SENG 637- Dependability and Reliability of Software Systems*

Lab. Report #5 – Software Reliability Assessment

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Introduction

This assignment is about understanding the basics of software reliability assessment as well as the analysis of integration test data using reliability assessment tools. In this assignment specifically, we will use the provided failure dataset for both Reliability Growth Testing and Reliability Demonstration Chart.

The following were used to complete this assignment:

- Reliability Growth Testing (RGT): `C-SFRAT`
- Reliability Demonstration Chart (RDC): `RDC-11 (an EXCEL worksheet and macro)`

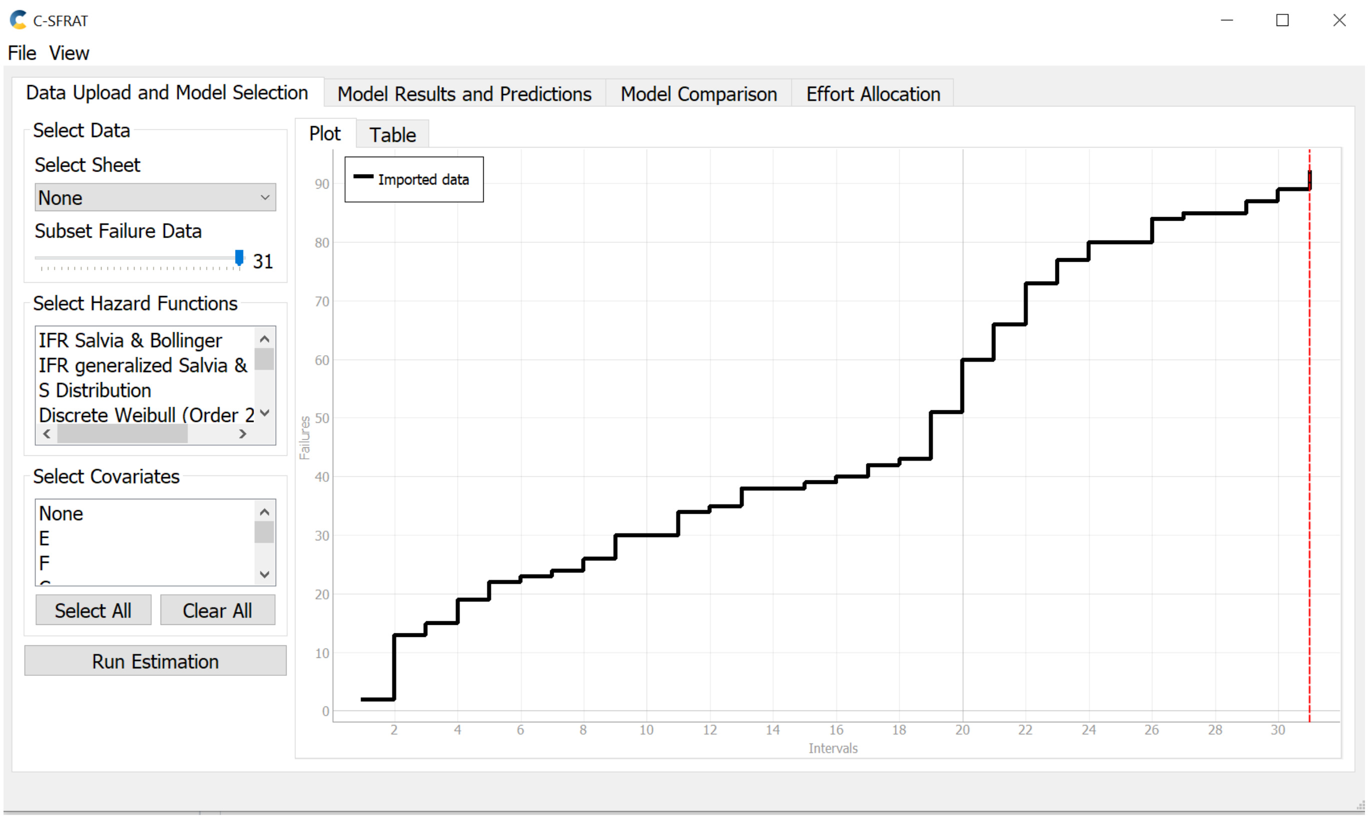
Additionally, the assignment aims to help us understand how to measure the failure rate, MTTF and reliability of the SUT through analyzing the test data.

Assessment Using Reliability Growth Testing

We decided to use the Covariate Software Failure And Reliability Analysis Tool (C-SFRAT) since it was:

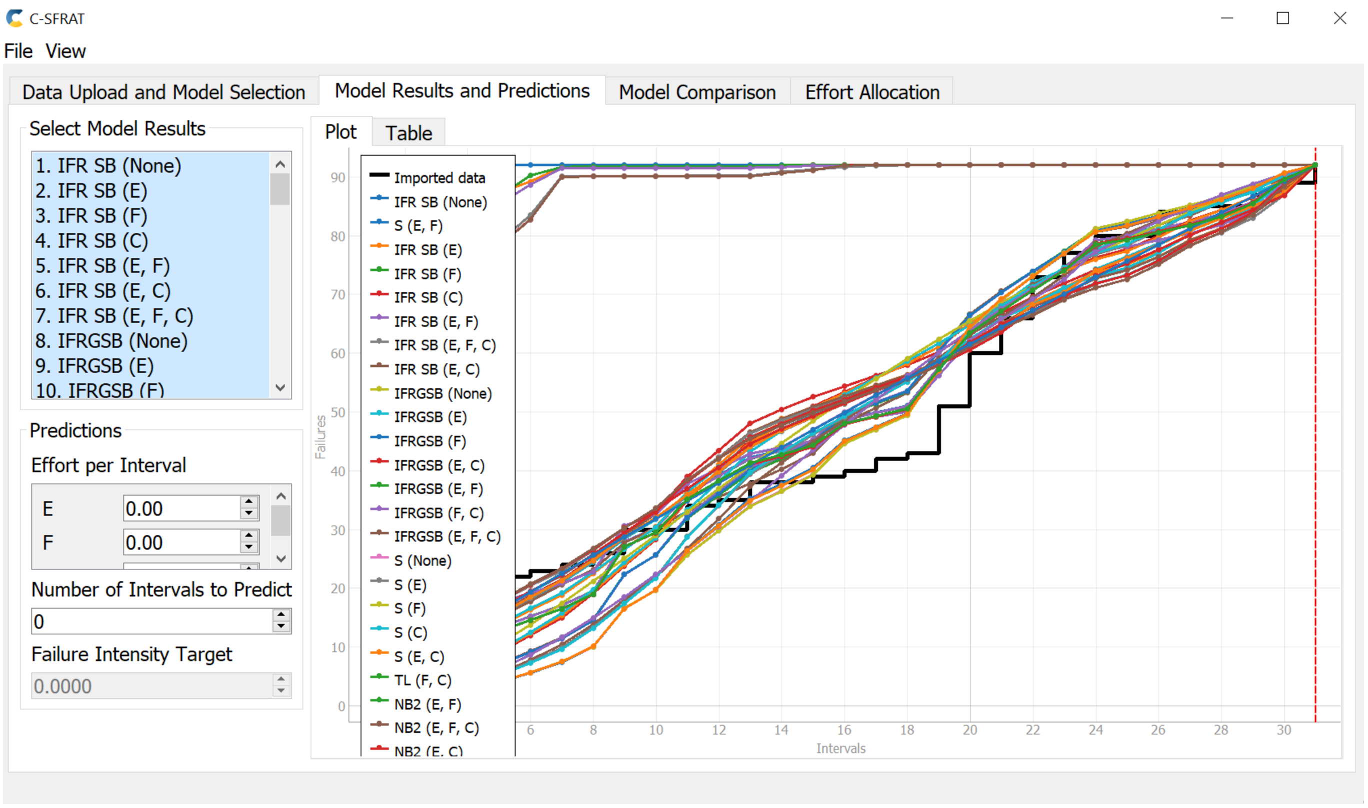
- Simple to use
- Cleaner UI than the alternative START tool.

After importing, the MVF graph below shows the imported data:



Result of model comparison (selecting top two models)

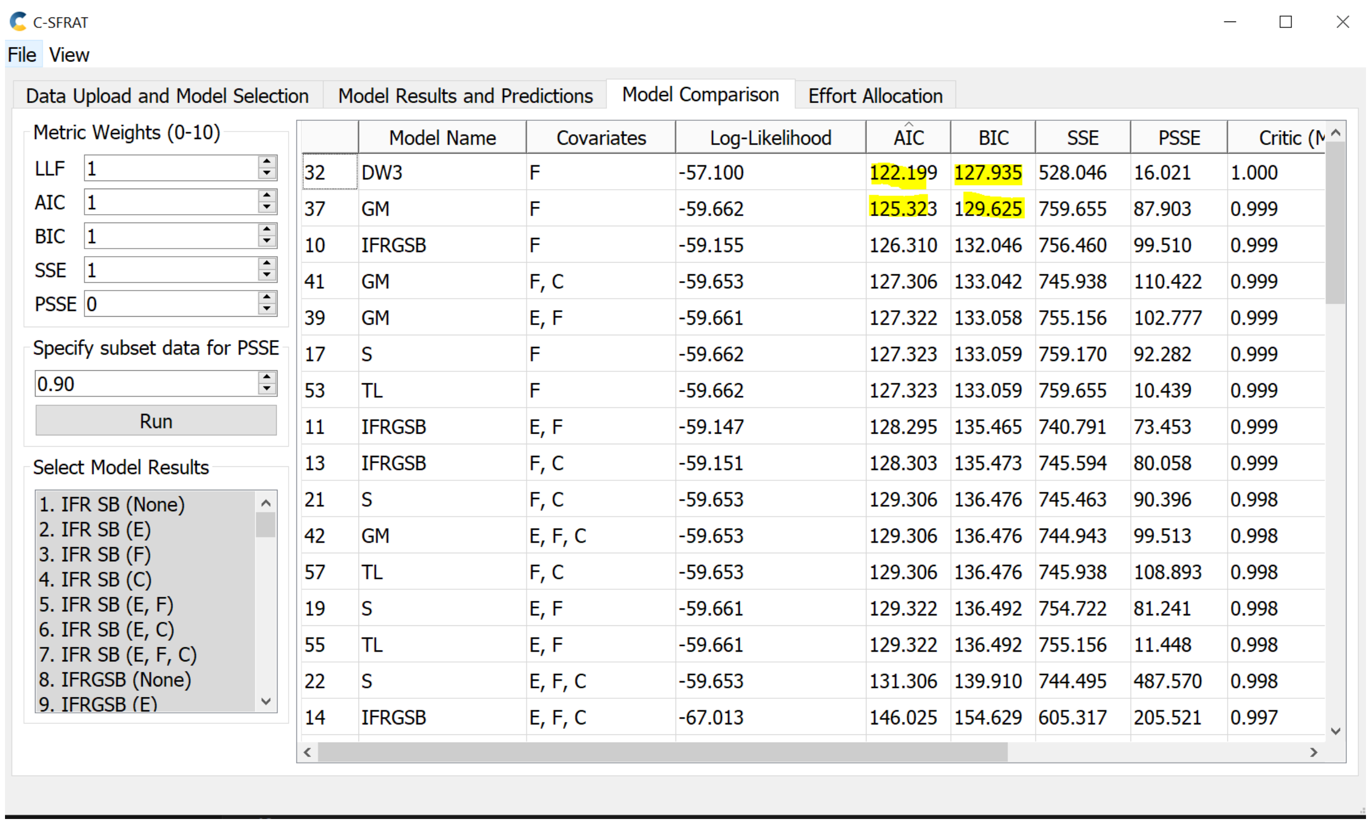
Initially, we selected all the hazard functions and all covariates for comparison. The graph below shows the results and the model fits:



Subsequently, these models were then analyzed to determine the top two models. Using C-SFRAT model comparison tab, we were able to identify the two top models by selecting the lowest Akaike Information Criterion (AIC) which balances the goodness of the fit with the complexity of the model as well as the Bayseian

Information Criterion (BIC). The lower the values of AIC/BIC, the better the trade-off between model fit and complexity.

The table below shows the comparison of all the models sorted by the lowest AIC/BIC.


C-SFRAT
File View
Data Upload and Model Selection
Model Results and Predictions
Model Comparison
Effort Allocation
Run

Metric Weights (0-10)

LLF	1
AIC	1
BIC	1
SSE	1
PSSE	0

Specify subset data for PSSE: 0.90

Select Model Results

1. IFR SB (None)
2. IFR SB (E)
3. IFR SB (F)
4. IFR SB (C)
5. IFR SB (E, F)
6. IFR SB (E, C)
7. IFR SB (E, F, C)
8. IFRGSB (None)
9. IFRGSB (E)

	Model Name	Covariates	Log-Likelihood	AIC	BIC	SSE	PSSE	Critic (M
32	DW3	F	-57.100	122.199	127.935	528.046	16.021	1.000
37	GM	F	-59.662	125.323	129.625	759.655	87.903	0.999
10	IFRGSB	F	-59.155	126.310	132.046	756.460	99.510	0.999
41	GM	F, C	-59.653	127.306	133.042	745.938	110.422	0.999
39	GM	E, F	-59.661	127.322	133.058	755.156	102.777	0.999
17	S	F	-59.662	127.323	133.059	759.170	92.282	0.999
53	TL	F	-59.662	127.323	133.059	759.655	10.439	0.999
11	IFRGSB	E, F	-59.147	128.295	135.465	740.791	73.453	0.999
13	IFRGSB	F, C	-59.151	128.303	135.473	745.594	80.058	0.999
21	S	F, C	-59.653	129.306	136.476	745.463	90.396	0.998
42	GM	E, F, C	-59.653	129.306	136.476	744.943	99.513	0.998
57	TL	F, C	-59.653	129.306	136.476	745.938	108.893	0.998
19	S	E, F	-59.661	129.322	136.492	754.722	81.241	0.998
55	TL	E, F	-59.661	129.322	136.492	755.156	11.448	0.998
22	S	E, F, C	-59.653	131.306	139.910	744.495	487.570	0.998
14	IFRGSB	E, F, C	-67.013	146.025	154.629	605.317	205.521	0.997

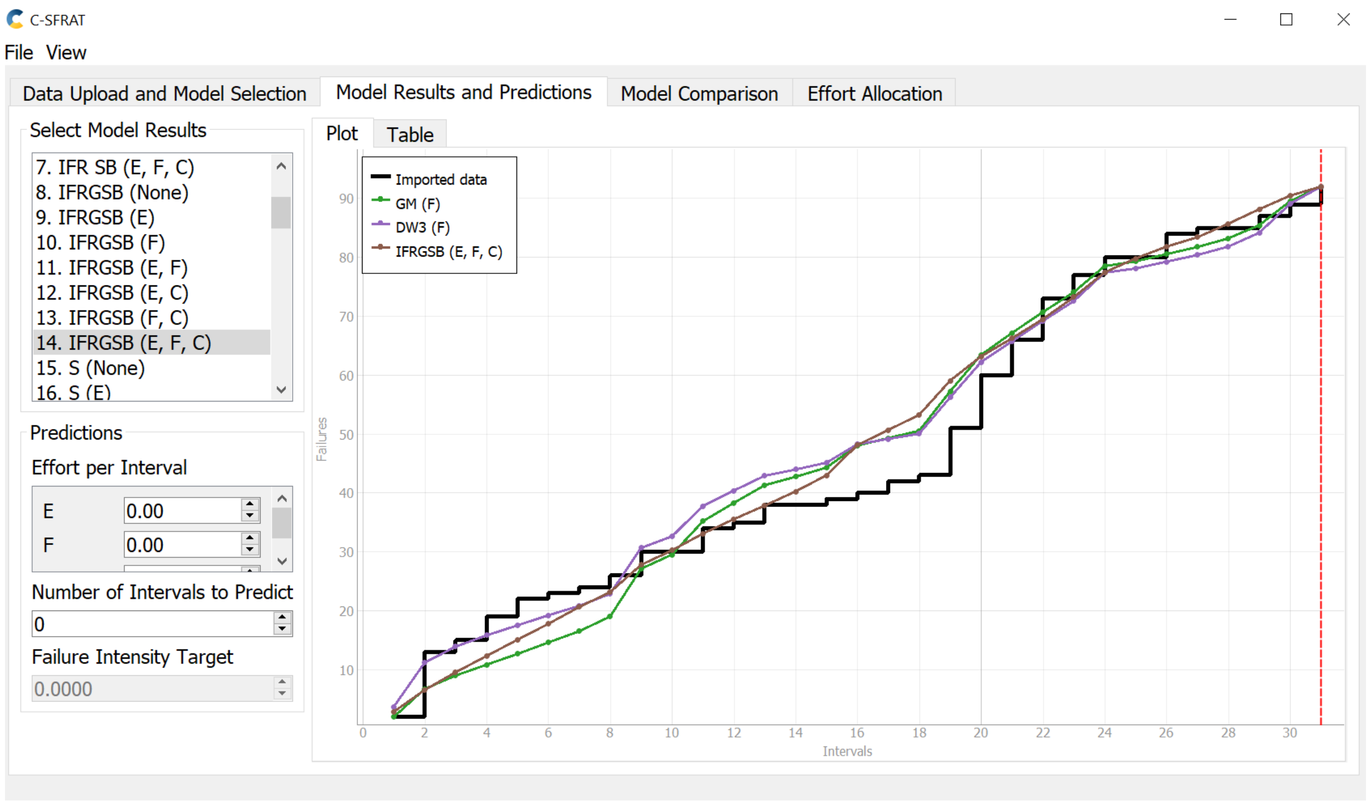
As shown in the graph above the top two models selected are:

- **DW3(F)** - Discrete Weibull Type III (DW3) model covariate F
  - AIC = 122.199, BIC = 127.935
- **GM(F)** - Geometric model covariate F
  - AIC = 125.323, BIC = 129.625

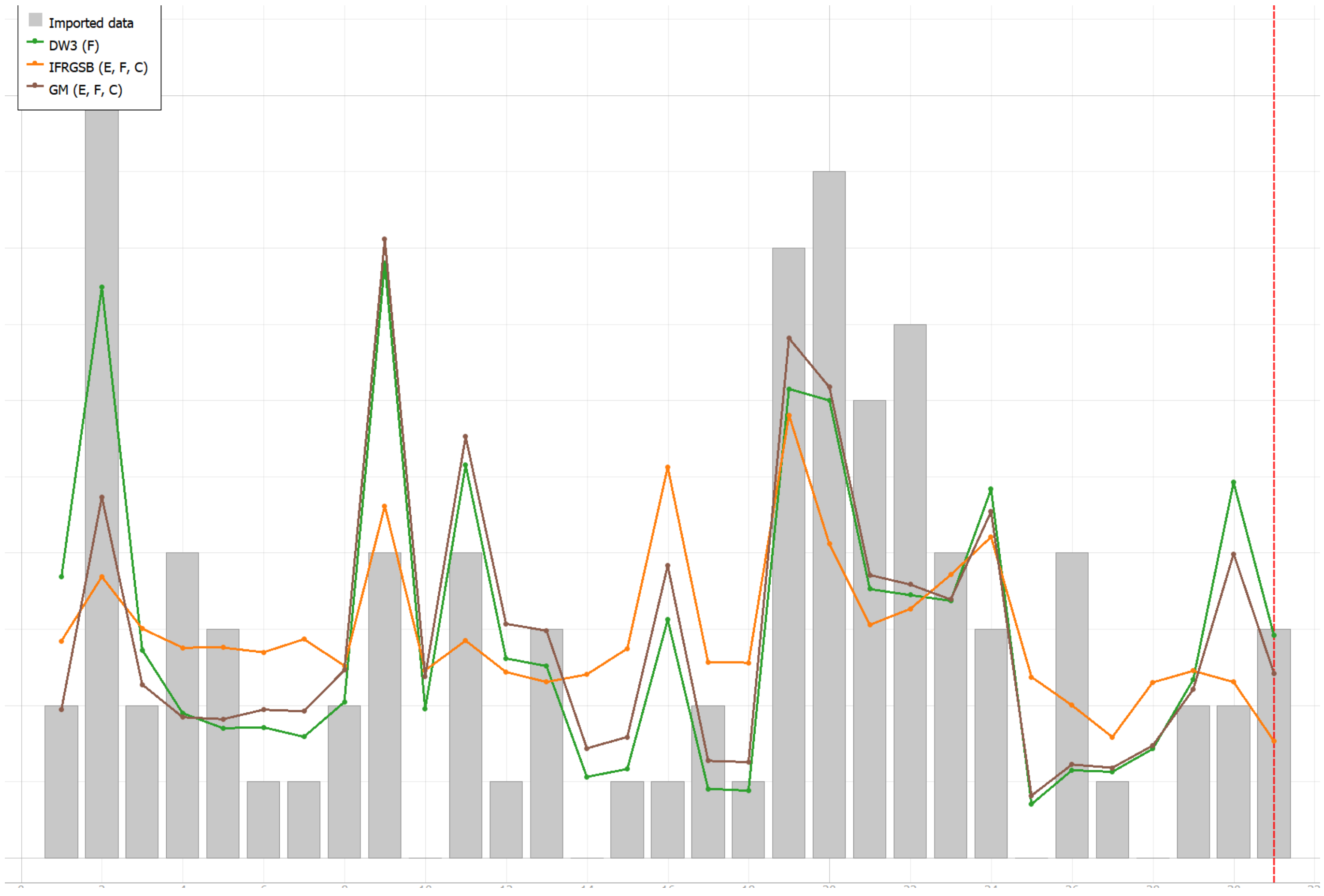
It is also worth to note a third model. Using the same criterion (lowest AIC/BIC) but also considering and sorting by the lowest Sum of Squares Errors (SSE), the IFR Generalized Salvia & Bollinger **(IFRGSB) with E,F,C covariate** may also be a good model to highlight as well. However for analysis, we decided to only use DW3(F) and GM(F).

Showing top two models + notable third on entire dataset:

MVF graph:



Intensity graph:



Result of range analysis (an explanation of which part of data is good for proceeding with the analysis)

As shown in the graphs above, we can observe an initial steep curve which corresponds to an infant mortality phase as per lecture notes. Subsequently, we can also observe a phase of stability in the system's performance after interval 4. As indicated by the intensity graph, some locations are much higher/lower than they should be which suggests the results can be improved by performing a range analysis.

Furthermore, we tested the two models with various ranges of the subset failure data. Looking at the graph, it looks like the results are the closest around 20-21 interval range. The best yielding result was found by:

- Using 21 of the 31 of the full set (~67%)
- Setting the prediction as follows:
  - E = 0
  - F = 20
  - C = 0
  - Number of intervals to predict = 10

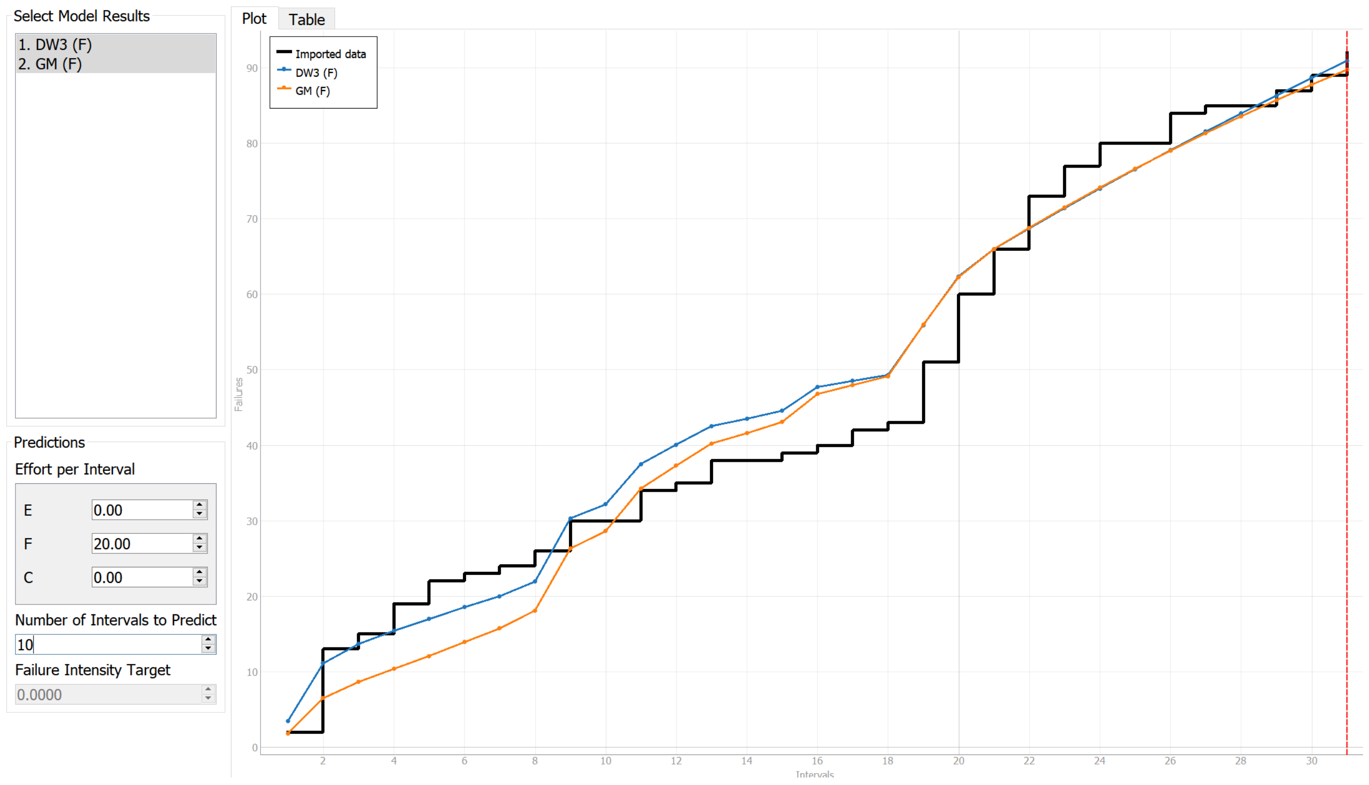
These setting improved the two models AIC/BIC to:

- DW3(F): [AIC: 122.199 → 83.817], [BIC: 127.935 → 87.995]
- GM(F): [AIC: 125.323 → 88.499], [BIC: 129.625 → 91.632]

Model comparison table:

Model Name	Covariates	Log-Likelihood	AIC	BIC	SSE	PSSE	Critic (Mean)	Critic (Median)
DW3	F	-37.908	83.817	87.995	395.432		1.000	1.000
GM	F	-41.249	88.499	91.632	674.581		0.000	0.000

MVF/Time to Failure graph:



1. DW3 (F)
2. GM (F)

Predictions

Effort per Interval

E 0.00

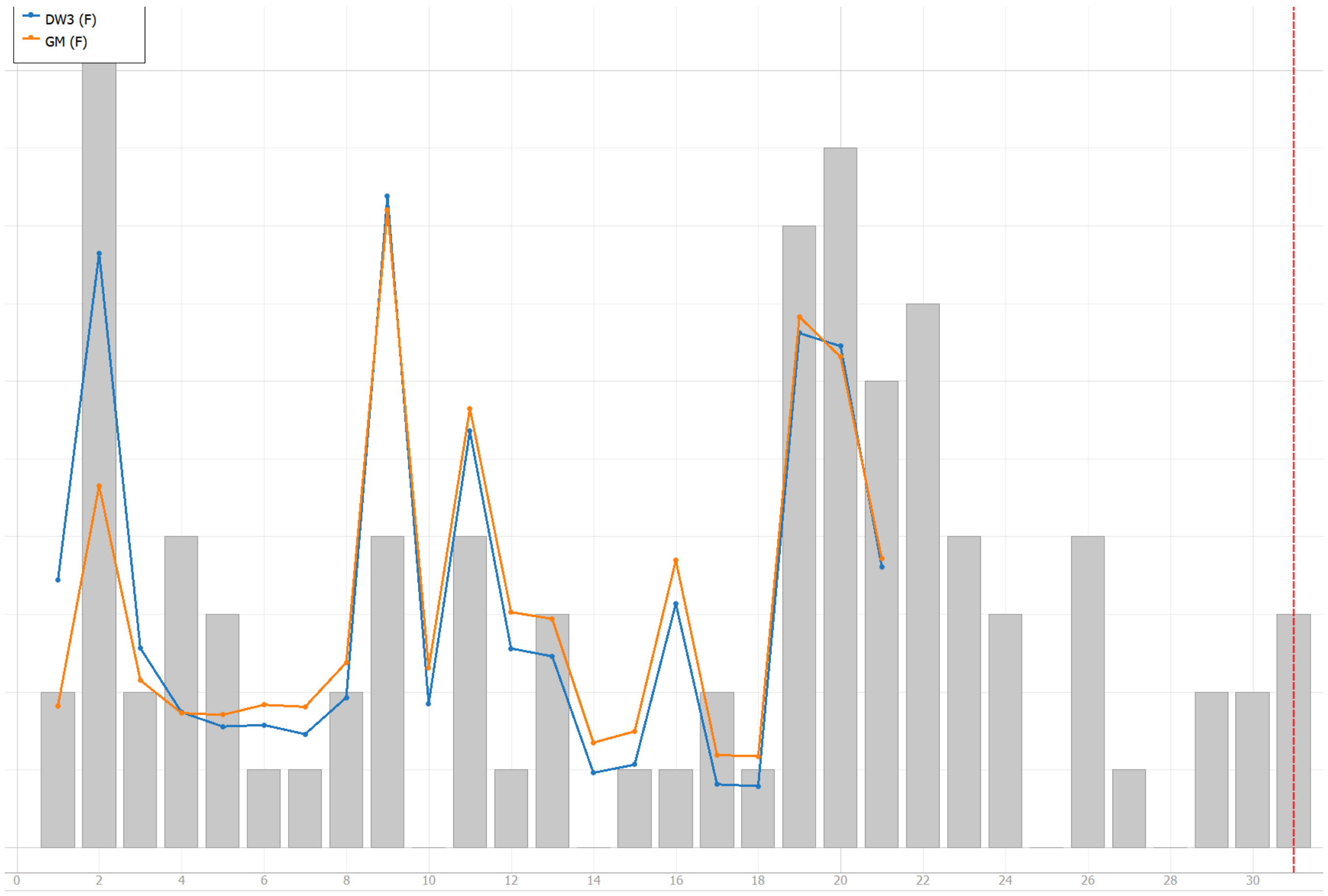
F 20.00

C 0.00

Number of Intervals to Predict 10

Failure Intensity Target 0.0000

Intensity graph:

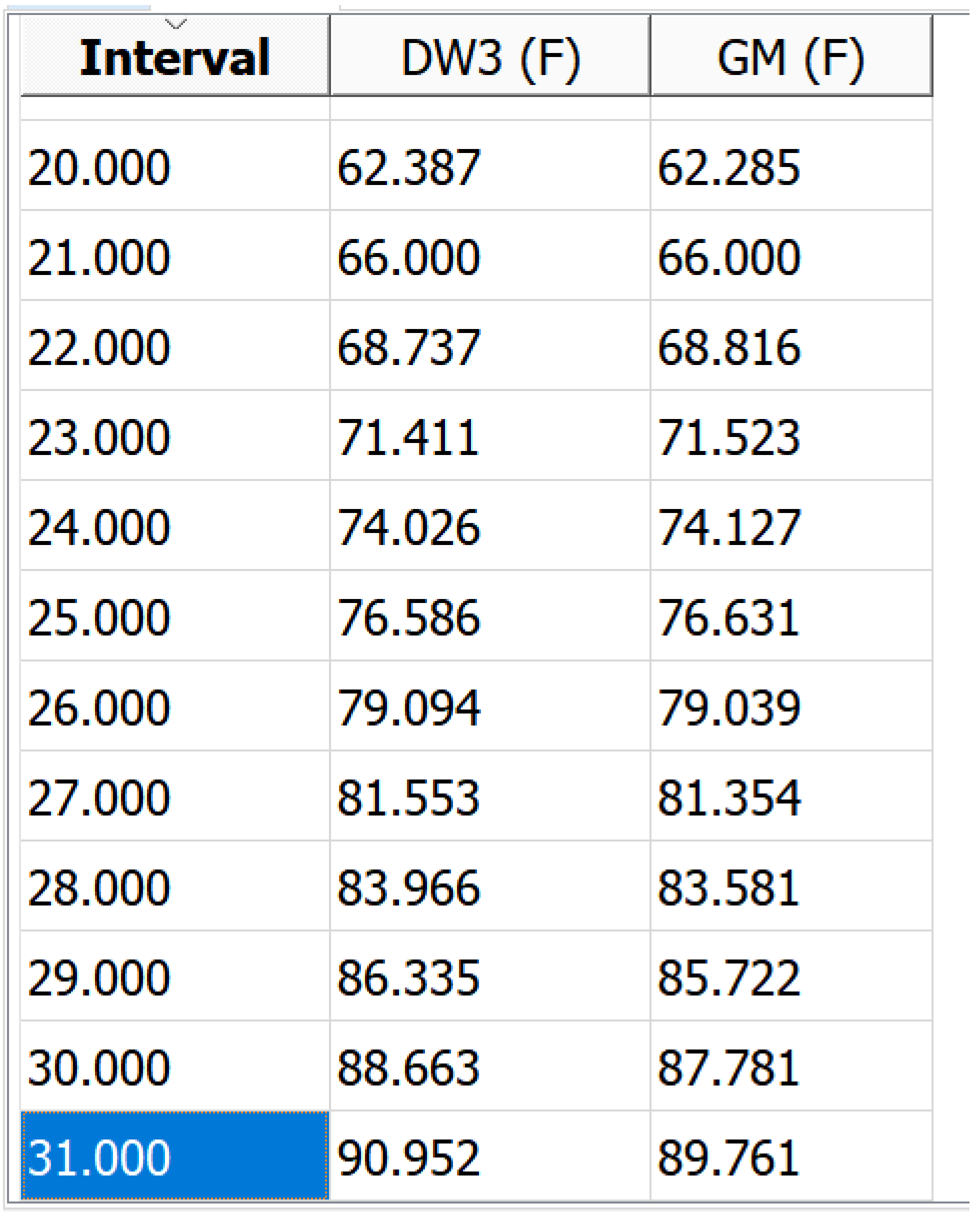


The improvements can be directly observed in the graphs above when compared to the original graphs in various ranges. Although there are still imperfections and discrepancies, the results more closely match the model estimation after applying the range analysis.

A discussion on decision making given a target failure rate

The dataset we are given showed a higher failure rate during infant mortality, which can be expected. Subsequently in the next phase, we can see a decrease in the failure rate indicating improved overall system reliability. There are multiple considerations for assessing the acceptable range of failure rate for the provided test data. In general terms, if the System Under Test (SUT) <= of the target failure rate, the assumption is that the system is operational and functioning properly. Conversely, if its > the target rate, additional bug fixing may be required.

From our analysis above, the following table shows the comparison of the models to interval 31:



Interval	DW3 (F)	GM (F)
20.000	62.387	62.285
21.000	66.000	66.000
22.000	68.737	68.816
23.000	71.411	71.523
24.000	74.026	74.127
25.000	76.586	76.631
26.000	79.094	79.039
27.000	81.553	81.354
28.000	83.966	83.581
29.000	86.335	85.722
30.000	88.663	87.781
31.000	90.952	89.761

This table above can be used to calculate the failure rate and MTTF. At interval 31 (last interval):

- DW3 (F):
  - Failure Rate: ~91/31 = `2.94` Failures/Interval
  - MTTF: 1/(~91/31) = `0.341` intervals
- GM (F):
  - Failure Rate: ~90/31 = `2.90` Failures/Interval
  - MTTF: 1/(~90/31) = `0.344` intervals

Compared to original input failure data:

- Failure Rate: ~92/31 = `2.96` Failures/Interval
- MTTF: 1/(~92/31) = `0.337` intervals

This indicates that the acceptable failures/interval is ~3. Similar to the calculation above, we can predict future failure rates to determine if the number of failures is acceptable or not.

Failures are inevitable for all SUT scenarios and its crucial to set expectation accordingly. Setting unrealistic low failure rate can result in inefficient resource allocation and conversely unrealistic high failure rate could have dire consequences as well. When making decisions regarding the targeted failure rate during reliability growth testing, it worth to consider determining the acceptable targeted failure rate for the SUT being evaluated. This determination can be set from expected failure rates set by users/clients or industry standards while taking into account factors such as project-specific requirements and safety. Finally, it is important to monitor the trend of the failure rate as this could lead to improved insights.

A discussion on the advantages and disadvantages of reliability growth testing

Below are some of the advantages of RGT:

Advantages of RGT:

- Various models with different covaraiates can be compared and used to access the SUT
- Allows users to identify reliability issues by analyzing failure data
- Different metrics/criteria such as AIC/BIC/SSE and others can be used for tailored analysis
- Allows users to test the overall reliability of the system prior to deployment

Below are some of the disadvantages of RGT:

Disadvantages of RGT:

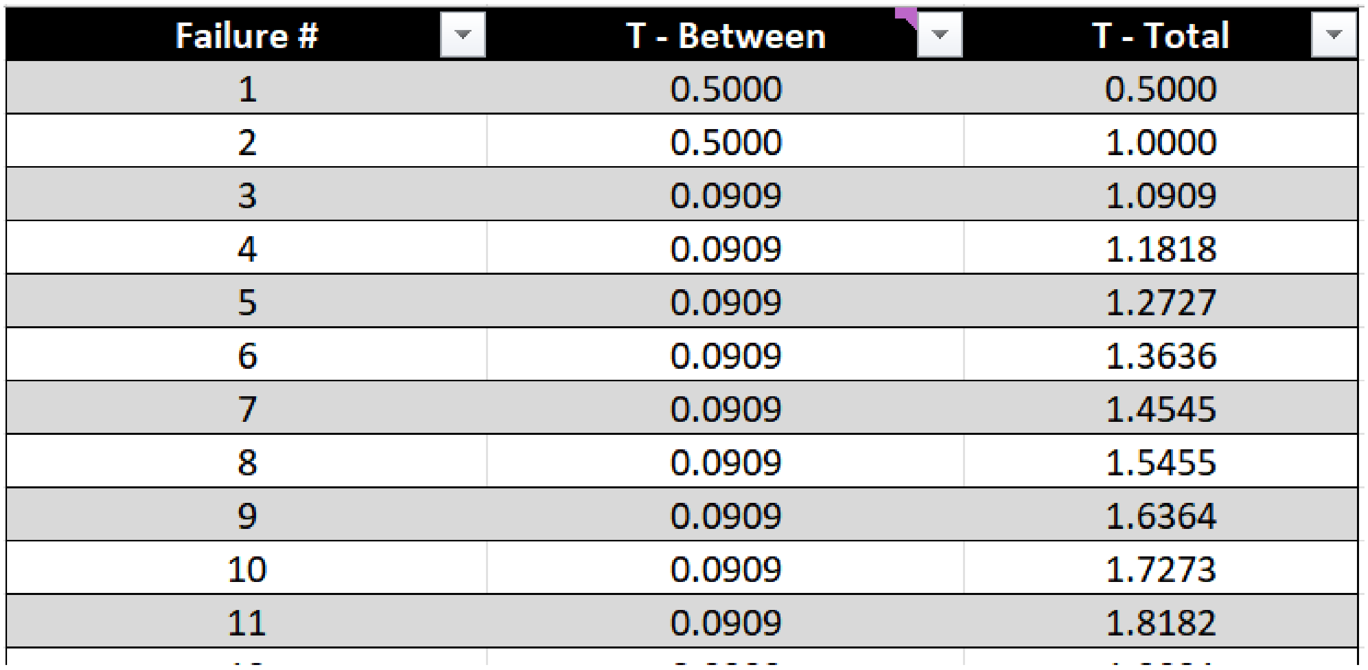
- Limited software(s) with little or poor documentation
- Requires large amount of data if we want to accurately access the reliability of the SUT
- Performance is based on model selection which could be sensitivity for ranges of data leading to undesirable results
- Can be time/cost intensive

Assessment Using Reliability Demonstration Chart

We utilized the RDC-11 (an EXCEL worksheet and macro) for this part of the assignment. After exploring the workbook and getting familiarized with its usage, we realized the need to create a new modified dataset that can be expressed in terms of cumulative failure count. This was done by first converting the `FC` faults/interval column. This yielded 92 rows or failures. Assuming a uniform distribution, we also calculated the time between and total time. The following shows the sample calculation for the first two rows:

- 1/# failures (in FC column) = 1/2 = 0.5
- T=1, FC=2 becomes two rows with: failure 1 = 0.5 , failure 2 = 0.5
- Cumulative total always adds up to the interval number as its uniformly distributed across the interval

The following table shows the first 11 rows of the modified dataset:



Failure #	T - Between	T - Total
1	0.5000	0.5000
2	0.5000	1.0000
3	0.0909	1.0909
4	0.0909	1.1818
5	0.0909	1.2727
6	0.0909	1.3636
7	0.0909	1.4545
8	0.0909	1.5455
9	0.0909	1.6364
10	0.0909	1.7273
11	0.0909	1.8182

This was then provided as input to the excel workbook. It is worth to mention that we kept the risk profile the same, for reference this was kept as:

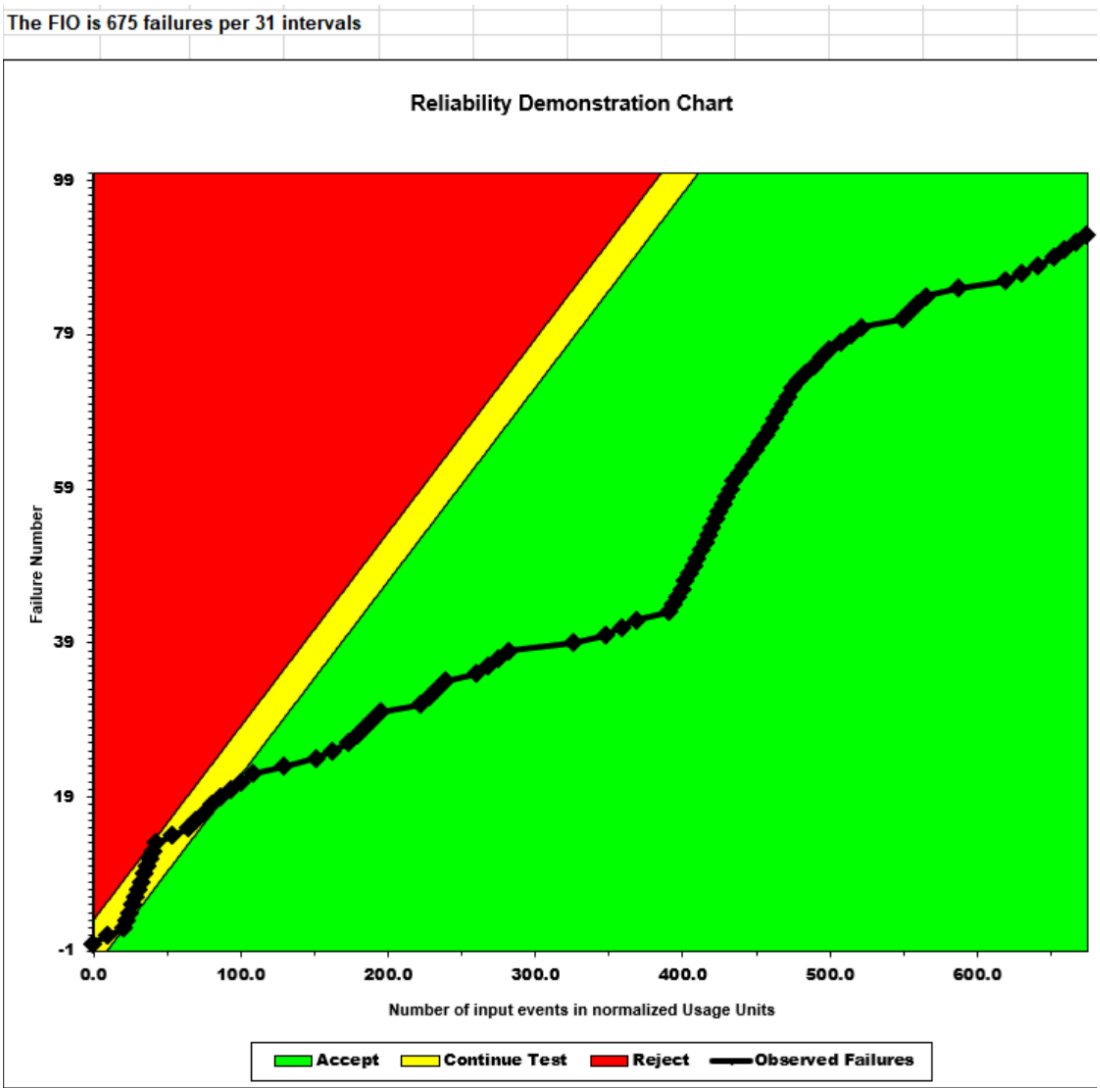
- Discrimination Ratio (gamma) - `2`
- Developer's Risk (alpha) - `0.1`
- User's Risk (beta) - `0.1`

Explain your evaluation and justification of how you decide the MTTFmin + 3 plots

Initially, we decided to check the original data of 92 failures/31 intervals. This yielded a graph which was mostly in the rejected reason. We determined the value of MTTFmin by adjusting the Failure Intensity Objective (FIO) so that we can sustain and not dip into the rejected region. Through trial and error, the value was estimated to be roughly around `675` failures per 31 intervals. See below calculation for failure rate, MTTF, FIO and their associated graphs:

Below is the graph of MTTFmin:

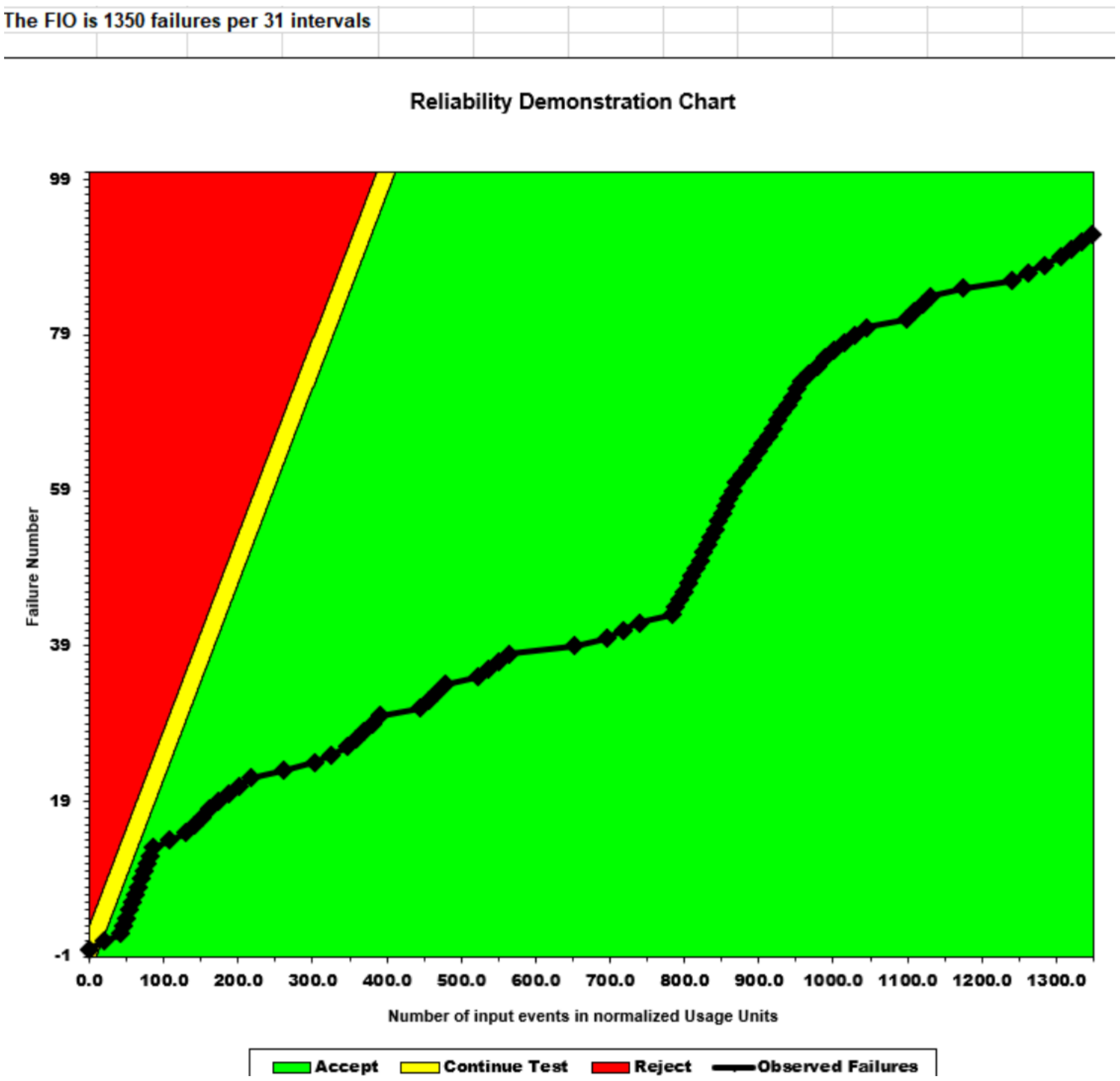
- FIO = `675` failures per 31 intervals
- Failure Rate: ~675/31 = `21.77` Failures/Interval
- MTTF: 1/(~675/31) = `0.046` intervals
- Results: Minimum Acceptable - no dip into red region



The FIO is 675 failures per 31 intervals

Below is the graph for twice MTTFmin (FIO = 675*2 = 1350)

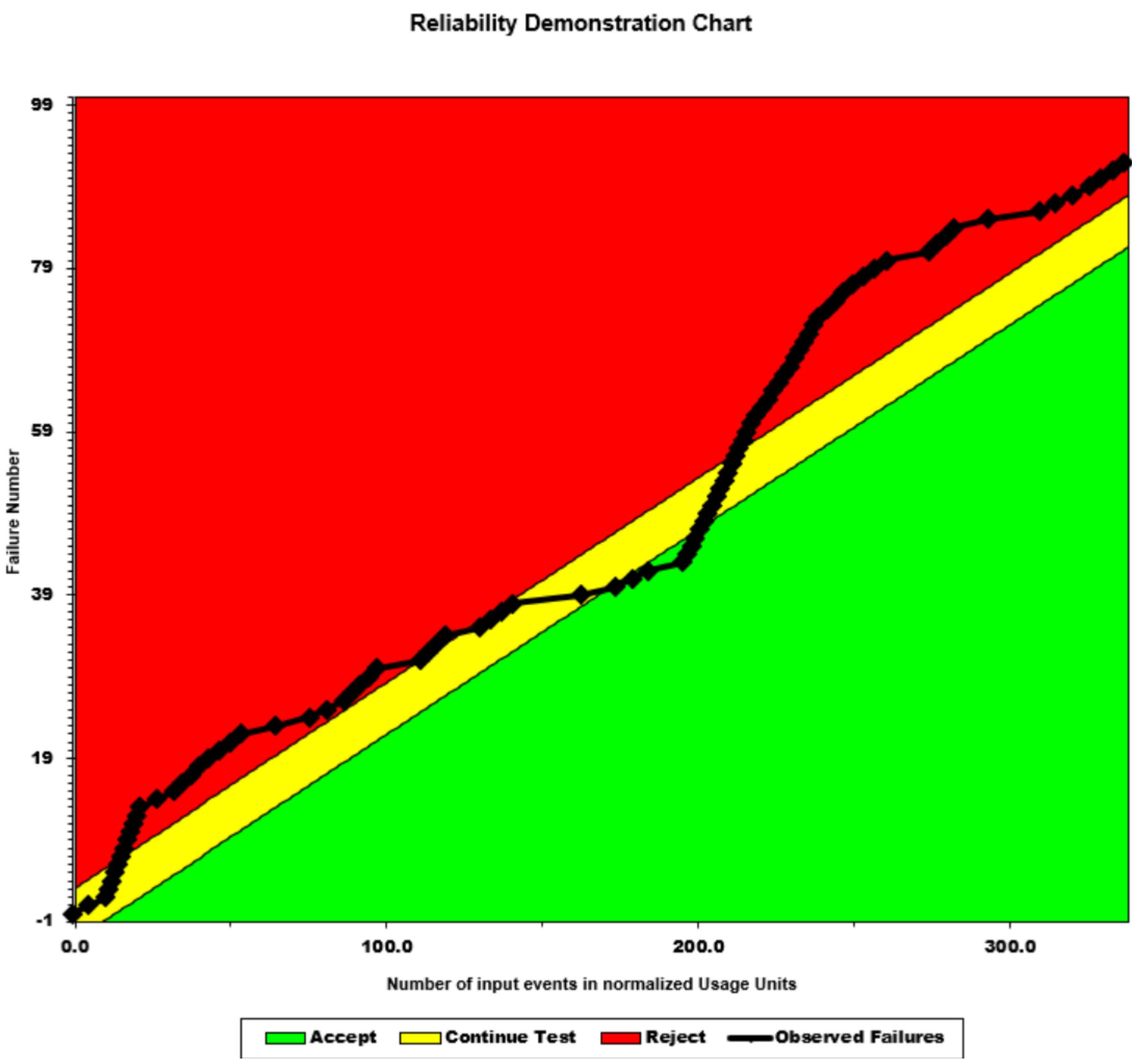
- FIO = `1350` failures per 31 intervals
- Failure Rate: ~1350/31 = `43.55` Failures/Interval
- MTTF: 1/(~1350/31) = `0.023` intervals
- Results: Acceptable - mostly all green small dip into yellow


The FIO is 1350 failures per 31 intervals

Below is the graph for half MTTFmin (FIO = 675/2 = 337.5)

- FIO = `337.5` failures per 31 intervals
- Failure Rate: ~1350/31 = `10.89` Failures/Interval
- MTTF: 1/(~1350/31) = `0.092` intervals
- Results: Unacceptable - dips into red

The FIO is 337.5 failures per 31 intervals



A discussion on the advantages and disadvantages of RDC

Below are some of the advantages of RDC:

Advantages of RDC:

- Graphical representation and color codes makes it easy to determine the acceptance/continue/reject regions and results
- User risk profiles are adjustable which allows for flexibility in analysis
- As per lecture notes, RDC is cost and time efficient way of analyzing reliability

Below are some of the disadvantages of RDC:

Disadvantages of RDC:

- Complex and the minimal documentation makes it difficult to setup

- Adjusting the output graph to visualize different results is hectic
- Cannot be used for accurate quantitative analysis of the SUT

Comparison of Results

The lab introduced two separate approaches to software reliability assessment. In the first part, we used C-SFRAT for RGT and we were able to pick the top two models DW3(F) and GM(F) based on the lowest AIC/BIC criterion. Moreover, we performed range analysis to improve the model fit which allowed us to more accurately predict failure rates for future intervals. Using the top model DW3(F), we were able to determine the MTTF of the SUT to be `0.341` interval and the failure rate `2.94` Failures/Interval.

In the next part of the lab, we used the RDC as a visual tool to determine the MTTFmin. The tool was also used to observe when failures dipped into the rejected regions in a graphically helpful manner. In this analysis, the MTTFmin was determined to be `0.046` which corresponds to `21.77` Failures/Interval.

Both of the results obtained could be used to determine if the SUT passes or if there is more work to be done. The answer also depends on the application of the software and considering factors such as project requirements and other constrains. Comparing the two techniques, both have their advantages and their disadvantages as described in the above section. Ultimately, both could be used for software reliability assessment and provide important insights about the SUT and its testing.

Discussion on Similarity and Differences of the Two Techniques

Below are some of the similarities between the two techniques:

Similarities

- Can be used for software reliability assessment
- Used the same input failure data to analyze performance and quality
- Provides insight related to the system's failure behavior
- Makes use of failure rates and MTTF metrics

Below are some of the differences between the two techniques:

Differences

- RGT can be used for reliability prediction, RDC can be used for checking MTTFmin and SUT acceptance
- RGT assessment revolves around using models whereas RDC revolves around using risk profiles
- Cost and time differences. RGT generally is associated with more cost/time

How the team work/effort was divided and managed

Initially, we spent time checking out the tools that we will be using as a team. The first group focused on RGT while the second group focused on the RDC. Eventually, all group members helped each other out since the documentation was limited for both tools used. Once both groups have completed their sections, we scheduled a peer review meeting to go over the issues found from each group. The meeting was also used to discuss results, formatting, and removed any duplicate issues that were found by both teams.

Group 1: Bogdan and Andy

Group 2: Juan, Billy and Moaz

Difficulties encountered, challenges overcome, and lessons learned

In this assignment, none of our group members had previous experience with using the tools suggested in both parts of the lab. There was a learning curve to learn how the RDT and RGC tools functions, get aquatinted with the user interface and how to use it effectively for the lab. Ultimately, we spent a lot of time figuring out thing through trial and error as the documentation of the tools was minimal. Additionally, we also faced an issue in adjusting the views of RDC graphs as it was only limited to 16 inputs. This is when we realized that we had to adjust a few things to get it working. We ultimately learned how to adjust it and continued to use the tool effectively. The biggest lesson learned is that tool documentation really matters! One could have a very powerful tool but without knowing how to use it effectively, it can be practically useless.

Comments/feedback on the lab itself

We all thought the lab was very helpful as it exposed us to software reliability assessment using different tools. Recommendation would be to provide more instructions in lab for both parts as the tools used have very little or poor documentation.