



Failure Assessment of Differential Unit of Automobile: A Case Study

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ABSTRACT

The Dissertation presents differential unit failures on behalf of Toyota vehicles assessed, built upon professionals' judgment. And this was finished by means of statistics collected by means of approach established on verbal dialogs and survey on failures of differential unit repair. Data obtained were assessed using a statistical approach. With this approach, failure probability for each model of Toyota vehicles namely Corolla, Hilux van, and Hiace buses was assessed. The results collected indicated that Hilux and Corolla vehicles had low catastrophe level on the first time while Hiace motor vehicle had more catastrophe level. Earlier, every model of Toyota vehicles observed had their failure rate put together with fixed and steady reliability. As part of this research, 3-sigma quality application presented auxiliary dependability by better-quality Toyota applies oil lubricant method mostly in gears. This revealed Hilux with 94.6% reliability, Corolla 89.6%, and Hiace 73% reliability. The numerical results, from the Bayesian analysis using Matlab program, presented Hilux and Corolla with the highest reliability. This show that more enlightenment adverts among all Toyota Industries will increase the reliability of the differential unit for Hiace buses.

Keywords: Differential Unit Negligence, Statistical Examination, Sigma value, Bayesian analysis.

1. INTRODUCTION

The conveyance sectors are an essential part of the national economy of any nation and a popular tool for innovation and development (Glen, 2007; Duncan and Lars, 2011). This is true in an international frugality wherever financial chances remain progressively linked towards flexibility of individuals & roadsides investment (Andreas, 2007; Todd, 2005; Todd, 2010). The transportation of information, goods, and people is made possible by means of road, water, rails, air, space, pipelines, and cables. Conveyances through roads are mostly public as it is of low cost (Daniel, 2007; David and Others, 2001). Toyota Vehicles such as corolla, buses, Hilux vans, Land cruisers are used for transportation purposes. Therefore, Toyota industry played an important part on financial growth of some people in some regions of conveyance of underdone resources & belongings towards consumers from the manufacture trades. Improvement in the enactment quality, conveyance area would be beneficial to the national economy (Todd, 2010). However, the motorized manufacturing continuously facing fresh tests by way of request on behalf of low-cost & great excellence mechanisms surges. Therefore, to ensure the design and manufactured of components by enough excellence towards endure variability of facility environment, extreme diligence must be imparted (Suess, 2004). Over the events that such components fail, it's domineering which is main reason of miscarriage should be resolute rapidly & precisely.

2. MATERIALS & METHODS

Most engineering problems are resolved created on initial values or by the sequencer of severe scientific research. Nevertheless, useful results can also determine through learning in what way components act at preparation & their failure mode. As utmost manufacturing negligence has opinions of harmony by any other and earlier examined disappointments and the practical results of such knowledge are the control since way of assessments in proposal, and manufacturing and, utilization of result in component designs. Such understanding can only be achieved through statistical approach using the Bayesian model to predict the condition necessary for reliability of components.

2.1 Materials

Data were obtained from some selected Toyota workshops logbook in Port Harcourt. All of them are listed archives of annual maintenances among 2009 & 2015 & working figures screening number of foremost failure & year of checking out. While dispensation of information on behalf of that assessment effort & key emphasis remained subsequent analytic methods which were being cast-off to observe & measurement of probability and reliability of differential component: poor differential unit failure, wear, improper installation, operation beyond designed capability and the used of inferior oil figures 3.2 and 3.3. The

focus automobile selected was from between 10-18 years old (with average of 14 years) and mileage covered, of between 100,000-160,000 km (with average of 130,000 km). The models of Toyota vehicles covered are Toyota Corolla, Hilux van, and Hiace buses serviced by Toyota workshops X, Y and Z, respectively. The total numbers of repaired vehicles per year, in the stated Toyota workshops, for the period of 2009-2015 were 52 Corollas, 37 Hilux, and 88 Hiace buses. The component presentation was evaluated by means of subsequent considerations resolute continuously on yearly source.

2.2 Governing Equation

In other to analyze quantitatively the failure rate of the differential components, a heuristic approach has been employed. Characterizing the probability of success as Reliability. The probability of the failed component can be gotten from the relations in equation (2.1) and the reliability in equation (2.2).

$$\left(\text{Probability of failure} = \frac{\text{Numbers of failed components}}{\text{Total numbers of repairs}} \right) \tag{2.1}$$

$$(\text{Reliability} = 1 - \text{Probability of failure}) \tag{2.2}$$

2.3 Posterior Probability and Bayesian Analysis

Bayesian System or possibility system which states ambiguity in data & commonsense suggestions. Bayesian system, an absorbed a cyclic chart wherever bulges signify inexact variables. Connections among variables are assumed through conditional probability table (CPT). By usage of actual information, information of specialists, system could use to compute prospect of existence of concluding result. Bayesian constraint knowledge is an assessable examination technique just to examine requirement & communication of variables founded by Bayesian System. Concluding production is provisional prospect of every bulge. Bayesian system constraint knowledge is worthy technique to examine variables which influence humanoid actions & enumerate inspiration of manufacturing project (Pin-Chao & others, 2016). A preliminary prospect declaration to assess predictable outcome known as preceding prospect dispersal, but if probability statement is being studied due to additional information, then such a probability statement known as posterior prospect dispersal. Examination of difficulties by means of posterior prospects through novel predictable outcome and supplementary data known as preceding-subsequent examination (Sharma 2013).

2.4 Bayes' Theorem Statement

Assume A_1, A_2, \dots, A_n be a commonly exclusively comprehensive results. And their prospects $P(A_1), P(A_2), \dots, P(A_n)$ are identified. There is an experimental outcome B for which the conditional prospects $P(B|A_1), P(B|A_2) \dots P(B|A_n)$ is also identified. Assumed data whose result B is happened, reviewed provisional prospects of results A_i , that is $P(A_i|B)$, $i = 1, 2, \dots, n$ is being examined through by means of subsequent association:

$$P(A_i|B) = \frac{P(A_i \text{ and } B)}{P(B)} = \frac{P(A_i \cap B)}{P(B)} = \frac{P(A_i)P(B|A_i)}{P(B)} \tag{2.3}$$

Where

$$P(B) = \sum_{i=1}^n P(A_i)P(B|A_i)$$

Meanwhile every combined prospect could be articulated by way of merchandise of a recognized bordering (former) & conditional probability, i.e.,

$$P(A_i \cap B) = P(A_i) \times P(B|A_i) \tag{2.4}$$

The Subsequent prospects (achievement/dependability or miscarriage of differential unit) With reference to the failure and reliability appendix A1 for numerical computation established on novel enhanced engineering excellence data (3-sigma/6-sigma) is possible applying equation 2.3. The differential unit miscarriage results remained exposed towards development plans touching since earlier excellence condition, 3-sigma to 6-sigma excellence figures. All of the progress policies disclose tendency of repeated development (dependability) of organization. 6-sigma excellence of 99.99966% of faultless, not more than 1% nonconformance each billion chances & 3-sigma excellence data of 93.3% conformance, not more than 6.7% nonconformance remained practical by way of incessant development tackles in motorized segments. Sigma excellence capacities remained practical toward inaugurate wherever motorized segments & they must be progressive engineering of excellence artefact/scheme. Formerly founded on binomial delivery & component experimental on difference important toward choices; conformance (approved) or nonconformance (miscarried), provisional prospects of a result $P\{A_i\}$ after specified 6-sigma excellence development being obligatory, which are as tracks:

$$P\{A_1 \setminus B_1\} = C_1^1 (0.99999)^1 (0.00001)^0 = 0.99999$$

$$P\{A_2 \setminus B_1\} = C_0^1 (0.99999)^0 (0.00001)^1 = 0.00001$$

$$P\{A_1 \setminus B_2\} = C_1^1(0.99999)^1(0.00001)^0 = 0.99999$$

$$P\{A_2 \setminus B_2\} = C_0^1(0.99999)^0(0.00001)^1 = 0.00001$$

Table 2.1: Probabilities $P\{A_i B_i\}$

$A_i B_i$	A_1	A_2
B_1	0.99999	0.00001
B_2	0.99999	0.00001

Combined prospects $P\{A_i B_i\}$ are calculated by tabularized probabilities through increasing his primary commotion through reliability and its second row by failure. The results are tabularized as tracks $P\{A_i B_i\}$;

Table 2.2: Joint Probabilities $P\{A_i B_i\}$

$A_i B_i$	A_1	A_2
B_1	$0.99999(1 - f)$	$0.00001(1 - f)$
B_2	$0.99999(f)$	$0.00001(f)$

$P\{A_i\}$ Are obtained using equation (2.3) as $P\{A_1\} = 0.99999$, $P\{A_2\} = 0.00001$. Subsequent prospects are being found by means of equation (2.5) through separating pillars of former tabularized prospects among consistent $P\{A_i\}$.

Applying the Bayern’s statement for the reliability of the differential unit component, the procedure of equation (2.5) remained cast-off to calculate the limitations. And results remained cast-off to regulate enhancements in difference component dependability (fractions) since years,

$$R_{new} = R + \frac{R \times F}{T} \tag{2.5}$$

Where

R_{new} = New probability of success (reliability)

R = probability of success in failure

F = number of failure

T = total sampled

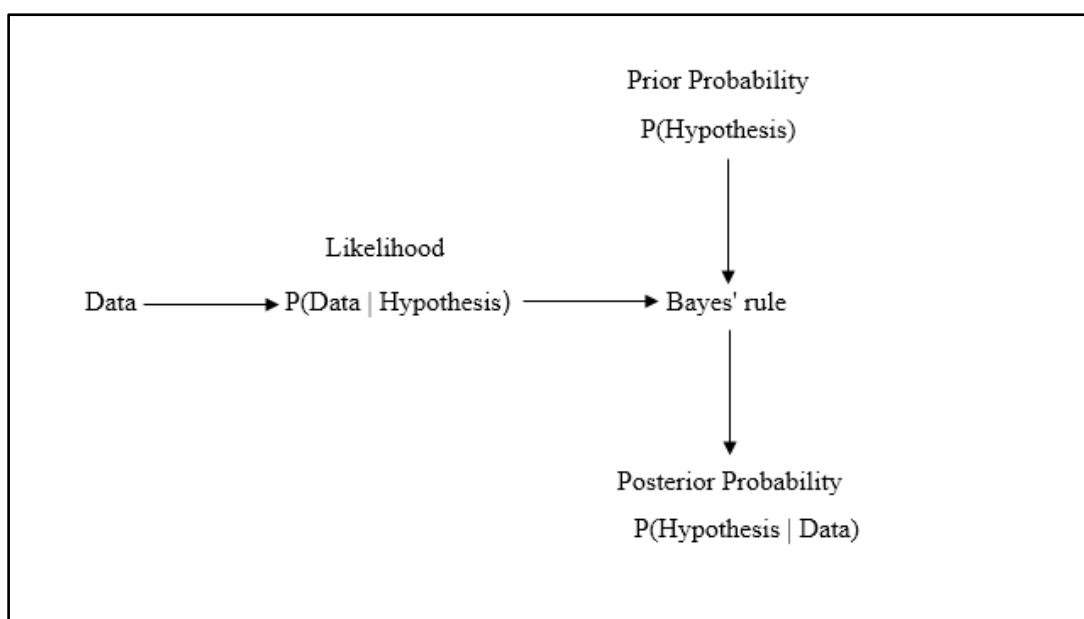


Figure. 2.1: Schematic Representation of Bayes Rule

2.4 Numerical analysis

By means of subsequent supply will allow an investigator to bring up-to-date strategy afterward individually remark & evade extremely prejudiced approximations by initial steps. Though, informing an earlier on base of a slighter amount of explanations than amount of projected limitations is hard job & subsequent would classically has an intricate procedure. On the way to

overwhelm that trouble a Bayesian estimate which feats a discretization of stricture interplanetary have been suggested. First the prior distributions have been represented by a large sample of discrete vectors founded on chance model from the same distribution, and computation of likelihood for each of these vectors will be recorded.

Bayesian Subsequent Intermission permits clarification of information, the technique that agrees approximation of subsequent info even after sealed method of later is actual compound which have been propose, misusing of discretization of previous delivery. That essential for later delivery is fairly recurrent & it's been cast-off aimed at examining minor example information among general lined replicas. By means of reversion methods for GLM by minor examples aren't consistent & frequently extremely unfair. Consecutive new project previously covers that operation. The m file in appendix A.2 comprises binomial method. X0 comprises site of testing; R Result comprises replies experiential (0/1). Four conspiracies have been provided (1) Performance of previous through an example of likely separate opinions; (2) Performance of subsequent through separate opinions; (3) Performance of previous through an example of likely arcs; (4) Performance of later intermission verses new Bayes sureness intermission. Shown in figure 2.1 is a diagram of a hierarchical causes and modes of differential unit failure. And figure 2.2 presents the proposed differential unit reliability improvement strategy while figure 2.3 is a schematic diagram of differential component

Table 2.3: Differential unit repairs and failures data (2009-2015)

S/N	Vehicle Model	Workshop	Years	Y	Vehicles Repaired per year, Ry	Numbers failure per year, Fy
1	Corolla	Workshop X	2009	1	52	16
			2010	2		13
			2011	3		10
			2012	4		8
			2013	5		6
			2014	6		4
			2015	7		2
2	Hilux Van	Workshop Y	2009	1	37	12
			2010	2		10
			2011	3		8
			2012	4		4
			2013	5		2
			2014	6		3
			2015	7		6
3	Hiace Bus	Workshop Z	2009	1	88	28
			2010	2		22
			2011	3		14
			2012	4		8
			2013	5		7
			2014	6		4
			2015	7		2

Source: Toyota workshop Port Harcourt

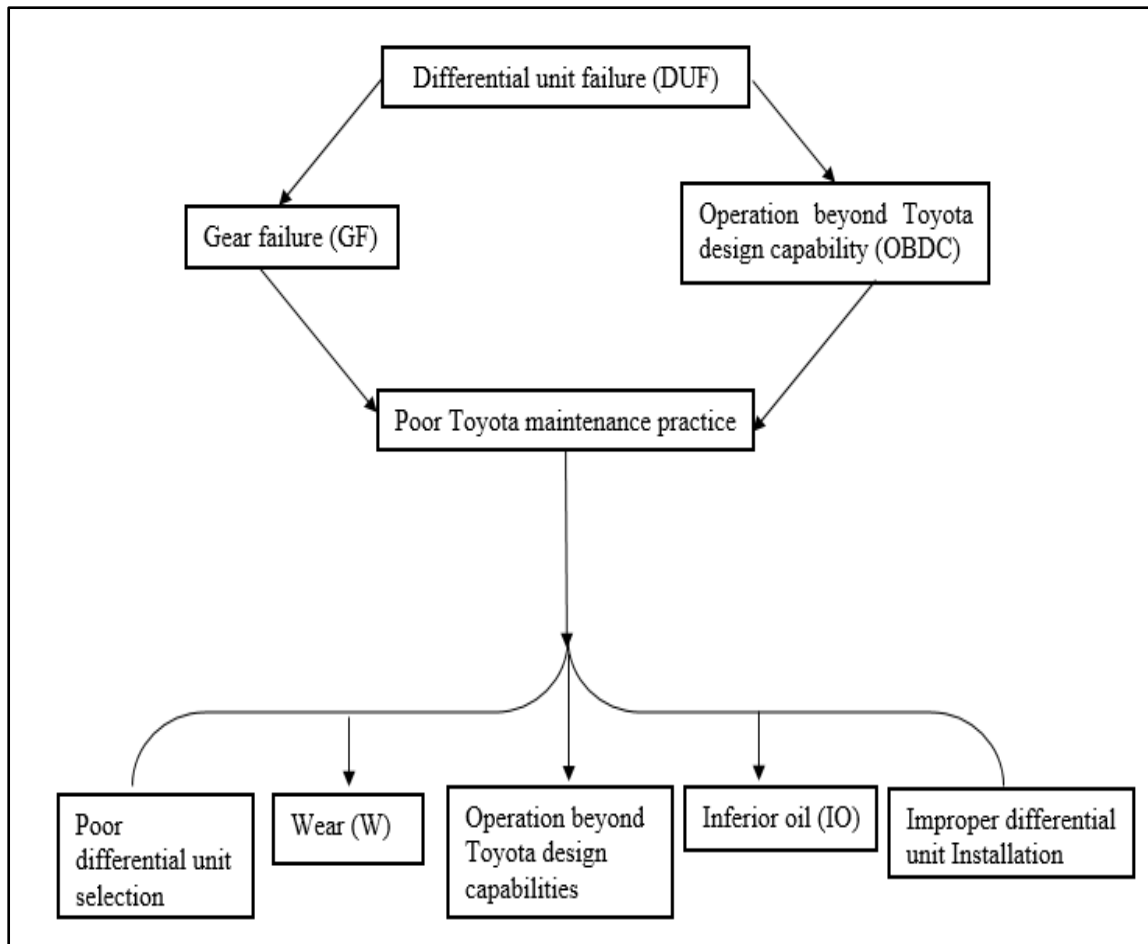


Figure 2.2: Categorized reasons & styles of differential unit miscarriage

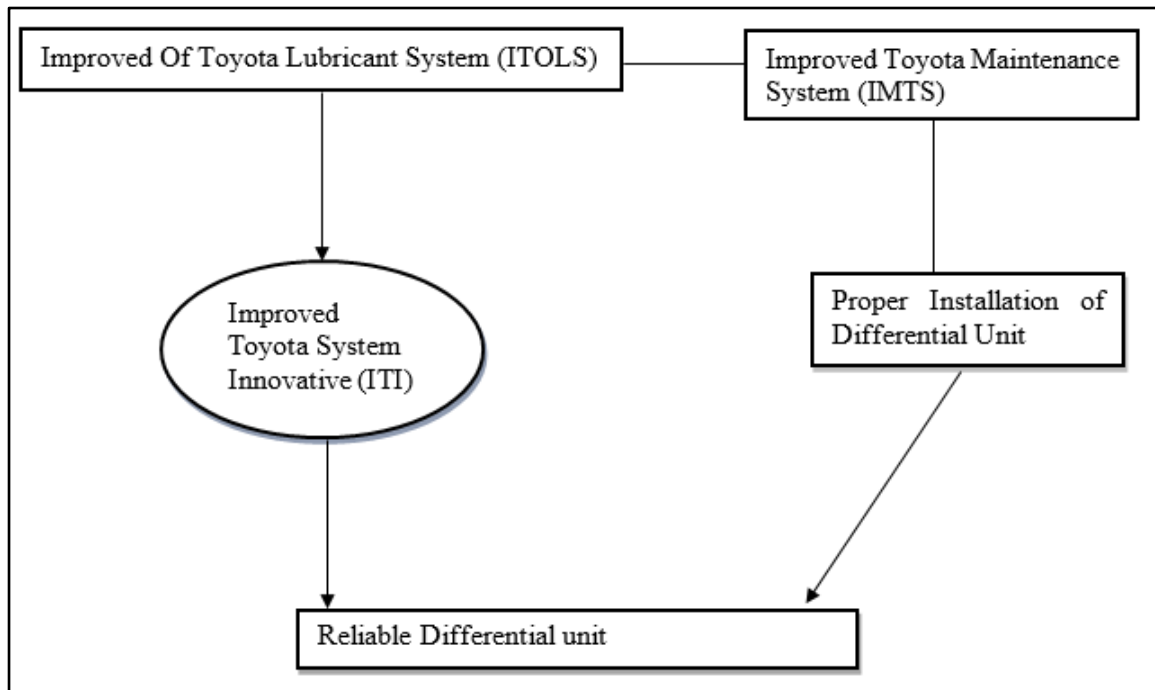


Figure 2.3: Future differential unit dependability upgrading plan

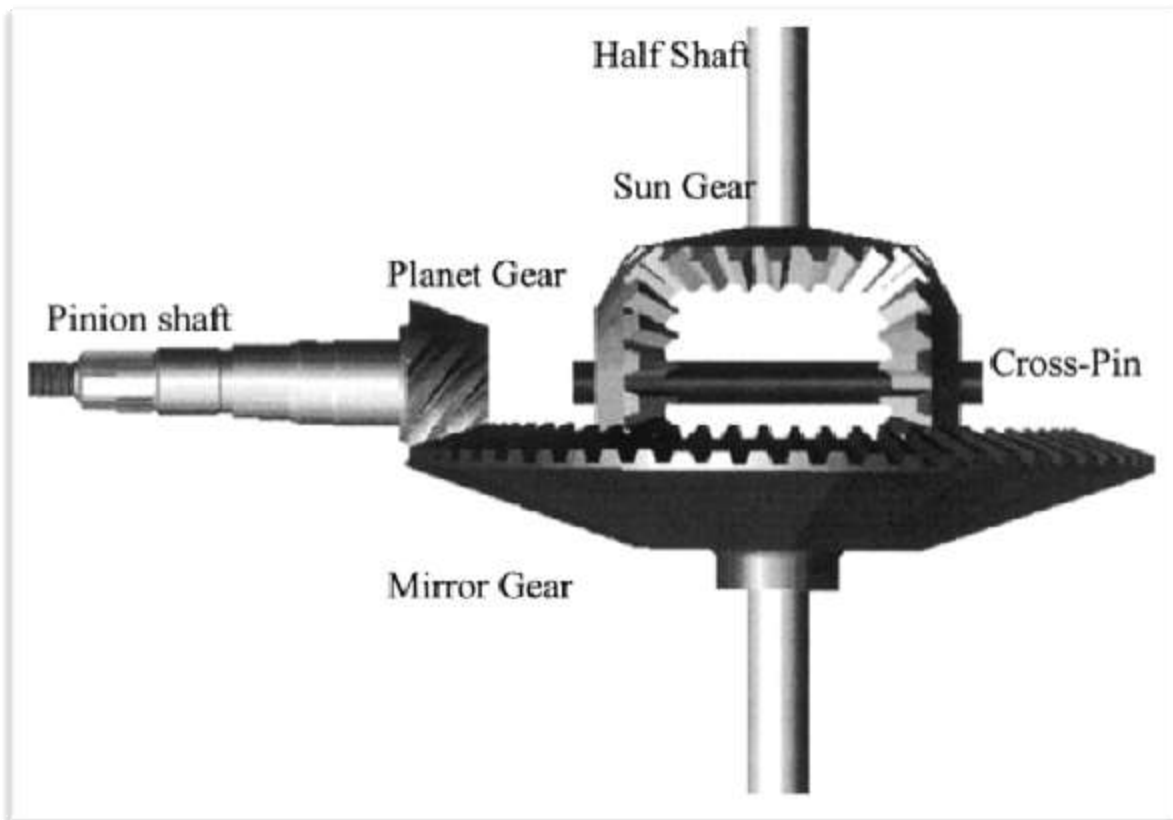


Figure2.4: Differential component

3. RESULTS AND DISCUSSION

In this research, Bayes have been a better tool because of the "the prior." (Having reason to believe something about the research before beginning estimation and to use the information to improve the estimate). The previous confidences are valuable once cast-off correctly & ample safeguard in which every indication ropes aspiring rational uncertainty cast-off indecorously. Likewise, Bayes approaches are uniting outline aimed at schmooze around dissimilar approximation methods. It was realized that many circumstances are responsible to immediate failure in Toyota differential unit when the mean repair years of vehicle is limited to 14years and the corresponding average mileage is limited to 130,000 km. These prior knowledge include; improper installation of differential unit, poor differential unit selection, operation beyond Toyota design capabilities of differential unit, poor Toyota service practice, which can be amended with new technology through Toyota oil lubricant system, and an improved Toyota service culture. The average limits of vehicle mileage covered before differential unit miscarriage archives might be accredited toward bad boldness of Toyota vehicle operators are not succeeding the normal service repetition which is absorbed through Toyota builders.

In the failure probability assessment figure 3.1, the results got showed decreased in the failure rate of the vehicles under investigation. Hilux (Y) in 2009,-2011 and 2014-2015, have highest failure probability, and closely followed by Toyota Corolla, but the Hiace buses (Z) was seen with lower failure rate. These failure probabilities showed an improvement in technology of differential unit and the maintenance culture developed by the hiace bus drivers.

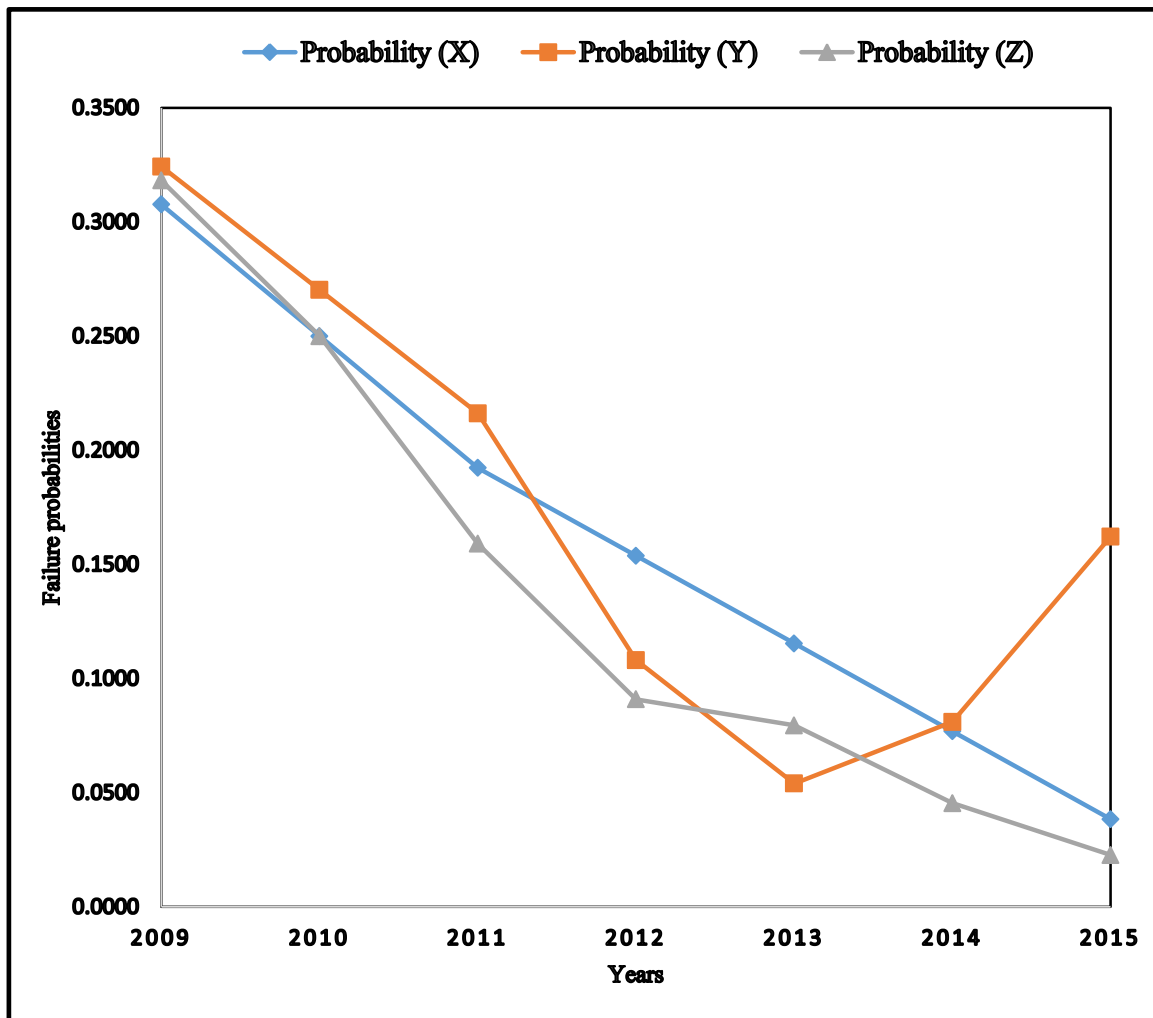


Figure 3.1 probability of failure

Figure 3.2. Shows that reliabilities of differential unit have improved rapidly at all models of repaired automobiles & it reach it maximum in 2015. That is equal to period of smallest disappointment degree. That shows, around positive changes through ages on Toyota differential unit dependability. As shown in figure 4.1 and 4.2, the failure probability and reliability of the corolla vehicle decreased and increased respectively at a regular interval while that of the other two vehicle Toyota Hilux and Hiace buses has increased and decreased across the years. This is evidence that the Toyota Hilux and corolla users did not use the Toyota, vehicles load capacity limit and also did not carry out regular maintenance. Which have resulted in misalignment of differential unit? This is due to excessive torque pressure build up in the differential unit. However, causes of failure are mostly likely to be due to irregular service either in oil system of differential or use of inferior Toyota engine oil. Irregular service of differential unit is very unusual among the users of Hilux and corolla since these vehicles are not used for business purposes. Also not only mechanical circumstances cause failure of differential unit, ergonomic factors are also involved.

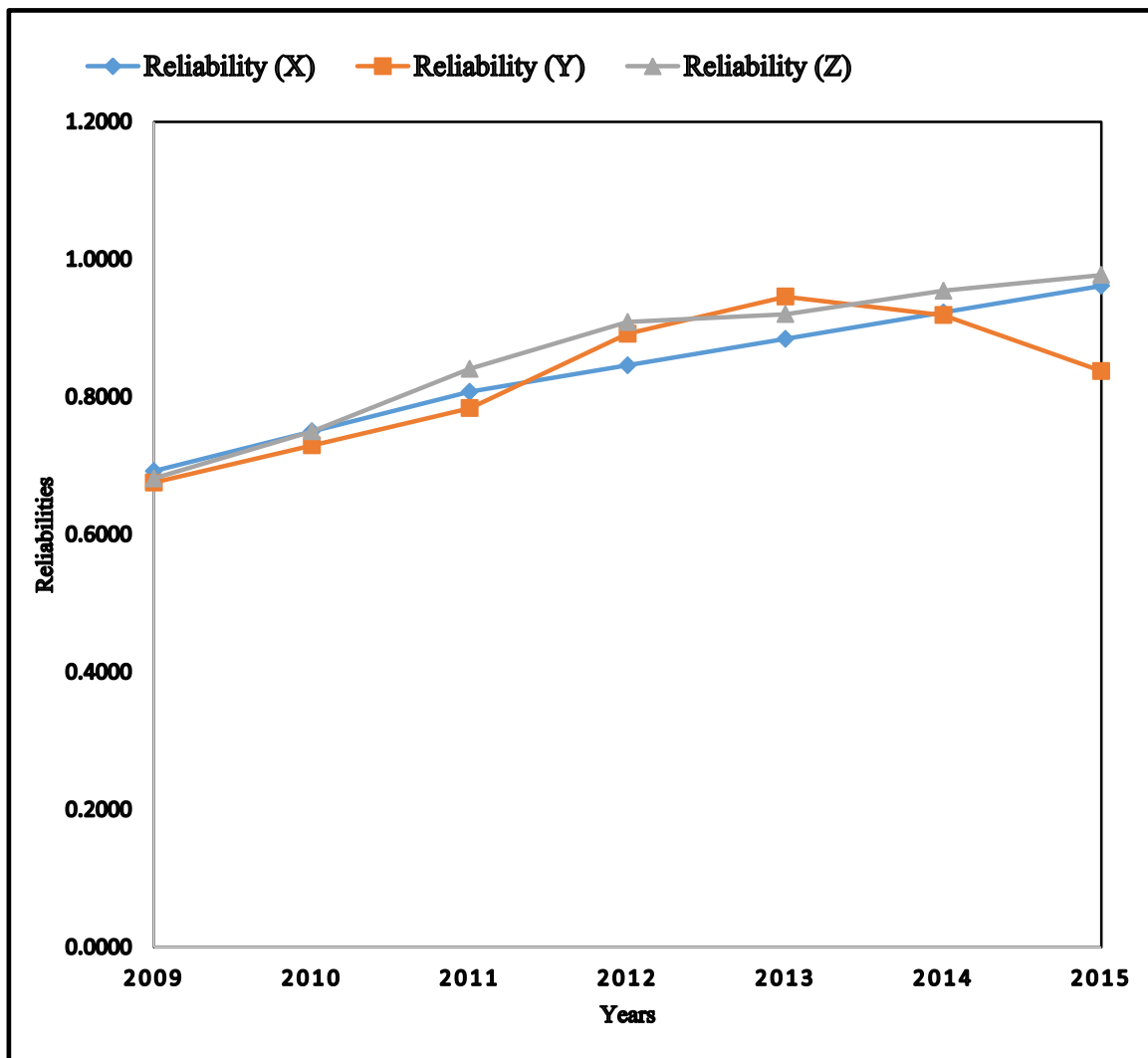


Figure 3.2: Dependability

Consequences attained after functional incessant development system founded on 6-sigma & 3-sigma excellence developments on oil lubrication scheme on specified stage (time) & bounds are obtainable in Tables 4.1 and 4.2, correspondingly. That examination remained approved available to distinguish whether is there slightly additional development chances or not, behind lifetime expectation (dependability) of differential unit. After consequences, this container be inferred that two of those 6-sigma and 3-sigma did fine after functional on fruitful difference component to found likelihood tendency of incessant development of ages.

Table 3.1 present the 6-sigma probability and reliability of the differential unit for the tested automobile vehicle under study from 2009 to 2015. The probabilities and reliabilities for the different vehicle under study. These values are further used for the improvement analysis. The changes in consistencies of dual arrangements (previous & later) presented no palpable development, as outcomes are zero. When equation (3.5) is applied for the improvement analysis. This shows that the 6-sigma is not suitable for this analysis.

Table 3.1: 6-sigma probability and reliability

Year	Probability	Reliability (X)	Probability (Y)	Reliability (Y)	Probability (Z)	Reliability (Z)
2009	0.3077	0.6923	0.3243	0.6757	0.3182	0.6818
2010	0.2500	0.7500	0.2703	0.7297	0.2500	0.7500
2011	0.1923	0.8077	0.2162	0.7838	0.1591	0.8409
2012	0.1538	0.8462	0.1081	0.8919	0.0909	0.9091
2013	0.1154	0.8846	0.0541	0.9459	0.0795	0.9205
2014	0.0769	0.9231	0.0811	0.9189	0.0455	0.9545
2015	0.0385	0.9615	0.1622	0.8378	0.0227	0.9773

Table 3.2 present the 3-sigma probability and reliability of the differential unit for the tested automobile vehicle under study from 2009 to 2015. The probabilities and reliabilities for the different vehicle under study. These values are to be used for the improvement analysis. The changes in consistencies of dual arrangements (previous & later) presented no palpable development, with outcomes in table 4.3. When equation (3.5) is applied for the improvement analysis. This shows that the 3-sigma is suitable for this analysis.

Table 3.2: 3-sigma probability and reliability

Year	Probability (X)	Reliability (X)	Probability (Y)	Reliability (Y)	Probability(Z)	Reliability(Z)
2009	0.4024	0.9053	0.4295	0.8948	0.4194	0.8987
2010	0.3125	0.9375	0.3434	0.9269	0.3125	0.9375
2011	0.2293	0.9630	0.2629	0.9533	0.1844	0.9747
2012	0.1775	0.9764	0.1198	0.9883	0.0992	0.9917
2013	0.1287	0.9867	0.0570	0.9970	0.0858	0.9937
2014	0.0828	0.9941	0.0877	0.9934	0.0476	0.9979
2015	0.0400	0.9985	0.1885	0.9737	0.0232	0.9995

Table 3.3 shows the 3-sigma continuous improvement. The 3-sigma arrangement did outstandingly all the ages & progressively touched ideal dependability presentation (near toward 100%) & advanced ages (Table 3.4). That development, though practical, suggests that lifetime expectation &/or kilometer enclosed of automobiles beforehand best of slightly difference component remain predictable toward upsurge & spread top nearly double than preceding standards in 2015. However, 6-sigma excellence development established stable inferior incessant dependability development in years than 3-sigma that reached uppermost likely dependability at initial phase of examination (Table 3.3). Progressively sluggish 6-sigma dependability development remained not maintainable in preceding dependability presentation of difference component. Changes in consistencies of two arrangements (previous & subsequent) presented no palpable development (NTI) (Tables 3.1 and appendix A) by way of results are 0.

Table 3.3: Improvement from 3-sigma

Year	Probability (X)	Reliability (X)	Probability (Y)	Reliability (Y)	Probability (Z)	Reliability (Z)
2009	0.0947	0.2130	0.1052	0.2191	0.1012	0.2169
2010	0.0625	0.1875	0.0731	0.1972	0.0625	0.1875
2011	0.0370	0.1553	0.0467	0.1695	0.0253	0.1338
2012	0.0237	0.1302	0.0117	0.0964	0.0083	0.0826
2013	0.0133	0.1021	0.0029	0.0511	0.0063	0.0732
2014	0.0059	0.0710	0.0066	0.0745	0.0021	0.0434
2015	0.0015	0.0370	0.0263	0.1359	0.0005	0.0222

From the improvement analysis, the corolla (X) has a reliability of 89.6%, the Hilux(Y) has reliability of 94.3% and the hiace bus (Z) has a reliability of 76%. These presented the Hilux with the highest reliability value. Showing a greater improvement and also the corolla them followed by the hiace bus with a reliability of 76%

Table 3.4: 3-sigma Percentage Improvement

Year	Probability (X)	Reliability (X)	Probability (Y)	Reliability (Y)	Probability (Z)	Reliability (Z)
2009	9	21.3	10.5	21.9	10.1	21.7
2010	6	18.8	7.3	19.7	6.2	18.8
2011	4	15.5	4.7	16.9	2.5	13.4
2012	2	13.0	1.2	9.6	0.8	8.3
2013	1	10.2	0.3	5.1	0.6	7.3
2014	1	7.1	0.7	7.5	0.2	4.3
2015	0	3.7	2.6	13.6	0.1	2.2
%		89.6		94.3		76

Also, the actual results gotten from the failure assessment figure 3.3 to 3.5 indicate that numbers of differential unit failures was reducing constantly with time for all models of the Toyota vehicles, except the Hiace buses used for business purpose. The main reason for this abnormally for Hiace buses may likely be vehicle overloading, and the poor routine service by portion of operators or usage of inferior Toyota lubricant grease. Inferior grease attributed to weaken of oil lubrication system of differential unit. In the overall, the consequences displays the prospects of differential unit disappointments reduced progressively through period aimed at 3 models of Toyota automobiles that was assessed. This may be that users of the Toyota vehicles were servicing their vehicles, also it could be as an improvement in technology in manufacturing differential unit. Therefore, for optimal production in any production facility, there should be minimal down time for all equipment to use in the process, which entails that the reliability of this item is of high priority to the Production Engineers.

Figure 3.3 presents the responses of the corolla vehicle the prior distribution exploiting discretization, the posterior exploiting discretization, the prior distribution sample of possible curves and the 95% Bayesian posterior interval. In the curves, it is observed that some are not normally distributed depicting fair reliability

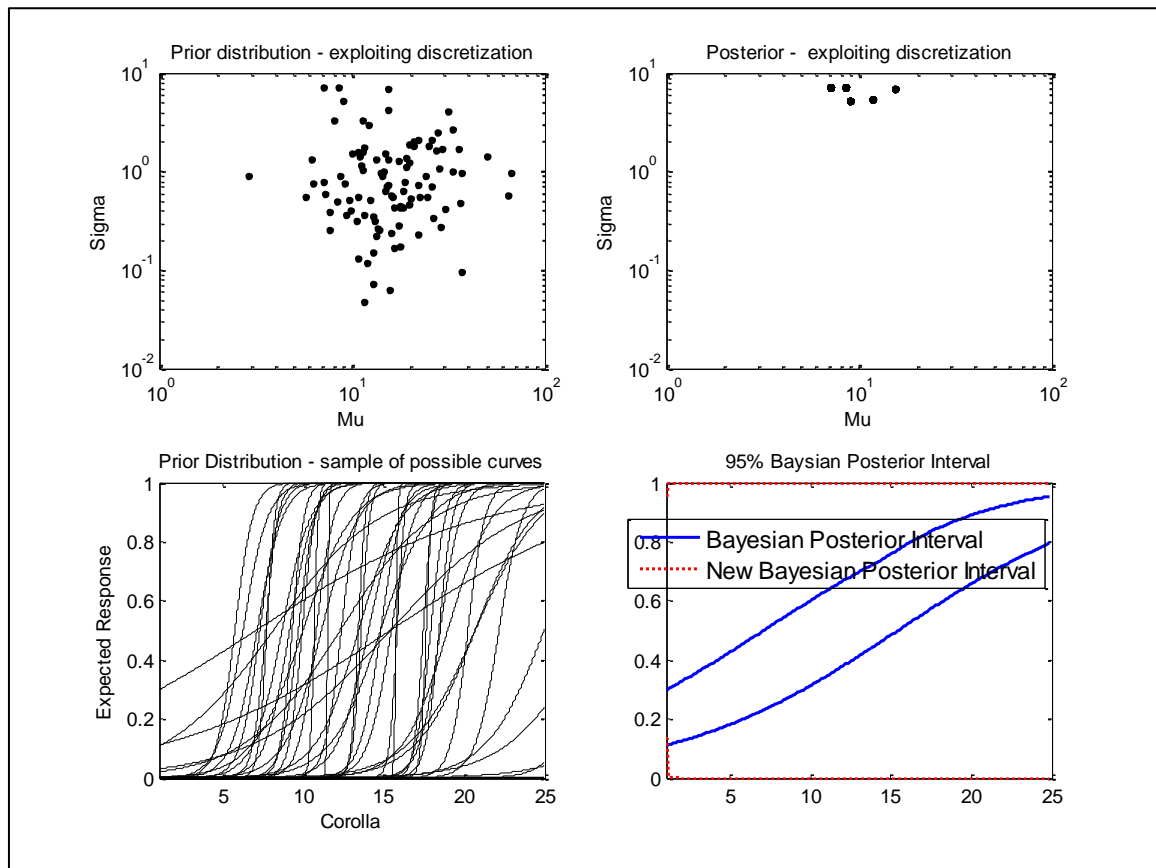


Figure 3.3 Responses of the Toyota Corolla Vehicles

Figure 3.4 presents the responses of the hilux vehicle the prior distribution exploiting discretization, the posterior exploiting discretization, the prior distribution sample of possible curves and the 95% Bayesian posterior interval. In the curves, it is observed that some are not normally distributed depicting good reliability

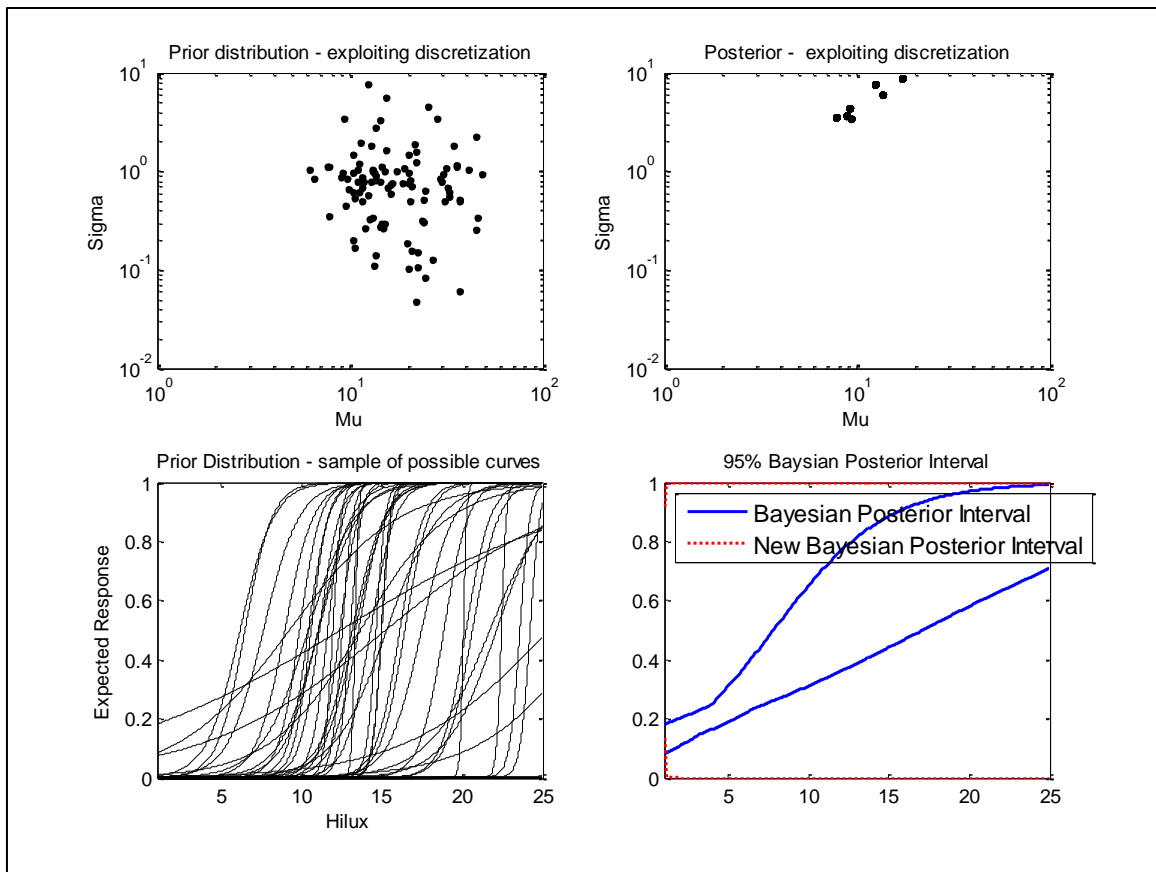


Figure 3.4 Response of the Hilux Toyota Vehicle

Figure 3.5 presents the responses of the Hiace Buses the prior distribution exploiting discretization, the posterior exploiting discretization, the prior distribution sample of possible curves and the 95% Bayesian posterior interval. In the curves, it is observed that some are not normally distributed depicting lesser reliability

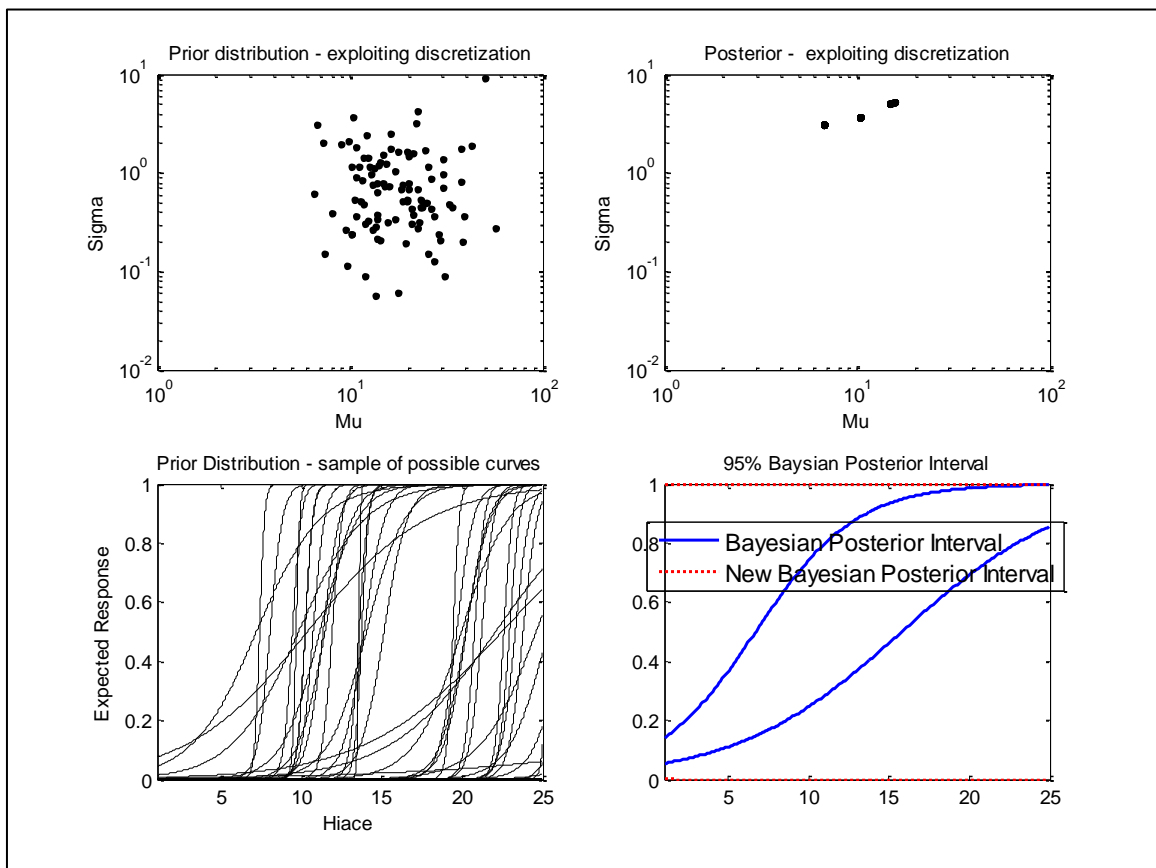


Figure 3.5 Responses of the Toyota Hiace Buses

4. CONCLUSION

In line with the objective of this work, a descriptive summary of available failure data of the component have been presented. A reliability difference over time of the component under two different conditions using excel and matlab have been carried out and the results shows that the Hilux and hiace buses differential are vulnerable to failure by the consequence of over loading and not good preservation ethos. Also, component failure probability over test time, have been compare. Generally, a whining sound in difference usually resources of sphere equipment or restrain requirements of change. Improper familiar sphere equipment or restrain avoids usual projection interaction among gears & consequently harvests fast projection attire. Uncertainty worries are not modified directly, droning sound would slowly yield on roaring comprehensive & sphere and restrain would perhaps have to be substituted. The notable causes of differential unit failure, was called for urgent attention of the Toyota manufacturers through promotion of total quality management (TQM) scheme. By novel six-sigma excellence method would recover dependability of part failed by improved Toyota oil lubricant system. Inadequate Toyota oil lubricant system as a result of oil leakages, Inferior Toyota oil, poor Toyota service practices and overloading of vehicles, may likely to have adverse effects on differential unit. This will likely cause the differential unit failure. Hence, to minimize or reduce the failure rates adequate attention must be given to the use of differential units. Outline of good schemes & usage of advanced resources would deliver a better method which will lead to attainment of TQM scheme. Good Innovations and design in the Toyota manufacturing Industry is obligatory to recover dependability of differential unit. All of the novelties can be achieved after (total quality management (TQM) & entire creative Toyota service (TPTS) wanted to use on organization.

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