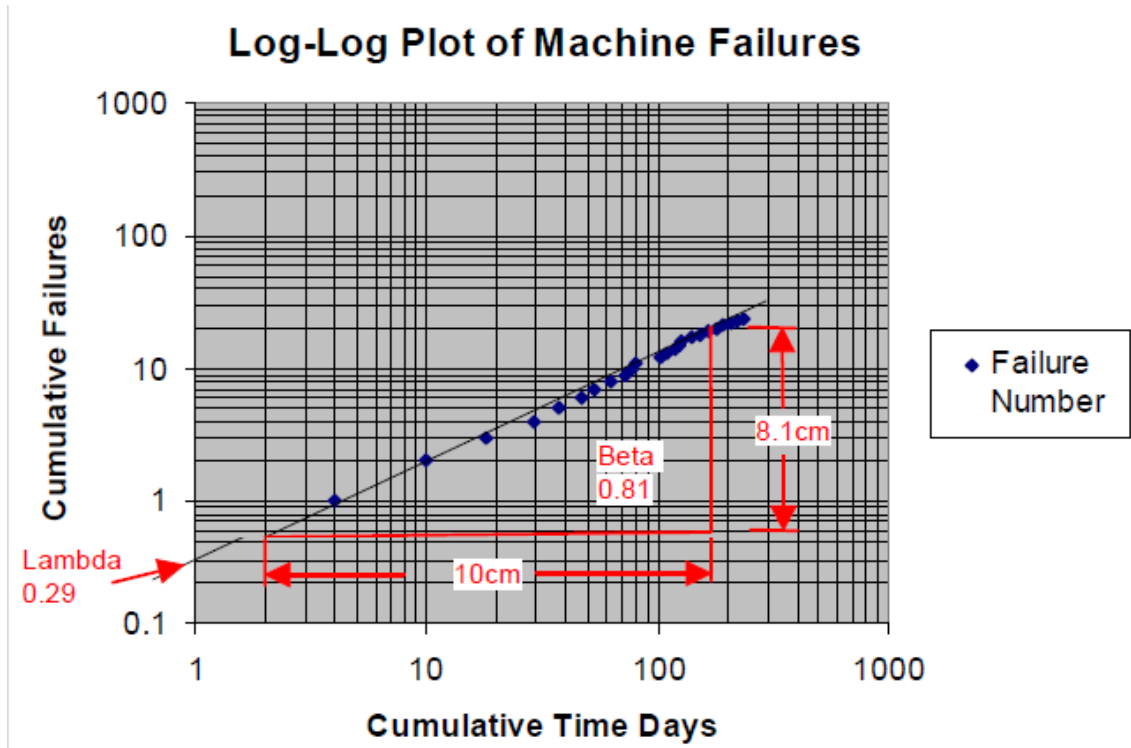


Fig 6:  Plot failure vs cumulative time on log-log in sample data.

From figure 6, Cumulative Failure Events at time t is represented by n(t). the scale parameter which is $\lambda$ is the intercept on the y-axis of n(t) at t=1 unit. With the data plotted ,$\lambda$ is estimated as 0.29. the slope $\beta$ however can be graphically calculated providing log paper with a 1 x 1 scale is used. In this case, $\beta$ is 8.1/10 = 0.81. In Fig 4 also shows the plot manual method from sketching in a log-log plot in the journal to find the parameters $\beta$ and $\lambda$. But since the data of cumulative time is in days the graphical plot is not valid as to key into the Weibull++ software, it needs to convert to hours. Thus, by changing the cumulative time days into hours, a more reliable graphical method can be plotted in the Excel Microsoft software and also the Weibull++ . The graphical method equation gained can be compared with the Regression method and MLE method for the parameters estimation of $\beta$ and $\lambda$.

26

Excel Microsoft Sofware



**Log-log Plot of Failure Vs Cumulative Time (days)**
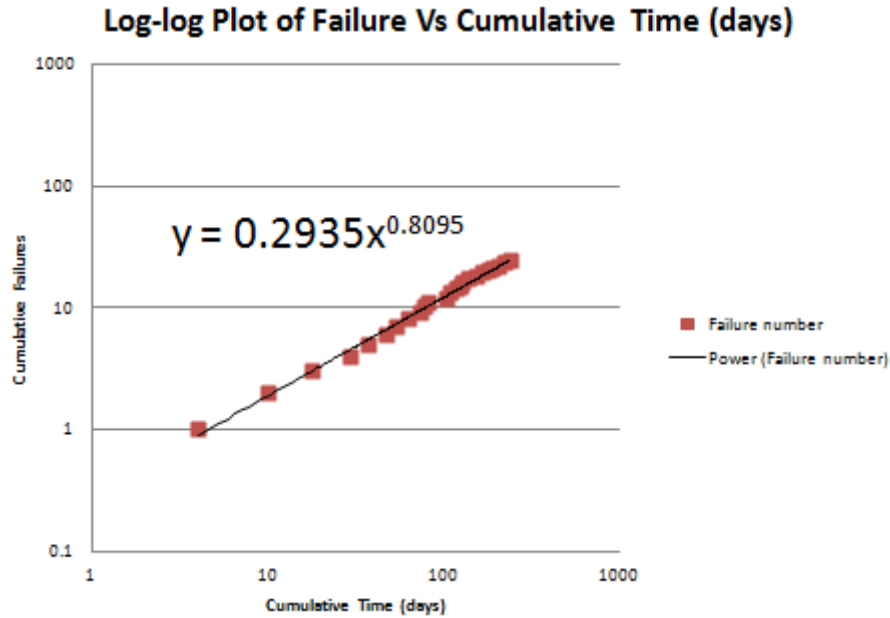
$y = 0.2935x^{0.8095}$

Fig 7: Graphical method in plotting the Plot failure vs cumulative time on log-log in Excel Microsoft Software.

Fig 7 shows the Plot Failure Vs Cumulative time on log-log by running the data of failure in the system into Excel Microsoft Software which is validated with the journal has same results (Fig 6). The trend shows that there is an improvement to the data obtained where the cumulative failure rate is decreasing in time. By the graphical method obtained by the equation $y = 0.0224x^{0.8095}$ power line from the equation n(t)= $\lambda\ t^{\beta}$. To prove that the parameters obtained is valid, it is to be tested by using the formula's below in the regression method from Crow-AMSAA-NHPP method.

$$\beta = \frac{n}{n\ lnT* - \sum_{i=1}^{n} \ln T_i} \qquad (1)$$

$$\lambda = \frac{n}{T^{\beta}} \qquad (2)$$

$$\lambda_i(T) = \lambda\beta\ T^{\beta-1} \qquad (3)$$

$$MTBF = 1/\ \lambda_i(T) \qquad (4)$$

$$T = (n/t)^{(1/\beta)} \qquad (5)$$

Table 3: Table of Failure data input of system in Excel Microsoft Software.

In table

| | A | B | C | D |
|---|---|---|---|---|
| 6 | Failure date | Failure Number | Cumulative time (days) | Ln T |
| 7 | 2/5/2003 | 1 | 4 | 1.386294361 |
| 8 | 8/5/2003 | 2 | 10 | 2.302585093 |
| 9 | 16/5/2003 | 3 | 18 | 2.890371758 |
| 10 | 27/5/2003 | 4 | 29 | 3.36729583 |
| 11 | 4/6/2003 | 5 | 37 | 3.610917913 |
| 12 | 14/6/2003 | 6 | 47 | 3.850147602 |
| 13 | 20/6/2003 | 7 | 53 | 3.970291914 |
| 14 | 30/6/2003 | 8 | 63 | 4.143134726 |
| 15 | 10/7/2003 | 9 | 73 | 4.290459441 |
| 16 | 14/7/2003 | 10 | 77 | 4.343805422 |
| 17 | 18/7/2003 | 11 | 81 | 4.394449155 |
| 18 | 8/8/2003 | 12 | 102 | 4.624972813 |
| 19 | 16/8/2003 | 13 | 110 | 4.700480366 |
| 20 | 25/8/2003 | 14 | 119 | 4.779123493 |
| 21 | 30/8/2003 | 15 | 124 | 4.820281566 |
| 22 | 2/9/2003 | 16 | 127 | 4.844187086 |
| 23 | 14/9/2003 | 17 | 139 | 4.934473933 |
| 24 | 28/9/2003 | 18 | 153 | 5.030437921 |
| 25 | 11/10/2003 | 19 | 166 | 5.111987788 |
| 26 | 25/10/2003 | 20 | 180 | 5.192956851 |
| 27 | 5/11/2003 | 21 | 191 | 5.252273428 |
| 28 | 20/11/2003 | 22 | 206 | 5.327876169 |
| 29 | 4/12/2003 | 23 | 220 | 5.393627546 |
| 30 | 20/12/2003 | 24 | 236 | 5.463831805 |
| 31 | | | | 104.026264 |

From sample data of failure in the system which is run into Excel Microsoft Software, the parameters can be calculated for λ and β . Furthermore, the cumulative time originally counted as day to apply the formula of Crow-AMSAA-NHPP and also to plot the data into Weibull++ software. The total for Ln T is calculated and sum up to be 104.026. this value then can be used in the formula (1) and (2) for the parameter λ and β. The results for the parameter λ and β can be found from Fig 6 and Table 5.

Table 4 : Table of results for parameters β and λ .

| β | λ | λi(T) | MTBF (days) |
|---|---|---|---|
| -0.664946841 | 2.5138415 | -0.166 | -6.0155185 |
| 2.182713336 | 0.0131316 | 0.4365 | 2.29072683 |
| 1.434127607 | 0.0475226 | 0.239 | 4.18372812 |
| 1.135513202 | 0.0873952 | 0.1566 | 6.38477825 |
| 1.111821538 | 0.0902422 | 0.1502 | 6.65574442 |
| 1.053875327 | 0.1037453 | 0.1345 | 7.43288426 |
| 1.091339006 | 0.0919028 | 0.1441 | 6.9377421 |
| 1.049312629 | 0.1035188 | 0.1332 | 7.50491301 |
| 1.022420972 | 0.1119804 | 0.1261 | 7.93324015 |
| 1.077266955 | 0.0928423 | 0.1399 | 7.14771762 |
| 1.123688765 | 0.0788587 | 0.1526 | 6.55309245 |
| 0.973634961 | 0.132904 | 0.1145 | 8.73017131 |
| 0.982538153 | 0.1282913 | 0.1161 | 8.61191846 |
| 0.982221853 | 0.1280797 | 0.1156 | 8.6538494 |
| 1.011489712 | 0.1144503 | 0.1224 | 8.17276396 |
| 1.053449746 | 0.0972453 | 0.1327 | 7.53476854 |
| 1.022077819 | 0.1096784 | 0.125 | 7.99985132 |
| 0.985536043 | 0.1265262 | 0.1159 | 8.62474798 |
| 0.962899493 | 0.1383607 | 0.1102 | 9.07347254 |
| 0.940270184 | 0.1515181 | 0.1045 | 9.57171689 |
| 0.935128217 | 0.1545826 | 0.1028 | 9.72619361 |
| 0.91497126 | 0.1679967 | 0.0977 | 10.2338038 |
| 0.902279187 | 0.1770959 | 0.0943 | 10.6011726 |
| 0.885422645 | 0.1901872 | 0.09 | 11.1058074 |

| β value | 0.885422645 |
|---|---|
| λ value | 0.190187172 |
| MTBF(days) | 11.10580737 |

Fig 8: Parameter value of β ,λ and MTBF.

The results in table 4 and figure 8 shows that the parameters for λ and β can be calculated with ease by using the formula from Crow-AMSAA-NHPP (1)(2) and (3). After calculating for the parameters MTBF value is calculated by using the equation (4). From the MTBF which values 266.5 hours, we can already predict the next failure of the system by equation (5). The equation calculated to be for example in this sample data, For 25th failure, to continue Table 3, will occur at (25/0.19018)^(1/0.885422645) =247days. Therefore, the next cumulative failure will occur in 247-236=11 days.

Table 5: Results for time to next failure

| β | λ | λi(T) | MTBF (days) | Time to next Failure (days) |
|---|---|---|---|---|
| -0.664946841 | 2.5138415 | -0.166 | -6.0155185 | -2.589584355 |
| 2.182713336 | 0.0131316 | 0.4365 | 2.29072683 | 2.041355942 |
| 1.434127607 | 0.0475226 | 0.239 | 4.18372812 | 3.998384542 |
| 1.135513202 | 0.0873952 | 0.1566 | 6.38477825 | 6.297397014 |
| 1.111821538 | 0.0902422 | 0.1502 | 6.65574442 | 6.593256222 |
| 1.053875327 | 0.1037453 | 0.1345 | 7.43288426 | 7.402924974 |
| 1.091339006 | 0.0919028 | 0.1441 | 6.9377421 | 6.89826089 |
| 1.049312629 | 0.1035188 | 0.1332 | 7.50491301 | 7.483774042 |
| 1.022420972 | 0.1119804 | 0.1261 | 7.93324015 | 7.923921683 |
| 1.077266955 | 0.0928423 | 0.1399 | 7.14771762 | 7.122955162 |
| 1.123688765 | 0.0788587 | 0.1526 | 6.55309245 | 6.521357835 |
| 0.973634961 | 0.132904 | 0.1145 | 8.73017131 | 8.739765703 |
| 0.982538153 | 0.1282913 | 0.1161 | 8.61191846 | 8.617662246 |
| 0.982221853 | 0.1280797 | 0.1156 | 8.6538494 | 8.659317136 |
| 1.011489712 | 0.1144503 | 0.1224 | 8.17276396 | 8.169736736 |
| 1.053449746 | 0.0972453 | 0.1327 | 7.53476854 | 7.523075179 |
| 1.022077819 | 0.1096784 | 0.125 | 7.99985132 | 7.994867728 |
| 0.985536043 | 0.1265262 | 0.1159 | 8.62474798 | 8.628201613 |
| 0.962899493 | 0.1383607 | 0.1102 | 9.07347254 | 9.082521259 |
| 0.940270184 | 0.1515181 | 0.1045 | 9.57171689 | 9.586686087 |
| 0.935128217 | 0.1545826 | 0.1028 | 9.72619361 | 9.742026522 |
| 0.91497126 | 0.1679967 | 0.0977 | 10.2338038 | 10.2551274 |
| 0.902279187 | 0.1770959 | 0.0943 | 10.6011726 | 10.62581638 |
| 0.885422645 | 0.1901872 | 0.09 | 11.1058074 | 11.13539259 |

| | |
|---|---|
| β value | 0.885422645 |
| λ value | 0.190187172 |
| MTBF(days) | 11.10580737 |
| Time next Failure(days) | 11.13539259 |

Fig 9 Results for time to next Failure.

Time to next failure from Fig 7 is easily assessable for the user to predict the time to next failure where when the time occurs, maintenance can be made towards the system before the failure actually occurs. This software toolkit is very realistic and futuristic to be devoped and used by any company or authority to be campared with the Weibull++ software which shows great success.
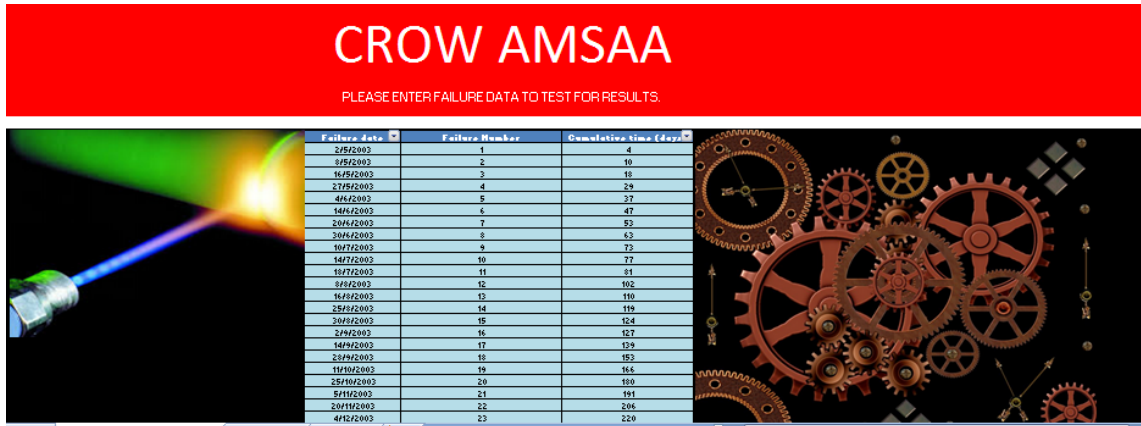
Fig 10: Table for user Interface to run failure data of a system in the Excel Microsoft Software toolkit.

Thus, from months of research and development, the user interface in the project is finally able to be produce where the failure data of any system can be run into the Excel Microsoft Software toolkit that can show the results automatically for the parameters $\lambda$ and $\beta$ that can be compared with the results for the parameter obtained from the Weibull++ software. The prediction of next failure can also be predicted from the toolkit which would be an advance and unique way of having this project which can save a lot of cost for an organization or company which have to pay a lot of money for licensing of using the Weibull++ software in their operations. The license for one user only for the Weibull++ would be RM6000 which can be a great loss and disturbance especially towards the cost.



| Percentage Error by Comparison | | |
|---|---|---|
| Estimated | Actual Value | |
| $\beta = 0.8116$ | $\beta = 0.8095$ | 0.25% |
| $\Lambda = 0.2846$ | $\lambda = 0.2935$ | 3% |

Fig 11: Percentage Error by comparison with the actual value of parameters.

Weibull++ Software



Fig 12: Weibull++ software input data.

| System ID | Event (F=Failure, E=End) | Time to Event (Hr) |
|---|---|---|
| AA | F | 4 |
| AA | F | 10 |
| AA | F | 18 |
| AA | F | 29 |
| AA | F | 37 |
| AA | F | 47 |
| AA | F | 53 |
| AA | F | 63 |
| AA | F | 73 |
| AA | F | 77 |
| AA | F | 81 |
| AA | F | 102 |
| AA | F | 110 |
| AA | F | 119 |
| AA | F | 124 |
| AA | F | 127 |
| AA | F | 139 |
| AA | F | 153 |
| AA | F | 166 |
| AA | F | 180 |
| AA | F | 191 |
| AA | F | 206 |
| AA | F | 220 |
| AA | E | 236 |

Fig 13: Running Failure data of a system into Weibull++Software.

Comparison of the results would be made with the Weibull++ Software with the Excel Microsoft Sofware results from the same sample of the failure data of the system. This is to show that the results obtained would be same and proves that the toolkit developed by the Excel Microsoft Software is as reliable and even more smarter to be used.
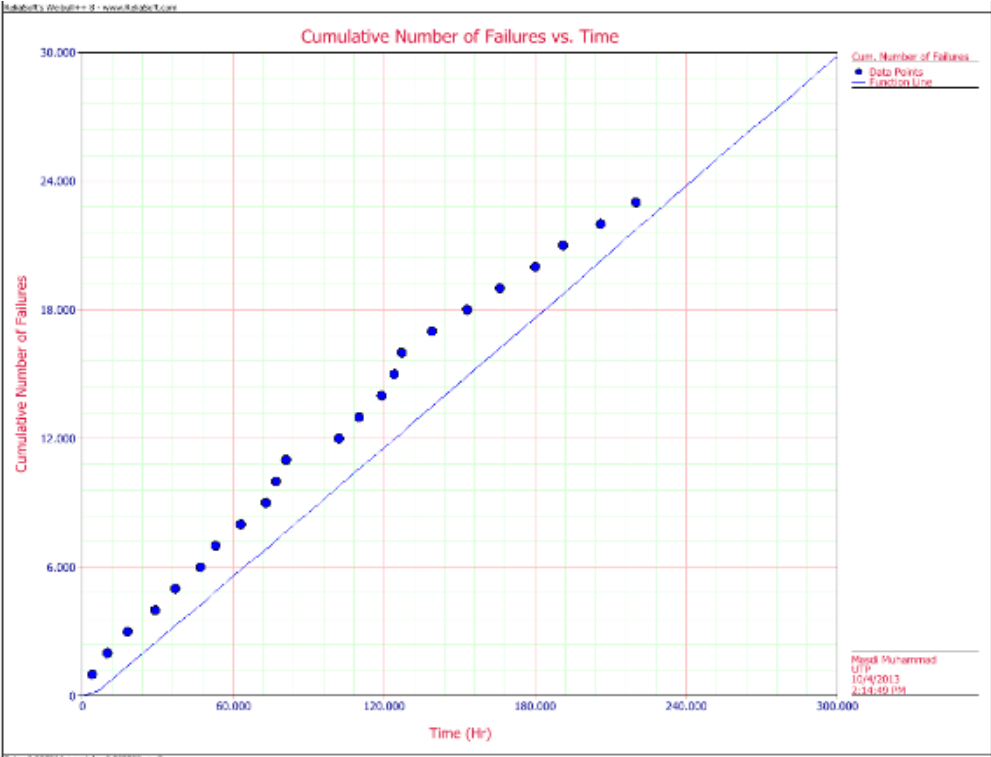


Fig 14: Plot failure vs cumulative time on log-log in Weibull++ software.

After running the failure data of the system into the Weibull++ Software, the plot failure vs cumulative time on log-log in Weibull++ software can be obtained automatically as same as the Excel Microsoft Software toolkit. Amazingly, This shows that both softwares can produce plots which are accurate for the sample failure data of the system.

**Analysis Summary**

| Results | |
|---|---|
| Beta | 2.299214 |
| Lambda | 0.003828 |
| q | 0 |

Fig 15: Analysis Summary of Weibull++ Software for Beta and Lambda.

In figure 6, the data set is key in into Weibull++ Software. However, the results obtained from using the Weibull++Software however has a slight change for the values of λ and β. Since using the software, it is much easier to analyze since the user do not have to calculate for any interception for the λ and also to calculate graphically for the slope β as it is automatically done for you as can be seen in fig 8.

After comparing both methods of using Excel Microsoft Software and Weibull++ software, it can be said that both could have produced different kind of results if to continue the progress which is to calculate all the parameters needed for Reliability prediction. The major causes is due to during the Weibull++ software experiment in the lab, the data which had been run into the software was not automatically change to days and Weibull++ software had shown some vital weaknesses in finding the parameters where the user itself must manually calculate the data by converting the cumulative time in days into hours which effects the results obtained.

Fortunately, in Excel Microsoft Software Toolkit can be run the failure data of the system even without converting the time from days into hours which would save the time of the user. This would have been time consuming for the user to convert lots of data sample from days to hours that is not so efficient if using Weibull++ Software. In addition, the values of the parameter β and λ is also not the same because the selection have to be in 2 parametric and the q value must be 1. In the Excel Microsoft Software toolkit developed, this type of data is not necessary to be included in finding the results for the parameter β and λ which is more smarter to use. The failure of changing the scale into log-log scale in weibull++ had also caused the failure of having the correct parameter.

# CHAPTER 5:

## Conclusion & Recommendation

## Conclusion

The simulation test was a success as the parameters for $\beta$ and $\lambda$ was gained from the from the from the Excel Microsoft Software toolkit. These parameters is useful to be used in Trend test on the failure rates whether increasing or decreasing. It is also useful to be used in some mathematical model for reliability prediction in the future. FYP II concentrates especially on the fantastic results obtained and literature review part where most of the sources were gained successfully.

## Recommendation

Based on the results obtained, the development of this project can be enhanced in the coming future with greater achievements as more application can be included. The toolkit can also be improved by having more parameters for failure numbers to be key in into it that can calculate for even more than 10 years calculation data which can be great to achieve in the future. Hopefully more research can be continued to be done in this project title as more time is actually needed to gain greater yet more impressive results.

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