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Reliability Assessment of a Base Transceiver Station Using 2-Parameter Weibull Distribution Method

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Authors' contributions

This work was carried out in collaboration between both authors. Author OKI designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author WEO managed the analyses of the study and also the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

About 80% interruptions of cellular network availability occur due to power outage on BTS stations and reliability analysis of these systems is yet to receive exhaustive studies. Most network providers solely depend on generating power on their BTS sites using diesel generators since the grid power is least reliable, but the frequency of power outages from the diesel generators is alarming, hence, the need to analyse the reliability of these generators and their maintenance routine in relation to the site availability.

In this study, the reliability of a Base Transceiver Station (BTS) is assessed by analysis of data obtained within a period of six months from four BTS sites used as case study using 2-parameter Weibull failure distribution method. The failure times of each BTS site were rank-ordered and the estimates of Weibull parameters θ and β were obtained from Weibull least-squares plots.

The Weibull plots for the four BTS sites had a good index of fit which shows that a strong linear relationship exists. The value of the shape parameter (β) was found to be between the range of 1< β

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< 3 for all the BTS sites studied. This means that the probability density function is skewed and the failure rate of the BTS sites is increasing. The reliability of each BTS site was successfully computed. The reliability of the four BTS sites was found to be increasing as their values of scale parameter, θ increases. From the results obtained, BTS site RV0144 had the highest reliability while BTS site RV0248 had the lowest reliability.

Keywords: Base transceiver station; reliability; 2-parameter weibull distribution method; weibull plots.

1. INTRODUCTION

The telecommunication industry has been experiencing unprecedented expansion in the number of subscribers since the inception of Global System for Mobile communication (GSM) in Nigeria in 2001 Ukhurebor et al. [1]; Lawal et al. [2]; Ukhurebor et al. [3]; Ukhurebor et al. [4]. This increase in demand for the use of GSM network, however, have put enormous pressure on the network providers to ensure reliability and quality of service desired by the customers, but the situation on the ground is that many of the network providers have not achieved the desired results. Base Transceiver Stations are designed basically for reliable and uninterrupted communication which is very essential for the growth and development of any nation as well as improvement of lives through industrialisation.

The poor availability and dependability of public power amidst mobile network expansion compelled the exigency for a supplementary power infrastructure at GSM sites to support the operation of network transmission and base station equipment so as to guarantee network reliability and minimise the impact of network failures due to power outages on customers. The supplementary power infrastructure is an integrated system with a collection of different power subsystems, which include a transformer, an automatic voltage regulator, two identical generators, a rectifier system, a battery bank, an automatic transfer switch, and automatic main failure, all interfaced in a definite topological structure, with redundancy scale that tolerates faults, allows for operation handover, and permits some degree of equipment downtime before restoration to optimal efficiency. Not only is the assessment of the rated capacity and the reliability standard of the major subsystems important to ascertain their effectiveness, sufficiency or superfluity in the face of maintenance resource scarcity and allocation challenges, but also the examination of the efficiency of the entire power system model is imperative to minimise network vulnerability due to fault occurrence and power outage on operating subsystems on the model.

Mas'ud [5] investigated fault management in intercellular network. This study showed that fault exists in the network due to radio frequency loss, down links and trunk outages. Intelligent agent technology was proffered as a solution to these problems coupled with preventive maintenance schedules. Chen [6], proposed empirical equations to the study of network reliability, availability, maintainability and survivability based on impacted incidents such as mean time to incident, mean time to restore network, quiescent availability, peak customer impacted and wireless prime lost line hours. These parameters provide an understanding of network characteristics concurrent outages and offer network operators valuable insights about predicting the frequency with which network incidents exceed severity thresholds. Snow et al. [7] proposed wireless network infrastructure element. This includes base station, mobile switching centers, home location registers and visitor location register database. The effect of mean time to failure and mean time to repair on the proposed network infrastructure was determined. These effects on network dependability were found to be significant impact. Albaghdadi and Razvi [8] studied 1320 cell GSM network. Their aim was to find an effective method for periodic transmission of network management information. The actual traffic loads were collected for 24 hours and analysed to determine their impact on the customer. Fawaz et al. [9] investigated fiber optic cable system reliability. It was concluded that the frequency of failure of optical network is not negligible and that cable cuts are the dominant failure scenario for long optical fiber networks.

In analysis of network reliability based on power outages, Goel and Gupta [10] proposed a window based simulation tool for reliability evaluation of electricity generating capacity using the Monte Carlo simulation. This simulation technique compared favorably with the analytic solution obtained from Markov analysis in the prediction of the loss of load expectation and the loss of energy expectation. Also, the developed Monte Carlo simulation can provide information regarding the unit forced outage rates, variations in system peak load and the cause consequences of partial generator unavailability. Paska [11] proposed novel approaches, models and tools to the electric power system reliability assessment on the first two hierarchical levels, with special attention to generating reliability assessment and computer program for generating adequate evaluation. Silverstein and Porter [12] described a methodology of contingency ranking for bulk system reliability criteria. This deterministic approach provides planning criteria for contingencies planning such that minimum acceptable performance level can be achieved. Outage data and models for multiple outages to examine the likelihood of various contingencies were provided. Burgio et al [13] investigated the reliability evaluation of a combined power system consisting of photovoltaic and wind power generation coupled with an uninterruptible power system using Monte Carlo simulation method. One important finding is the estimation of the critical loads interruption over a certain period of time. Chowdhury et al. [14] provide performance reporting of an area power pool using probabilistic technique. Midcontinent area power pool experiences outages that can be classified as either planned or forced outages. The impacts of such outages on the area pool were provided, showing significant impact on the delivery of power to the area power pool.

The aim of this study is to assess the reliability of a Base Transceiver Station (BTS) using 2-Parameter Weibull Distribution method. The objectives are as follows:

1. To rank-order the failure times of each of the four BTS sites under study.
2. To determine the probability of failures of each BTS site.
3. To plot a Weibull least-squares graph to determine the Weibull scale parameter, θ and Weibull shape parameter, β of each BTS site.
4. To determine the Mean Time to Failure of each BTS site.
5. To determine the Reliability of each BTS site.
6. To compare the results of the reliability of each BTS site.
7. To compute the overall reliability of four BTS sites.

This work will lead to more efficient, better monitoring, control and maintenance of a Base Transceiver Station (BTS). If the reliability and performance of an existing BTS is assessed and monitored, it will lead to an improved operation and maintenance of the system. With 2-parameter Weibull method, there will be better evaluation of the system reliability that can enable higher availability of the BTS. A better and improved system increases the capacity and the functionality of the mobile wireless communication system.

2. EXPERIMENTAL DESIGN

The method adopted in this research is the non-experimental research design. This research design approach is centered on the method used in collecting data. Four Base Transceiver Stations (BTS) stationed in the University of Port Harcourt, Rivers State, Nigeria were used for the purpose of this study. Data gathered from the BTS Stations for a period of six months were analysed and used in the modeling done in this work. During data gathering, assurance was given to the organisation studied that the data would be kept confidential and restricted to academic use only. This is to ensure that the correct data were released if at all.

2.1 Data Collection Technique

Various downtime and uptime data were pulled out from the NMC server. Root cause data was also available on the Affectli server. The reliability data collected for the major power subsystems were briefly described. The evaluation techniques used for the computation of secondary reliability data were presented. These data were examined, assessed for operational conditions for functionality, the characteristics of failures, appraisal of reliability data and assessment of the evaluated reliability standards to justify effectiveness of the redundancy model of the subsystem especially the diesel generators.

2.2 Method of Data Analysis

The basic model used in this research is the Two-Parameter Weibull Failure Distribution method. There are other models for analysing the failure data of a component or system depending on the type of failures. Some of these failure models are:

- The Exponential Failure Distribution
- The Normal Failure Distribution
- The Gamma Failure Distribution
- The Three-Parameter Weibull Distribution

2.2.1 The Weibull Method

One of the most useful probability distributions in reliability is the Weibull Failure Distribution. It may be used to model both increasing and decreasing failure rates. It is characterised by a hazard function of the form

$$\lambda(t) = at^b \quad (1)$$

is a power function. The function $\lambda(t)$ known as the failure rate or hazard rate is increasing for a > 0, b > 0 and is decreasing for a > 0, b < 0. There are three types of Weibull Failure Distribution, namely:

- The Single Parameter Weibull Method
- The 2-Parameter Weibull Method and
- The 3-Paraemter Weibull Method

The Weibull technique assumes, initially, that the distribution of failures, whilst not random, is at least able to be modeled by a simple 2-Parameter Weibull Distribution. It assumes that:

$$R(t) = \exp - (t/\theta)\ \beta \quad (2)$$

R(*t*) is the Reliability function or the Probability of Survival

The technique is to carry out a curve fitting (probability modeling) exercise to establish first that the data will fit this assumption. The next step is to estimate the values of the 2-parameters of Weibull distribution (θ and β). Generally, a least-squares fit of the data is recommended over a manual plot which is done using a Weibull Probability paper as it is more accurate and less subjective than fitting a straight line to the data by eye. Theta (θ) is a scale parameter that influences both the mean and spread of dispersion of the distribution. As θ increases, the reliability increases at a given point in time. The slope of the hazard rate decreases as θ increases. The parameter θ is also called the characteristics life and it has units identical to those of failure time T.

Beta (β) is referred to as the shape parameter. Its effect on the distribution varies for different values. If β = 1, then the failures are random and a constant failure rate can be assumed where failure rate,

$$\lambda(t) = 1/\beta \quad (3)$$

If β > 1, then the failure rate is increasing. The failures may be caused by fatigue, aging, corrosion and friction. If β < 1, then the failure rate is decreasing. The failures may be caused by poor quality control, manufacturing defects, poor workmanship etc. For 1 < β < 3, the density function is skewed. Two methods of estimating the Weibull parameters from a set of times to failure are the Least-Squares and Maximum Likelihood. The Least-Squares method is used as an initial calculation and involves calculating the hypothetical line for which the sum of the squares of the distances of the horizontal distances from the data points to the line is a minimum. The Weibull parameters (θ and β) are obtained from the line. They are parameters which allow us to compute Reliability and MTBF.

Probability of failure, $F(t_{i)} = (i - 0.3)(n + 0.4)$ (4)

Where

t_i = Failure time, hr
n = Number of failures
i = Rank of the failure time

$$y_i = lnln(1/(1 - F(t_i))) \quad (5)$$

$$x_i = \ln t_i \quad (6)$$

Where y_i are the values of the coordinates on the vertical axis and x_i the values of the coordinates on the horizontal axis.

2.2.2 Weibull plots

Probability plots provide an informal method of evaluating the fit of a set data to a distribution. A least-squares fit of the data is recommended over a manual plot which is done using Weibull Probability paper as it is more accurate and less subjective than fitting a straight line to the data by eye. The vertical scale and the horizontal scale have been modified to linearize the cumulative distribution function. Since straight lines are easily identifiable. Our primary approach to probability plots is to fit a linear regression (least-squares) line of the form

$$y = a + bx \quad (7)$$

If the failure times fit the assumed distribution, the transformed data will graph as a straight line and the fitted regression line will have a high index of fit, r.

A plot of

$$y_i = lnln\left(\frac{1}{1-F(t_i)}\right) \text{ against } x_i = \ln t_i$$

is constructed using a Weibull probability paper or by applying a least-squares fit to the data. From the plot, we obtain initial estimates of the Weibull parameters, θ and β of the distribution being fitted. β corresponds to the slope and βln θ is the intercept. From the initial estimates of Weibull parameters obtained, the mean time to failure (MTTF) and reliability of each BTS site is determined.

3. RESULTS AND DISCUSSION

3.1 Data Presentation

The data obtained from the four Base Transceiver Station (BTS) sites are presented in Tables 1 to 4.

From Table 1, the failure time in (hr; mins) is converted to hrs, so we can have a uniform unit and thus gotten below.

For Down time:

00:41:49, failure Time = 107:05. The minutes are converted as;

$$107:05 = \frac{05}{60} = 0.8$$
$$\therefore 107:05\left(hr:\min\right) = 107.08hrs$$

3.2 Data Analysis

The data obtained from the four BTS sites RV0144, RV0686, RV0248 and RV0421 under study was analysed in line with the theory and procedure described earlier in the experimental design. Tables 1 - 4 shows the 6-month data obtained from four BTS sites at University of Port Harcourt, Rivers State, Nigeria.

3.2.1 Analysis of BTS Site (RV0144)

The following failures were obtained after rank-ordering of eight (8) failure times obtained from BTS site (RV0144).

Where

t_i = Failure time, hr
i= Rank
F(t_i) = Probability of failure
n = Number of failures = 8
From equation (4)
F(t_i) = (i-0.3)(n+0.4)
i = 1, 2, 3,…,8

For *i* =1 and t = 26.53hr

F(t_i) = (1-0.3)(8+0.4) = 0.0833 (8)

Int_1 = In(26.53) = 3.2787 (9)

From equation (5);

y_i= InIn(1/(1-F(t_i)))
y_1= =InIn(1/(1-0.0833))

y_1= = -2.4417 (10)

Table 1. Data obtained from BTS Site RV0144

Downtime	Failure Time (t) , (hr; mins)	Failure Time (t), hr
00:41:59	107:05:00	107.08
00:28:59	26:32:00	26.53
00:03:59	119:53:00	119.88
00:43:00	1874:54:00	1874.90
00:27:00	1673:02:00	1673.03
02:09:00	280:51:00	280.85
01:40:00	129:41:00	129.68
1:33:00	40:47:00	40.78

Table 2. Data obtained from BTS Site RV0686

Down time	Failure time (t), (hr; min)	Failure time (t), hr
00:04:00	0:02:00	0.03
00:04:00	0:03:00	0.05
00:03:00	0:04:00	0.07
00:54:59	0:05:01	0.08
00:02:00	0:06:00	0.10
00:10:59	0:08:00	0.13
00:03:00	0:09:00	0.15

Down time	Failure time (t), (hr; min)	Failure time (t), hr
00:02:00	0:10:00	0.17
00:02:00	0:11:00	0.18
00:03:00	0:12:00	0.20
00:03:00	0:14:00	0.23
00:04:00	0:16:00	0.27
00:04:00	0:18:00	0.30
00:04:00	0:20:00	0.33
00:02:00	0:22:00	0.37
00:03:00	0:23:00	0.38
00:28:59	0:25:01	0.42
00:03:00	0:26:00	0.43
00:03:00	0:29:00	0.48
00:08:00	0:29:00	0.48
00:02:00	0:37:00	0.62
00:02:00	0:38:00	0.63
00:02:00	0:43:00	0.72
00:21:00	0:48:00	0.80
00:05:00	3:10:00	3.17
00:04:00	3:52:00	3.87
00:03:00	4:07:00	4.12
00:02:00	18:01:00	18.02
00:02:00	18:35:00	18.58
00:12:00	21:49:00	21.82
00:03:00	22:07:00	22.12
00:33:59	22:35:00	22.58
00:12:59	63:02:01	63.03
00:52:00	94:39:00	94.65
00:03:00	96:09:00	96.15

Table 3. Data obtained from BTS Site RV0248

Down time	Failure Time (t), (hr: mins)	Failure Time (t), hr
00:26:00	0:05:00	
00:08:00	0:12:00	0.20
00:34:00	0:12:00	0.20
00:41:59	0:12:00	0.20
00:02:00	0:13:00	0.22
00:05:00	0:13:00	0.22
00:01:00	0:15:00	0.25
00:18:00	0:16:00	0.27
00:02:00	0:17:00	0.28
03:07:00	0:40:00	0.67
00:07:00	1:13:00	1.22
00:03:00	1:49:00	1.82
12:05:00	6:41:00	6.68
00:03:00	24:12:00	24.20
00:28:59	26:32:00	26.53
00:11:00	69:53:00	69.88
00:00:59	106:52:00	106.87
0:04:00	119:53:00	119.88
00:06:00	127:29:00	127.48
00:11:00	192:32:00	192.53
00:07:00	236:44:00	236.73
01:03:00	569:56:00	569.93
00:15:00	940:23:00	940.38
00:51:00	1486:10:00	1486.17

Table 4. Data obtained from BTS Site RV0421

Downtime	Failure time (t), (hr: mins)	Failure time (t), hr
01:10:00	0:07:00	0.12
00:30:00	0:21:00	0.35
07:43:00	0:51:00	0.85
00:07:00	2:30:00	2.50
00:30:00	3:07:00	3.12
02:59:00	3:18:00	3.30
02:35:00	5:00:00	5.00
00:13:00	10:02:00	10.03
10:57:00	11:16:00	11.27
00:28:59	24:24:00	24.40
00:06:00	28:35:00	28.58
00:07:00	46:53:00	46.88
00:57:00	46:57:00	46.95
00:26:59	54:51:01	54.85
00:42:59	55:22:01	55.37
00:53:59	63:32:01	63.53
01:07:00	68:00:00	68.00
00:55:00	70:29:00	70.48
07:53:00	101:16:00	101.27
07:00:59	102:54:00	102.90
01:54:59	108:11:01	108.18
00:18:00	125:19:00	125.32
00:48:00	163:08:00	163.13
00:13:00	335:20:00	335.33
01:24:00	359:51:00	359.85
00:51:00	447:36:00	447.60
00:46:00	484:27:00	484.45
01:10:00	1589:48:00	1589.80

Table 5. Analysis of data obtained from (RV0144)

i	t_i (hrs)	Int_i	*F*(t_i)=(*i*-0.3)(*n*+0.4)	y_i= lnln(1/(1-F(t_i)))
1	26.53	3.278403	0.083333333	-2.441716399
2	40.78	3.708274	0.202380952	-1.486670964
3	107.08	4.673607	0.321428571	-0.947354424
4	119.88	4.78652	0.44047619	-0.543574052
5	129.68	4.865096	0.55952381	-0.198574256
6	280.85	5.637821	0.678571429	0.12661497
7	1673.03	7.422394	0.797619048	0.468504666
8	1874.90	7.536311	0.916666667	0.910235093

The following procedure was repeated to obtain values for y_2 , y_3 , $y_{4,}$ y_5 , ... y_8 and also for corresponding Int_i values as seen in Table 5.

A Weibull least-squares plot of y_i versus x_i is constructed as seen in Fig. 1.

From Fig. 1, the constructed plot shows that an obvious linear relationship exists. A least squares fit is applied yielding the slope (β), θ and index of fit, *r* as seen in Table 2. The estimated θ = 5.9204 and estimated β=1.3264. The index of fit, *r* = 0.8618 indicates a strong linear fit to the data. The estimated is calculated as follows:

MTTF is 1/ β = 1/1.3264 = 0.75 hr (11)

The sample MTTF, 531.59hr, is obtained from averaging the 8 failure times (sample mean).

The reliability of the BTS site is calculated using equation (2);

$$R(t) = e^{-(\frac{t}{\theta})\beta}$$

t = 6 months = 24*28*6 = 4,032 hr
Assumed 28 days = 1 month

From Table 6, β = 1.3264 θ = 59204 hr

$$R(4032) = e^{-\left(\frac{4032}{59204}\right)^{1.3264}}$$

$R(4032)$ = 0.9136 (12)

From the calculation above, the reliability of BTS site RV0144 is 91%.

Table 6. Weibull distribution parameters for RV0144

Slope (β)	θ	r
1.326403	5.920413	0.861816

3.2.2 Analysis of BTS Site (RV0686)

The following failures were obtained after rank-ordering of 34 failure times obtained from BTS site (RV0686).

Number of failures = 34

From equation (4);

F(t_i) = (i-0.3)(n+0.4)
i = 1,2,3,…,34
For i =1 and t = 0.03hr

$F(t_i)$ = (1-0.3)(34+0.4) = 0.02034 (13)

$x_i = \ln t_i$

$x_1 = \ln t_1$= ln(0.03) = -3.4012 (14)

From equation (5)

y_i= lnln(1/(1-F(t_i)))

y_1= lnln(1/(1-0.0833))

y_1= -3.8844 (15)

The following procedure was repeated to obtain values for y_2, y_3, y_4, y_5, …, y_{34} and also for corresponding ln t_i values as seen in Table 7.

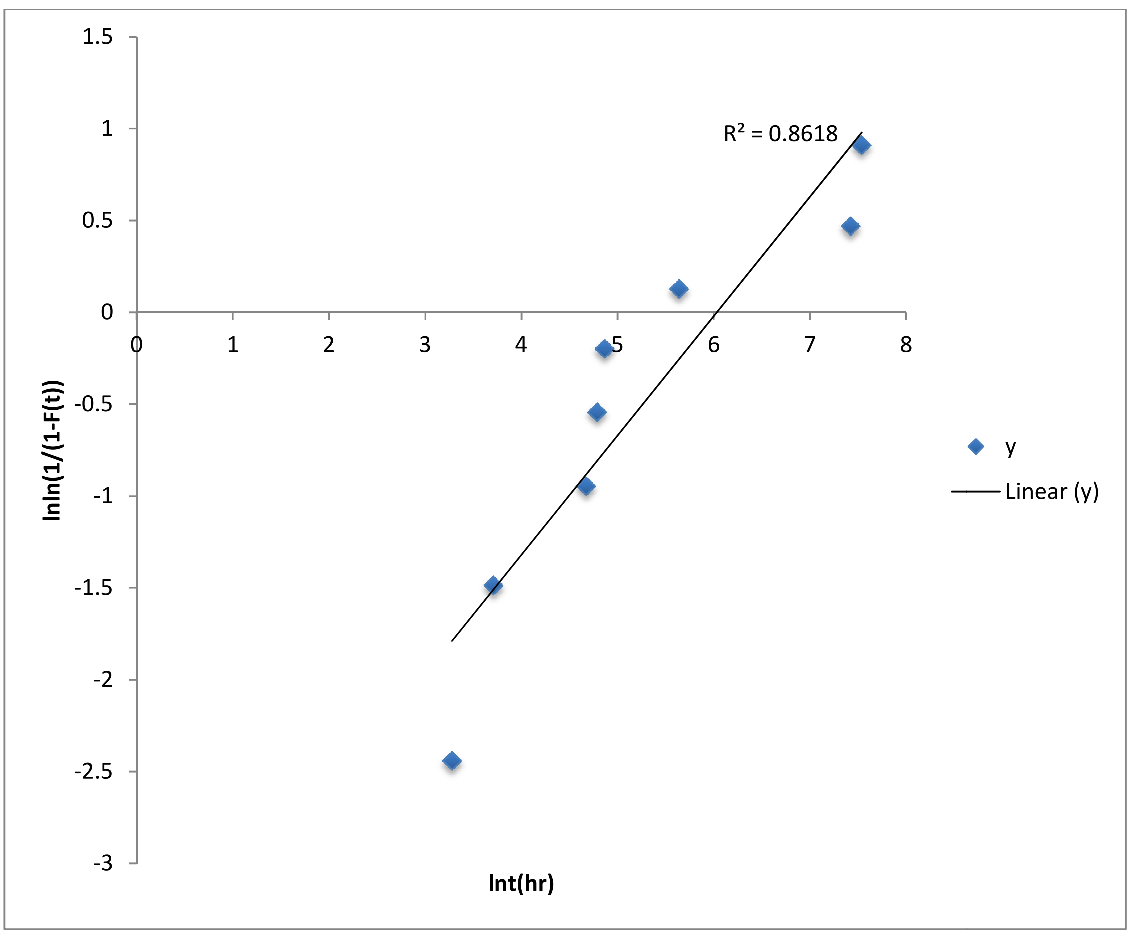

Fig. 1. Weibull least-squares plot of failure data

A Weibull plot of y_i = lnln (1/(1-F(t_i))) against $x_i = \ln t_i$ is constructed as seen in Fig. 2.

Table 8. Weibull distribution parameters for RV0686

Slope (β)	θ	r
1.600684	50.6866	0.792154

From Fig. 2, the constructed plot shows that an approximate linear relationship exists. A least-squares fit is applied yielding the slope (*β*), *θ* and index of fit, *r* as seen in Table 8. The estimated *θ* = 50.6866 and estimated *β*=1.6007. The index of fit, *r* = 0.79215 indicates a strong linear fit to the data.

MTTF = 1/ *β* = 1.26 hr. (16)

The sample MTTF, hr, is obtained from averaging the 34 failure times (sample mean).

The reliability of the BTS Station is calculated using equation (2);

$$R(t) = e^{-(\frac{t}{\theta})^{\beta}}$$

t = 6 months = 24*28*6 = 4,032 hr
Assumed 28 days = 1 month

From Table 8, *β* = 1.6007 *θ* = 50,686 hr

$$R(4032) = e^{-\left(\frac{4032}{50686}\right)^{1.6007}}$$

$R(4032)$ = 0.8805 (17)

From the calculation, the reliability of BTS Station RV0686 is 88%.

Table 7. Analysis of data obtained from BTS Site RV0686

i	ti(hr)	*F(ti)*	*Y*	lnt
1	0.03	0.020348837	-3.884469756	-3.4012
2	0.05	0.049418605	-2.982194593	-2.99573
3	0.07	0.078488372	-2.504213226	-2.70805
4	0.08	0.10755814	-2.173366276	-2.48184
5	0.10	0.136627907	-1.917938402	-2.30259
6	0.13	0.165697674	-1.708377743	-2.01419
7	0.15	0.194767442	-1.529591449	-1.89712
8	0.17	0.223837209	-1.37281364	-1.79176
9	0.18	0.252906977	-1.23249035	-1.69645
10	0.20	0.281976744	-1.104871877	-1.60944
11	0.23	0.311046512	-0.98729943	-1.45529
12	0.27	0.340116279	-0.877811544	-1.32176
13	0.30	0.369186047	-0.774912045	-1.20397
14	0.33	0.398255814	-0.677425685	-1.09861
15	0.37	0.427325581	-0.584404121	-1.0033
16	0.38	0.456395349	-0.495062122	-0.95885
17	0.42	0.485465116	-0.408732553	-0.87481
18	0.43	0.514534884	-0.32483325	-0.83625
19	0.48	0.543604651	-0.242841473	-0.72705
20	0.48	0.572674419	-0.162272994	-0.72705
21	0.62	0.601744186	-0.08266368	-0.48343
22	0.63	0.630813953	-0.003551729	-0.45676
23	0.72	0.659883721	0.075541258	-0.33314
24	0.80	0.688953488	0.155132617	-0.22314
25	3.17	0.718023256	0.235807566	1.15268
26	3.87	0.747093023	0.318259922	1.352393
27	4.12	0.776162791	0.403353704	1.415044
28	18.02	0.805232558	0.492223087	2.891297
29	18.58	0.834302326	0.586447096	2.922265
30	21.82	0.863372093	0.688382877	3.082674
31	22.12	0.89244186	0.801877697	3.096331
32	22.58	0.921511628	0.934053944	3.117213
33	63.03	0.950581395	1.101085333	4.143667
34	94.65	0.979651163	1.359624745	4.550186

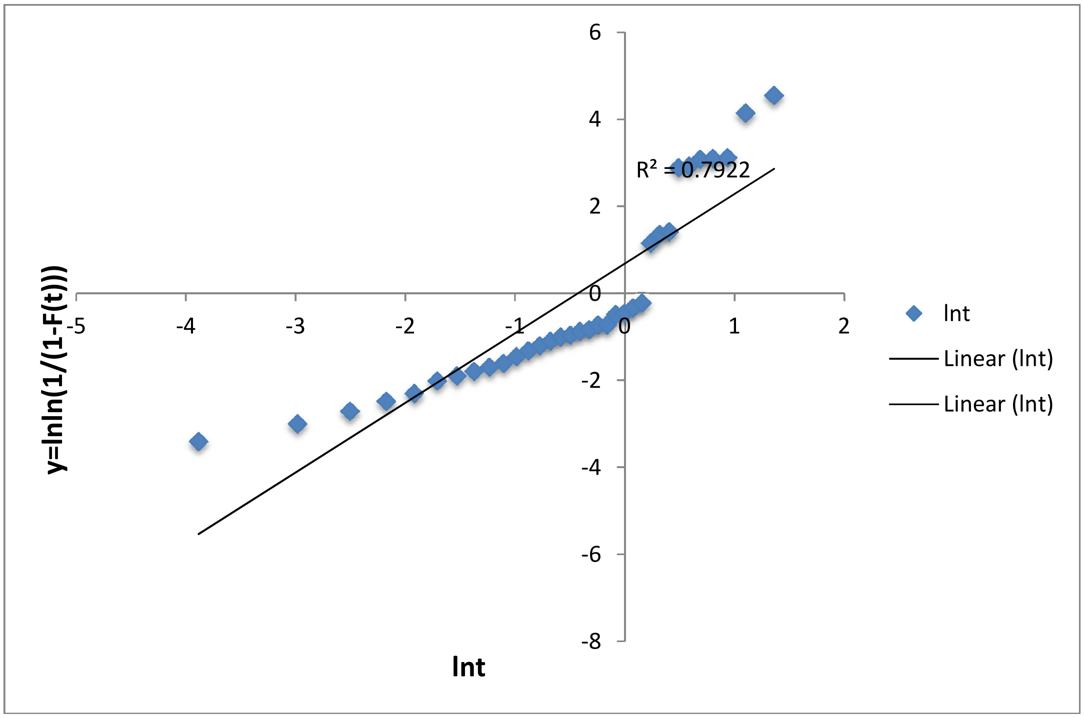

Fig. 2. A Weibull least-squares plot of failure data

3.2.3 Analysis of BTS Site (RV0248)

The following failures were obtained after rank-ordering of 23 failure times obtained from BTS site (RV0248).

Number of failures, *n* = 23

From equation (4)

$F(t_i)$ = (i-0.3)(n+0.4)
i = 1,2,3,…,23
For *i* =1 and *t* = 0.2hr

$F(t_i)$ = (1-0.3)(23+0.4) = 0.0275 (18)

Int_1 = ln(0.2) = -1.6094 (19)

From equation (5);

y_i= lnln(1/(1-F(t_i)))

y_1= lnln(1/(1-0.0275))

y_1= = -3.577 (20)

The following procedure was repeated to obtain values for y_2 , y_3 , y_4, y_5 , …, y_{23} and also for corresponding Int_i values as seen in Table 9. A Weibull plot of y_i = lnln(1/(1-F(t_i))) against $x_i = \ln t_i$ is constructed as seen in Fig. 3.

Table 10. Weibull distribution parameters for RV0248

Slope (β)	θ	r
2.569535	3.817928	0.782784

From Fig. 3, the graph shows that a linear relationship exists. A least squares fit is applied yielding the slope (β), θ and index of fit, *r* as shown in Table 10. The estimated θ = 3.8179 and estimated β=2.5695. The index of fit, *r* = 0.7828 indicates a strong linear fit to the data.

MTTF = 1/β = 1/ 2.5695 = 0.389 hr (21)

The reliability of the BTS site is calculated, using

$$R(t) = e^{-(\frac{t}{\theta})\beta}$$

t = 6 months = 24*28*6 = 4,032 hr
Assumed 28 days = 1 month

From Table 10, β = 2.5695 θ = 38,179 hr

$$\mathrm{R}(4032) = \mathrm{e}^{-(\frac{4032}{38179})2.5695}$$

$R(4032)$ = 0.7623 (22)

The reliability of BTS Station RV0248 is 76%.

Table 9. Analysis of data obtained from BTS site RV0248

i	t_i (hr)	$F(t_i)$	$\ln t_i$	y_i
1	0.20	0.027559055	-1.60944	-3.577483693
2	0.20	0.066929134	-1.60944	-2.669683806
3	0.20	0.106299213	-1.6094	-2.18583148
4	0.22	0.145669291	-1.5294	-1.84873045
5	0.22	0.18503937	-1.5294	-1.586622799
6	0.25	0.224409449	-1.38629	-1.369907214
7	0.27	0.263779528	-1.32176	-1.18343303
8	0.28	0.303149606	-1.26113	-1.018366276
9	0.67	0.342519685	-0.40547	-0.869072148
10	1.22	0.381889764	0.196115	-0.731704114
11	1.82	0.421259843	0.597003	-0.603486236
12	6.68	0.460629921	1.899617	-0.482313743
13	24.20	0.5	3.186353	-0.366512921
14	26.53	0.539370079	3.278403	-0.254685391
15	69.88	0.578740157	4.246827	-0.14559769
16	106.87	0.618110236	4.671582	-0.038093129
17	119.88	0.657480315	4.78652	0.06899061
18	127.48	0.696850394	4.847986	0.176914335
19	192.53	0.736220472	5.260269	0.287163174
20	236.73	0.775590551	5.466934	0.401646493
21	569.93	0.81496063	6.345519	0.523062447
22	940.38	0.854330709	6.846288	0.655661466
23	1486.17	0.893700787	7.303955	0.807144125

Table 11. Analysis of data obtained from (RV0421)

i	t_i, hr	$\ln t_i$	$F(t_i)$	y_i
1	0.12	-2.14843	0.024648	-3.69061
2	0.35	-1.04982	0.059859	-2.78506
3	0.85	-0.16252	0.09507	-2.3036
4	2.50	0.916291	0.130282	-1.96908
5	3.12	1.136764	0.165493	-1.70973
6	3.30	1.193922	0.200704	-1.496
7	5.00	1.609438	0.235915	-1.31276
8	10.03	2.305913	0.271127	-1.15121
9	11.27	2.421849	0.306338	-1.00575
10	24.40	3.194585	0.341549	-0.8726
11	28.58	3.352824	0.376761	-0.74903
12	46.88	3.847662	0.411972	-0.63303
13	46.95	3.849083	0.447183	-0.52302
14	54.85	4.004605	0.482394	-0.41773
15	55.37	4.013982	0.517606	-0.31609
16	63.53	4.151568	0.552817	-0.21718
17	68.00	4.219508	0.588028	-0.12014
18	70.48	4.255376	0.623239	-0.02414
19	101.27	4.617757	0.658451	0.071635
20	102.90	4.633758	0.693662	0.168109
21	108.18	4.683829	0.728873	0.266332
22	125.32	4.830844	0.764085	0.367612
23	163.13	5.094568	0.799296	0.473699
24	335.33	5.815125	0.834507	0.587135
25	359.85	5.885687	0.869718	0.711997
26	447.60	6.1039	0.90493	0.855749
27	484.45	6.183014	0.940141	1.035233
28	1589.80	7.371364	0.975352	1.309161

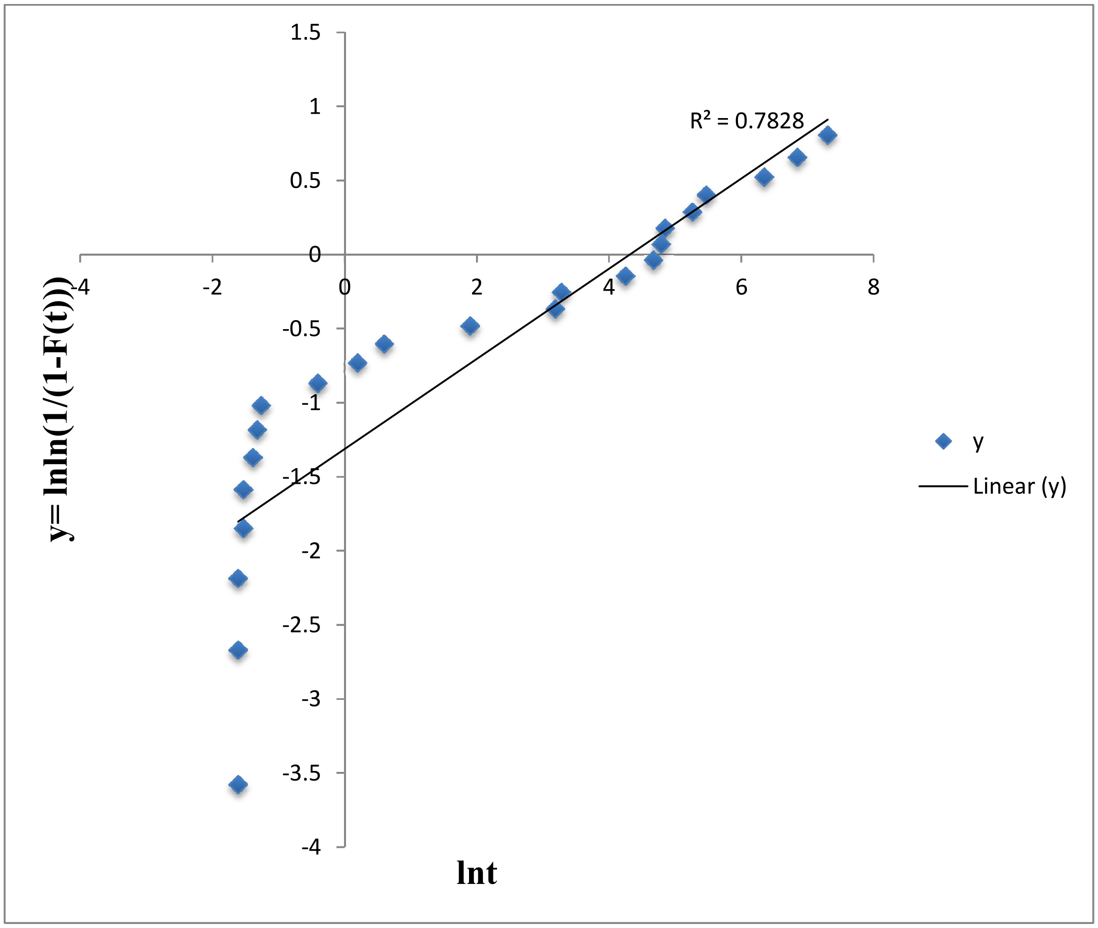

Fig. 3. Weibull least-squares plot of failure data

3.2.4 Analysis of BTS Site (RV0421)

The following failures were obtained after rank-ordering of 28 failure times obtained from BTS site (RV0421).

Number of failures, *n* = 28

From equation (3)

$F(t_i)$ = (*i*-0.3)(*n*+0.4)
i = 1,2,3,…,28
For *i* =1 and *t* = 0.12hr

F(t_i) = (1-0.3)(28+0.4) = 0.0246 (23)

Int_1 = In(0.12) = -2.1484 (24)

From equation (4)

y_i= InIn(1/(1-F(t_i)))

y_1= InIn(1/(1-0.0246))

y_1= = -3.6906 (25)

The following procedure was repeated to obtain values for y_2 , y_3 , $y_{4,}$ y_5 , …, y_{28} and also for corresponding Int_i values as seen in Table 11. A Weibull plot of $x_i = \ln t_i$ versus y_i = InIn(1/(1-F(t_i))) is constructed as seen in Fig. 4.

Table 12. Weibull distribution parameters for RV0421

Slope (β)	θ	r
1.896485	4.486904	0.984888

From Fig. 4, the graph shows that a linear relationship exists. A least-squares fit is applied yielding the shape parameter (*β*), scale parameter (*θ)* and index of fit, *r* as seen in Table 12 where *θ* = 4.4869 and *β* =1.8965. The index of fit, *r* = 0.9849 indicates a strong linear fit to the data.

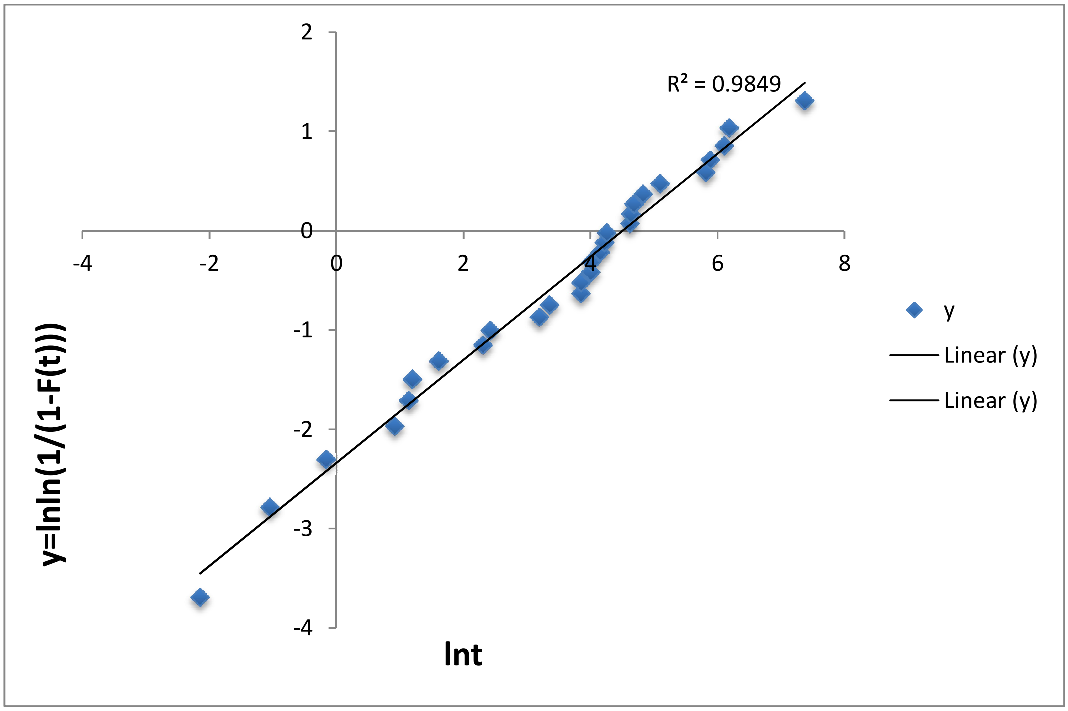

Fig. 4. Weibull least-squares plot of failure data

MTTF = 1/ β = 0.527 (26)

The sample MTTF, hr, is obtained from averaging the 34 failure times (sample mean).

The reliability of the BTS site is calculated, using

$$R(t) = e^{-(\frac{t}{\theta})\beta}$$

t = 6 months = 24*28*6 = 4,032 hr Assumed 28 days = 1 month

From Table 6, β = 1.8965 θ = 44,869 hr

$$R(4032) = e^{-(\frac{4032}{44869})1.8965}$$

$$R(4032) = 0.8433 \quad (27)$$

The reliability of BTS site RV0421 is approximately 84%.

The calculated reliability of the four BTS sites for the 6-month study is tabulated as shown in Table 13.

Table 13. Reliability of individual BTS site

RV0144	RV0686	RV0248	RV0421
0.9136	0.8805	0.7620	0.8433

To compute the overall BTS network reliability, we apply the parallel system reliability formula as stated in equation (28);

$$R_s = [1-(1-R_1)(1-R_2)(1-R_3)(1-R_4)] \quad (28)$$

Where

R_s = System reliability,
RV0144 = R_1
RV0688 = R_2
RV0248 = R_3
RV0421 = R_4

$$R_s = [1-(1-R_1)(1-R_2)(1-R_3)(1-R_4)]$$

$$= 1-(1-0.9136)\,(1-0.8805)(1-0.7620)(1-0.8433)$$

$$= 1-(0.0864)(0.1195)(0.238)(0.1567)$$

$$= 1-0.0003850593$$

$$R_s = 0.9996$$

The reliability of the BTS Network is 0.9996 (99.96%).

3.3 Discussion of Results

From the analysis carried out on the failure times obtained from each of the four Base transceiver stations, BTS site RV0248 has the maximum value of shape parameter, β = 2.5 while BTS site RV0144 has β = 1.3 which is the minimum as seen in Tables 10 and 6 respectively. The value of the shape parameter (β) was found to be between the range of $1< \beta < 3$ for all the BTS stations studied. This means that the probability density function is skewed and the failure rate of the BTS stations is increasing. Probable cause of failure is aging (wear-out) of components which can be reduced by preventive maintenance and parts replacement technology. The probability density function is skewed.

The Weibull plots for the four BTS sites had a good index of fit, r, ranging from 0.78 to 0.98 which shows that a strong linear relationship exists as seen in Figs. 1 to 4. BTS site RV0421 produced the highest value of index of fit, r, yielding 0.98. BTS site RV0144 recorded the lowest number of failures, n = 8 while BTS site RV0686 has a total of 34 failures.

The value of the scale parameter (θ) was found to be increasing as the number of failures decreases. This can be seen in BTS site RV0144 which had the highest value of θ = 59,204 hrs with number of failures, n = 8. From our results for reliability in equations (5), (10), (15) and (20), the reliability of the four BTS sites were found to be increasing as their values of scale parameter, θ increases. BTS site RV0144 had a scale parameter, θ = 59,204 hrs which resulted in a reliability of 0.91 (91%); BTS site RV0686 had a reliability of 0.88 (88%) for θ = 50,686hr; BTS site RV0421 yielded a reliability of 0.84 (84%) when θ = 44,869hrs and BTS site RV0248 had the lowest reliability of 0.76 (76%) for θ = 38,179hrs.

Table 13 shows the reliability of the four BTS sites studied. The results indicate that BTS site RV0144 had the highest probability of survival in the 6-month data studied. On the other hand, BTS site RV0248 had the lowest reliability. The overall reliability of the four BTS sites was computed using equation (28). The value of 0.9996 was obtained.

4. CONCLUSION

The reliability assessment of a Base Transceiver Station (BTS) has been studied. This study includes the rank-ordering of the failure times of each of the four BTS sites used as case study, the determination of the probability of failures of each BTS site, a Weibull least-squares plot to determine the Weibull scale parameter, θ and Weibull shape parameter, β of each BTS site, the determination of the Mean Time to Failure and Reliability of each BTS site.

The failure times obtained from the four BTS sites were analysed using 2-parameter Weibull failure distribution method. The estimates of Weibull parameters θ and β were obtained from the Weibull least-squares plots constructed. The reliability of each BTS site was successfully computed. From the results obtained, BTS site RV0144 was the most reliable while BTS site RV0248 had the lowest reliability.

In this study, the failure times of four Base Transceiver Station (BTS) sites was successfully analysed by 2-parameter Weibull failure distribution method and the reliability of each BTS site was successfully determined.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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