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Mr. Richard Boyd
Chief, Medium and Heavy Truck Division, Office of
Defects Investigation
National Highway Traffic Safety Administration
400 Seventh Street, S.W.
Room 5326
Washington, D.C. 20590

RE: EA05-002 Victory Motorcycles

Dear Mr. Boyd:

At our recent meeting to discuss issues related to EA05-002, we discussed a Weibull analysis that was recently commissioned by Polaris Industries. A copy of this analysis is enclosed.

Some of the other documents presented and discussed at that meeting have been submitted today under separate cover to the Office of Chief Counsel with justifications to protect them from public disclosure under the Freedom of Information Act.

Please let me know if you need any additional information.

Sincerely,

Erika Z. Jones

Erika Z. Jones

Enclosure

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Weibull Analysis of Polaris Warranty Data

Prepared for

Mayer, Brown, Rowe & Maw LLP

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1. Analysis Summary

This report presents an analysis to estimate the failure time distribution of a transmission using data provided by Polaris.

For this analysis, two excel files were provided by Steve Smith (steve.smith@polarisind.com) from Polaris. The file "Mileage Study Complete.xls" has four data sheets. Sheet "S_Consistent data" records the customer contact information, which is consistent and is used to derive the mileage distributions for different ownership lengths in this report. Sheet "S_Data Inconsistencies" also contains customer contact information; but this information is inconsistent. Failure information is given in sheet "N-S_Data Consistent" and "N-S_Data Inconsistent." "N-S_Data Consistent" gives the consistent repair/failure records by Polaris while sheet "N-S_Data Inconsistent" lists several inconsistent failure records. This information will be used to allocate unknown failures and suspensions in this report. The file "Mileage Study Complete adendum.xls" has one data sheet "S_Consistent Without Claims." This sheet gives the sales date for each vehicle without claims.

This report includes two analyses. One analysis is for the data by 10/3/2005, which is the main part of the report. Another analysis is for the data by 10/20/2000, which is given in the Appendix. By 10/20/2000, only 5 failure records are available. Without sufficient failures, the analysis results are to be used for reference purposes only. In this report, the methodology used in the analysis of the data by 10/3/2005 is presented in detail.

2. Mileage Distributions

In this section, the method of finding the mileage distributions for different vehicle ownership lengths is discussed. The Weibull distribution is used to describe the mileage. The relationship between month and the scale parameter η of the Weibull distribution is modeled while assuming the shape parameter, β stays constant.

2.1 Mileage Distribution from the Raw Data

A sample of vehicles that comes from the data sheet "S_Consistent data" is used to find the mileage distribution. The following rules are used:

1. Use the records that have contact dates after date of sale.
2. Use the records that have non-zero mileage.
3. Use 30.42 days as a month (the same number of days in each month is used for calculation; hence 365/12 = 30.42 days is taken as a standard month).

From the recorded contact data, the time length from date of sale to date of contact is calculated, as shown in Table 2.1.

Table 2.1: Calculations of the Ownership Length

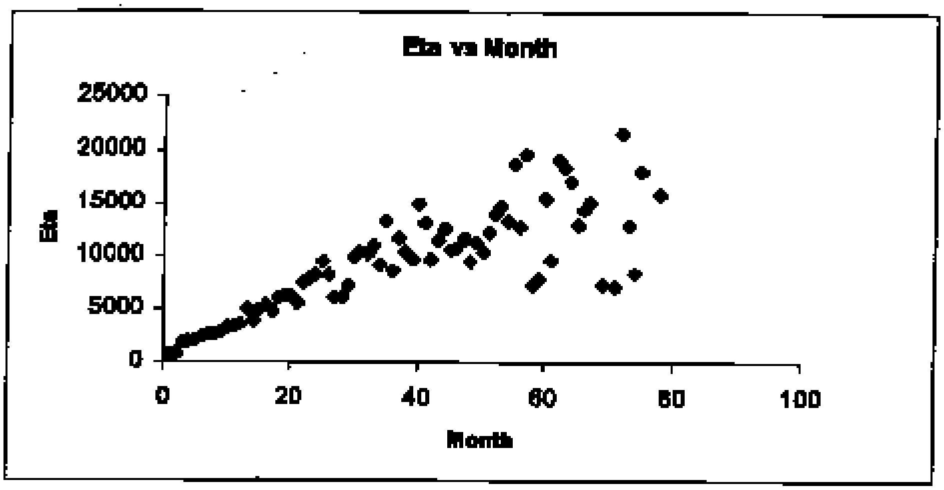
Date Sold	Contact Date	Miles	Days	Months
10/15/2001	1/16/2002	800	93	3.06

The calculated month in Table 2.1 is rounded to the nearest integer, 3. From the beginning time to 10/03/2005, there are records of 85 months. The length of ownership and the corresponding number of records are summarized in Table 2.2.

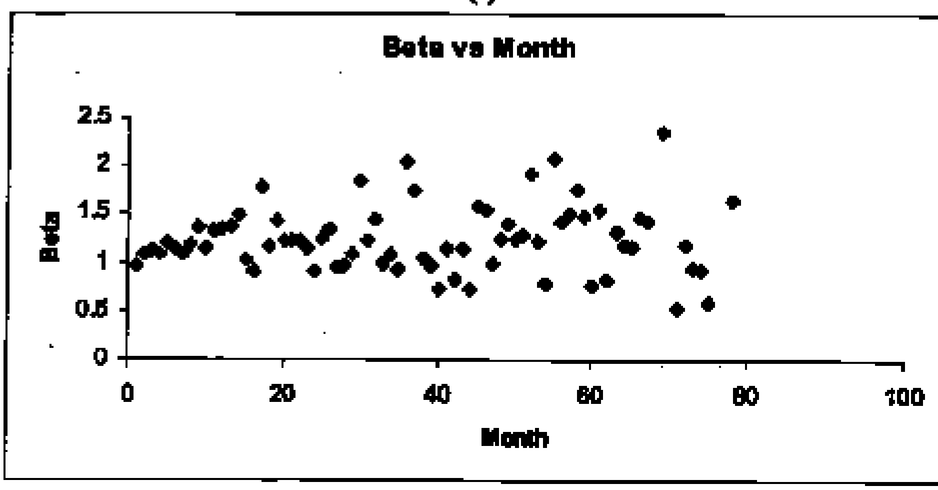
THE ATTACHMENTS TO THIS DOCUMENT HAVE BEEN REMOVED TO PROTECT UNWARRANTED INVASION OF PERSONAL PRIVACY PURSUANT TO EXEMPTION 6 OF THE FREEDOM OF INFORMATION ACT (FOIA), 5 U.S.C. 552(b)(6).

From Figure 2.1 and the following Figure 2.2 (b), it is clear that, except for some outliers, there is a common β, *i.e.* the lines for different months of ownership appear to be parallel. These outliers, such as 71, 75 and 68, are possibly caused by the small number of data points for those particular data sets.

We should define a criterion to detect the outliers in these β values. The procedure is given in Section 2.2. The following figures show how the individual η and β values change with ownership length. In Figure 2.2, only the months that have more than 3 data records (from Table 2.2) are used.



(a)



(b)

Figure 2.2: Distribution Pattern with Ownership Length

From Figure 2.2 (a), it can be seen that there is a clear relationship between η and the ownership length or months in service (MIS). If we can find the relationship, then we can use it to model the mileage distribution of any ownership length. The procedure of finding this relationship is given in Section 2.3.

2.2 Choose the Common β

Using the β values in Figure 2.2 (b), the normal probability plot is given in Figure 2.3.

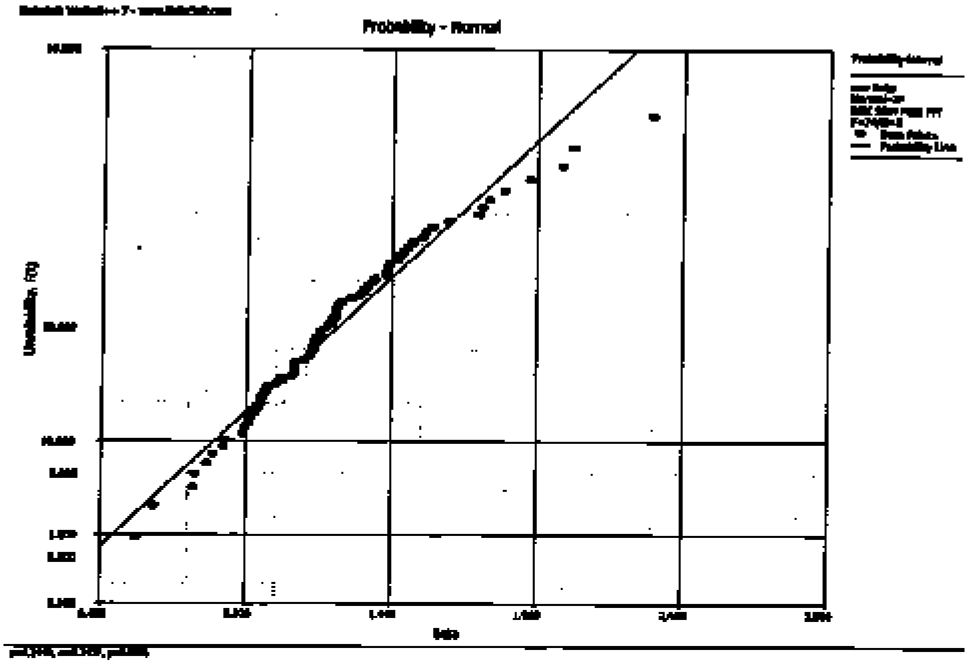


Figure 2.3: Distribution of All the Betas

The mean value of these betas is 1.2444 and the standard deviation is 0.3437. We then use the 2 sigma control limits to find the outliers. The values that are less than $1.2444-2\times0.3437=0.557$ or greater than $1.2444+2\times0.3437=1.932$ are considered as outliers. After deleting outliers, the normal probability plot is re-plotted, as shown in Figure 2.4.

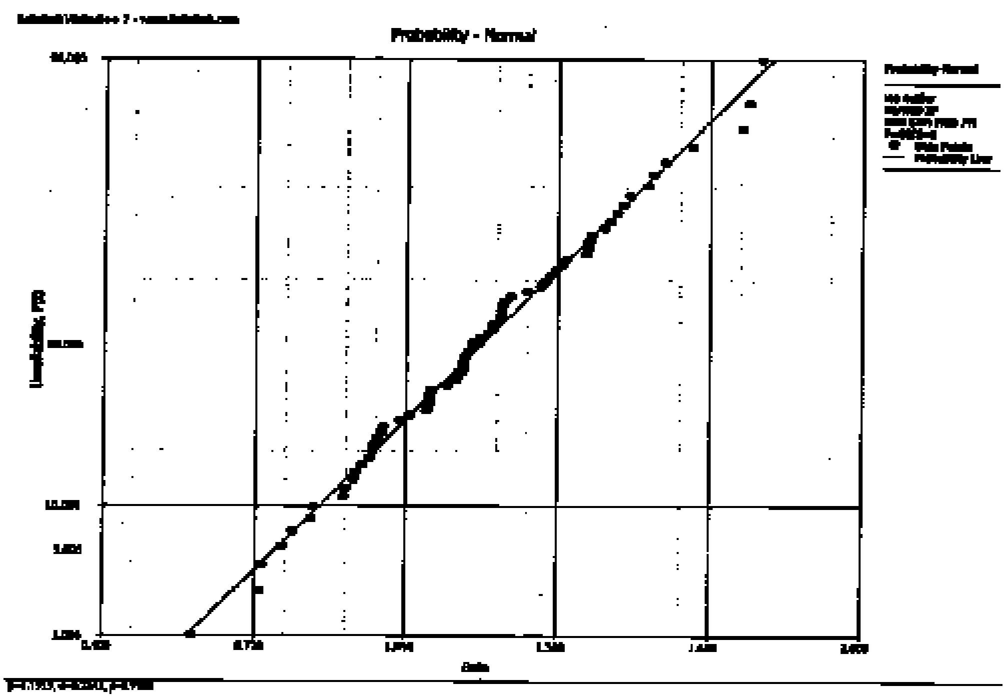


Figure 2.4: Distribution of Betas without Outliers

The recalculated mean value of the β is 1.195. This value will be used as the common β for the mileage distribution for different MIS (Months in Service or Ownership Length).

2.3 Build the Relationship Between MIS and η

First, we use the common β = 1.195 to recalculate the distribution for the data sets that have less than 64 months ownership, since few or no data points are available after that (see Table 2.2), and obtain the new η values. These values are given in Table 2.3.

Table 2.3: Summary of the η Values

Month of Ownership	η	Month of Ownership	η	Month of Ownership	η	Month of Ownership	η
1	902	21	5548.3183	41	12454.855	61	9511.2273
2	1017.3865	22	9716.9736	42	9487.9957	62	21070.701
3	2023.6543	23	7938.6737	43	11814.7	63	18381.937
4	2020.6401	24	8904.4156	44	13165.827		
5	2163.9811	25	9594.3042	45	9550.3921		
6	2647.2704	26	8327.3038	46	10225.599		
7	2934.4058	27	6942.7984	47	14326.442		
8	3005.2033	28	6456.5499	48	9642.6997		
9	2822.5861	29	6780.7718	49	11796.808		
10	3470.9219	30	9213.5233	50	10329.355		
11	3361.8191	31	9652.2017	51	11829.791		
12	3725.1336	32	9372.9272	52	13000.998		
13	4902.945	33	11118.968	53	13180.112		
14	3699.8122	34	8917.543	54	14913.383		
15	5105.0875	35	12726.521	55	16849.077		
16	5422.507	36	8066.1382	56	11824.433		
17	4799.1062	37	11722.065	57	18841.444		
18	6364.6643	38	10824.868	58	6813.9992		
19	6286.6109	39	9707.2056	59	7303.7755		
20	6815.5022	40	18657.783	60	18045.841		

Using the values in Table 2.3, a linear relationship between MIS and η is found and plotted in Figure 2.5.

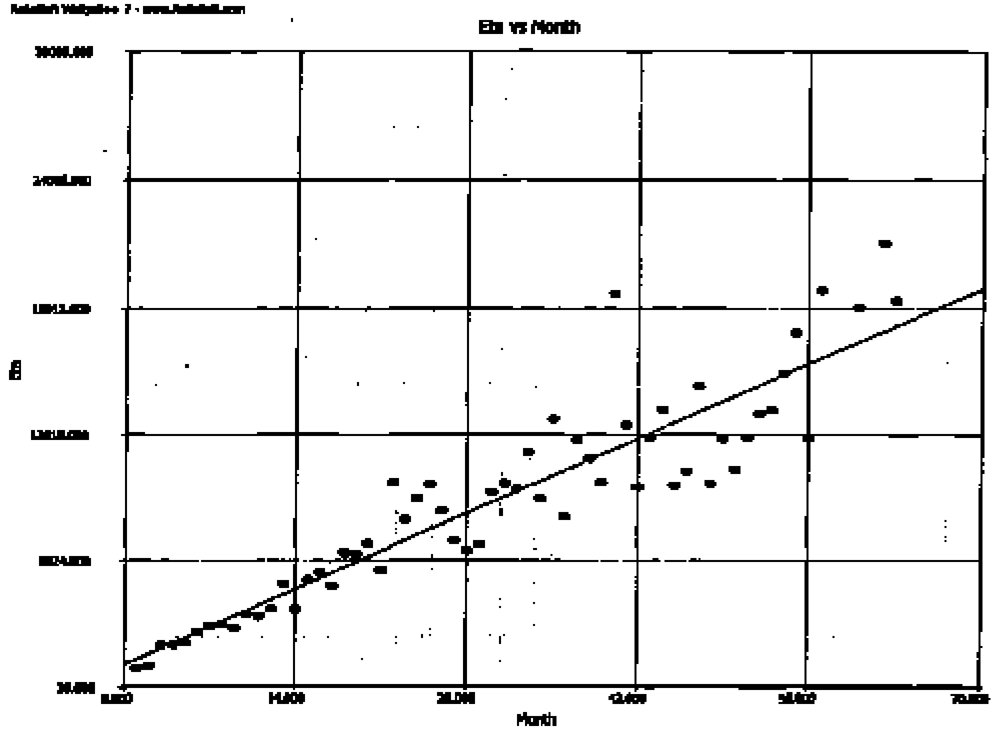


Figure 2.5: The Linear Relationship Between η and MIS

The linear model is $\eta = 254.95x + 1096.8989$, where x is the MIS or months of ownership.

2.4 One Year Mileage Distribution

There is a one year warranty for this product. In order to transfer the one year time length to the corresponding mileages, we need to utilize the information in Section 2.2 and 2.3. Using the common β and the linear relationship between η and MIS, the one year mileage distribution is found to be a Weibull distribution with $\beta = 1.195$ and $\eta = 254.95 \times 12 + 1096.8989 = 4156.3$. The probability plot of this distribution is given in Figure 2.6.

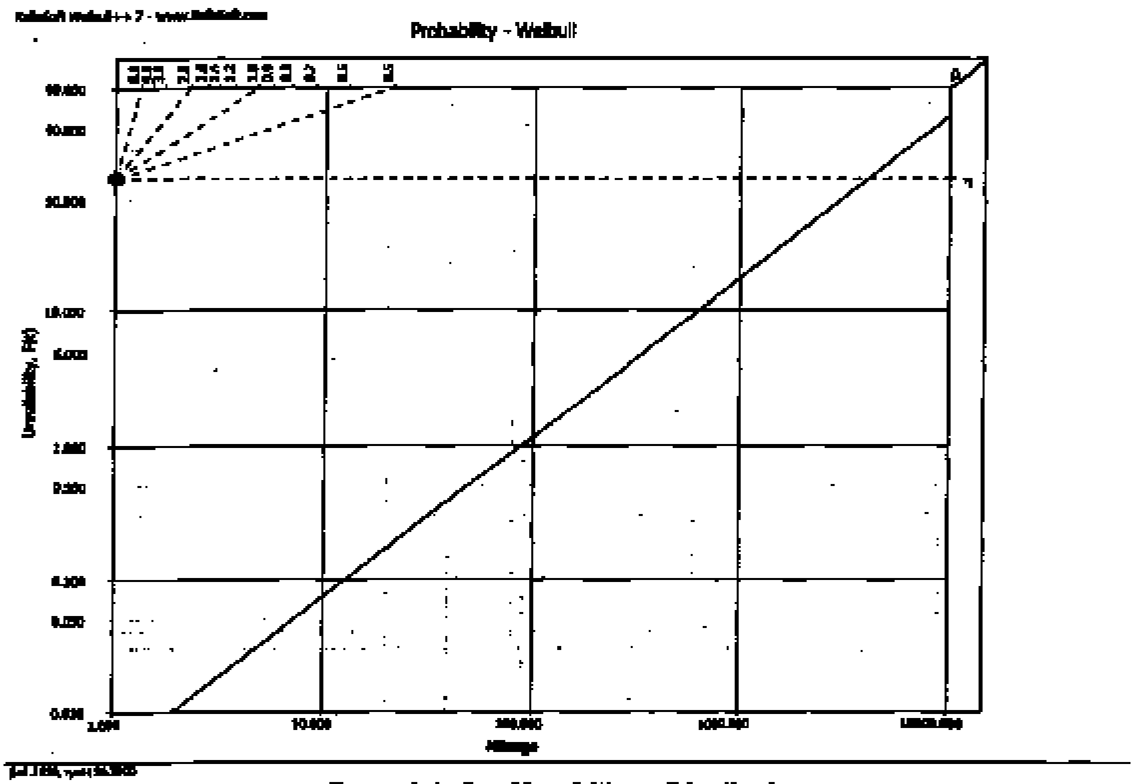


Figure 2.6: One Year Mileage Distribution

The BX mileage of the one year ownership is:

Table 2.4: BX Mileage of One Year Ownership

B%	Mileage	B%	Mileage
10	632.214	70	4854.769
30	1754.04	90	8352.495
50	3058.486	99	14918.47

The mean value of this distribution is 3914. This is the expected mileage by the end of the one year warranty.

3. Allocate Suspensions

In order to build the transmission life distribution, mileages are divided into intervals with the interval length of 2000 miles. For example, the first mileage interval is 0 – 2000 miles. The second interval is 2000 – 4000 miles and so on.

From the records, we found that the first vehicle was sold in August 1998. From August 1998 to October 3, 2005, it is 85 months. Based on the 85-month mileage distribution, we can allocate the vehicles sold in August 1998 to different mileage intervals and repeat this process for each month until Sept, 2005. The mileage intervals and the corresponding percentages are given in Table 3.1.

Table 3.1: Suspension Percentages in Each Mileage Interval

Mileage Interval		Aug-98	Sep-98	Oct-98	...	Sep-05
		85	84	83	...	1
0	2000	0.0532009	0.0539018	0.0546199	...	0.7974718
2000	4000	0.0644437	0.0652376	0.0660494		0.1766916
4000	6000	0.0662297	0.0669783	0.067742		0.0231917
6000	8000	0.0652747	0.0659404	0.0666176		0.0024132
8000	10000	0.0629531	0.0635216	0.0640979		0.0002137
10000	12000	0.0598795	0.0603473	0.0608193	...	1.67E-05
12000	14000	0.0563969	0.0567662	0.0571367		1.17E-06
14000	16000	0.0527178	0.0529945	0.0532698		
16000	18000	0.0489818	0.0491737	0.0493619		
18000	20000	0.0452832	0.0453988	0.0455093		
20000	22000	0.0416856	0.0417342	0.0417763		
22000	24000	0.0382318	0.0382224	0.0382057		
24000	26000	0.0349498	0.034891	0.0348244		
26000	28000	0.0318562	0.0317562	0.0316482		
28000	30000	0.0289597	0.0288261	0.0286845		
30000	32000	0.0262631	0.0261028	0.0259347		
32000	34000	0.0237648	0.0235839	0.0233955		
34000	36000	0.02146	0.021264	0.0210609		
36000	38000	0.0193418	0.0191353	0.0189224		
38000	40000	0.0174015	0.0171887	0.0169701		
40000	42000	0.0156295	0.0154139	0.0151931	...	
...	...	...	...	...	...	...

For example, from Table 3.1, we know that about 5.3% of the total vehicles sold in August 1998 will have less than 2000 miles by October 3, 2005. Therefore, if we know the number of sales for each month, we can allocate all of the vehicles into different mileage intervals based on the above table.

The data sheets "S_Consistent Data," "S_Data Inconsistencies" and "S_consistent without claims" are used to calculate the total number of recorded sales in each month. This number is also the number of recorded suspensions. There are 4720 recorded suspensions. Using this number, together with Table 3.1, the recorded suspensions are allocated to the different mileage intervals.

Since the total number of suspensions is 5226, as given by Polaris, we have 5226 – 4720 = 506 unknown suspensions. Assuming the unknown suspensions have the same percentage in each mileage interval as the recorded suspensions, we can assign the unknown suspensions into each mileage interval according to the percentages of the recorded suspensions.

The final suspension allocation is given in Table 3.2.

Table 3.2: Suspension Allocation

Mileage Intervals		Recorded suspensions	Unknown suspensions	Total suspensions	Mileage intervals		Recorded suspensions	Unknown suspensions	Total suspensions
0	2000	401	43	444	40000	42000	42	5	47
2000	4000	458	49	507	42000	44000	36	4	40
4000	6000	442	47	489	44000	46000	31	3	34
6000	8000	410	44	454	46000	48000	27	3	30
8000	10000	373	40	413	48000	50000	23	2	25
10000	12000	335	36	371	50000	52000	20	2	22
12000	14000	298	32	330	52000	54000	17	2	19
14000	16000	264	28	292	54000	56000	14	2	16
16000	18000	232	25	257	56000	58000	12	1	13
18000	20000	204	22	226	58000	60000	11	1	12
20000	22000	178	19	197	60000	62000	9	1	10
22000	24000	156	17	173	62000	64000	8	1	9
24000	26000	136	15	151	64000	66000	7	1	8
26000	28000	117	13	130	66000	68000	6	1	7
28000	30000	101	11	112	68000	70000	5	1	6
30000	32000	88	9	97	70000	72000	4	0	4
32000	34000	76	8	84	72000	74000	3	0	3
34000	36000	65	7	72	74000	76000	3	0	3
36000	38000	56	6	62	76000	78000	3	0	3
38000	40000	49	5	54	Total		4720	506	5226

For example, in the interval [0, 2000] in Table 3.2, the expected number of recorded suspensions is 401, which takes 401/4720 = 8.496% of the 4720 total recorded suspensions. Therefore, for the total of 506 unknown suspensions, $506 \times 8.496\% = 42.98 = 43$ vehicles will fall in the interval of [0, 2000].

4. Allocate Failures

There are also two types of failures: failures with claims (and therefore mileage records) and failures with unknown mileages. There are a total of 476 reported failures, as provided by Polaris, from which 406 records are under the "N-S_Data consistent" sheet and 8 are under the "N-S_Data Inconsistent" sheet. The rest of the failures have no records. However, from the 406 records, 17 did not have the information required for analysis. Therefore, we have 389 consistant failure records. We assume that 476 – 389 = 87 are unknown failures. We will treat these 87 failures as failures with unknown mileage. We know the total number of failures is 1402, from the sales records of transmission kits. We will assume that 1402 – 476 = 926 failures are out of warranty failures. Theses different failures are visualized in Figure 4.1.

First, based on the mileages at the time of the claims, the recorded failures are allocated to each corresponding mileage interval. By assuming that the 87 unknown mileage failures have the same percentage in each mileage interval as the failures with mileage records, we allocate these unknown failures to corresponding intervals.

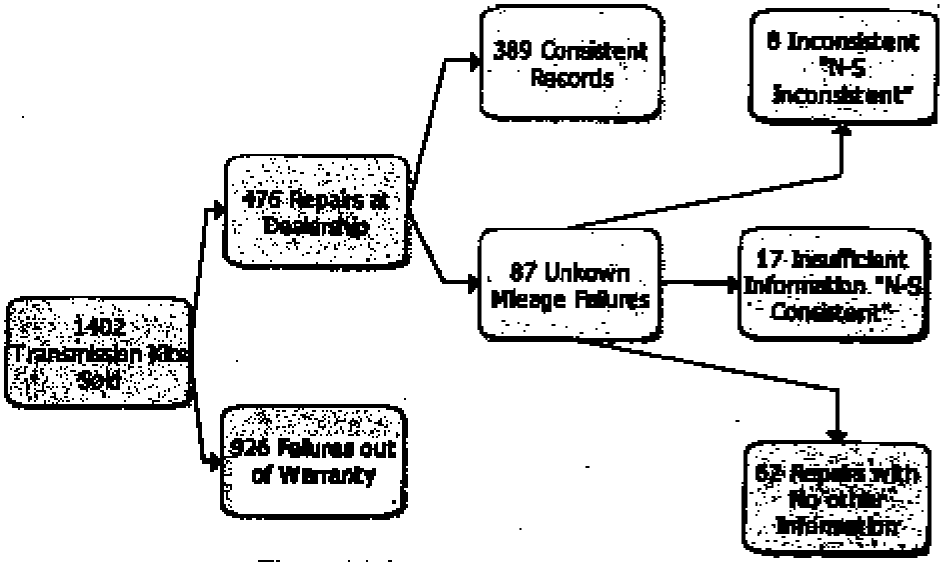


Figure 4.1: Failure Data Distribution

The allocation of failures corresponding to recorded repairs at the dealership is given in Table 4.1.

Table 4.1: Failure Allocation for Recorded Failures

Mileage Intervals		Recorded Failures	Unknown Mileage Failures	Total Failures
0	2000	53	12	65
2000	4000	65	14	79
4000	6000	57	13	70
6000	8000	49	11	60
8000	10000	32	7	39
10000	12000	30	7	37
12000	14000	43	10	53
14000	16000	12	3	15
16000	18000	11	2	13
18000	20000	6	1	7
20000	22000	7	2	9
22000	24000	4	1	5
24000	26000	4	1	5
26000	28000	3	1	4
28000	30000	3	1	4
30000	32000	4	1	5
32000	34000	1	0	1
34000	36000	2	0	2
36000	38000	1	0	1
48000	50000	1	0	1
70000	72000	1	0	1
	Total	389	87	476

Example: In the interval [0, 2000] in Table 4.1, there are 53 failures, which represent 53/389 = 13.6% of the total of 389 recorded failures. Therefore, $87 \times 0.136 = 11.8 \approx 12$ unknown mileage failures will be allocated in this interval.

Second, we will allocate the unknown failures, which are assumed not to be covered under warranty. From Section 2.4, we know that the mean value of the one year mileage is 3914. From the recorded failures in Table 4.1, we found that the closest mileage to 3914 is 4000. Therefore, by assuming that the 926 failures out of warranty have the same failure proportions with the failures recorded that have mileage greater than 4000 miles, we can allocate them to the mileage intervals. The final out of warranty failures are:

Table 4.2: Out of Warranty Failure Allocation

Mileage Intervals		Recorded Failures (Adjusted)	Unknown Out of Warranty Failures
4000	6000	70	195
6000	8000	60	167
8000	10000	39	108
10000	12000	37	103
12000	14000	53	148
14000	16000	15	42
16000	18000	13	36
18000	20000	7	20
20000	22000	9	25
22000	24000	5	14
24000	26000	5	14
26000	28000	4	11
28000	30000	4	11
30000	32000	5	14
32000	34000	1	3
34000	36000	2	6
36000	38000	1	3
48000	50000	1	3
70000	72000	1	3
	Total	332	926

For example, in the interval [4000, 6000] in Table 4.2, there are 70 failures, which represents 70/332 = 21% of the total of 332 recorded failures that have more than 4000 miles. Therefore, we compute $926 \times 0.21 = 195.2 \approx 195$ unknown out of warranty failures in this interval.

Combing Table 4.1 and Table 4.2, we get the final failure data in each mileage interval, which is given in Table 4.3.

Table 4.3: Summary of Failure Allocation

Mileage Intervals		Recorded Failures	Unknown Mileage Failures	Unknown Out of Warranty Failures	Total Failures
0	2000	53	12	0	65
2000	4000	65	14	0	79
4000	6000	57	13	195	265
6000	8000	49	11	167	227
8000	10000	32	7	108	147
10000	12000	30	7	103	140
12000	14000	43	10	148	201
14000	16000	12	3	42	57
16000	18000	11	2	36	49
18000	20000	6	1	20	27
20000	22000	7	2	25	34
22000	24000	4	1	14	19
24000	26000	4	1	14	19
26000	28000	3	1	11	15
28000	30000	3	1	11	15
30000	32000	4	1	14	19
32000	34000	1	0	3	4
34000	36000	2	0	6	8
36000	38000	1	0	3	4
48000	50000	1	0	3	4
70000	72000	1	0	3	4
	Total	389	87	926	1402

5. Analysis Using Weibull Distribution

Using the obtained failures and suspensions from Section 3 and 4, we get the final Weibull life distribution of the transmission with $\beta = 1.2265$ and $\eta = 48562$. The probability plot is given in Figure 5.1.

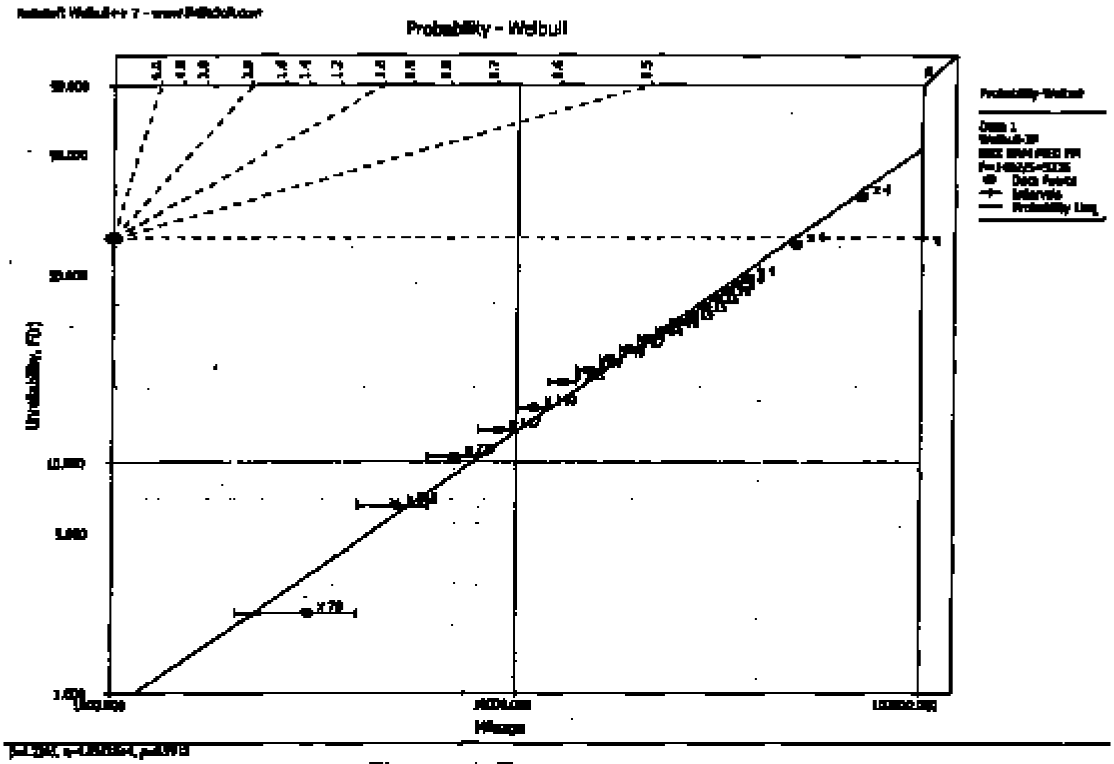


Figure 5.1: Transmission Life Distribution

The BX results are summarized in the following table.

Table 5.1: BX Mileage for the Transmission

BX%	Miles	BX%	Miles
1	1141	40	28082
5	4310	50	36017
10	7752	90	95858
20	14294	95	118800
30	20952		

NOTE: In the given data set, ReliaSoft used the best data available to it, which were the failures, customer contact records and sales information provided by Polaris. The allocation of the 926 mileage unknown failures can considerably affect the analysis results. The allocation method used in this report is based on the study of the distribution of the failures for which mileage was recorded and the allocation of the unknown mileage failures in the same distribution pattern. This is a reasonable method for allocating data with unknown mileage failures, when there is no reason to believe that data with unknown mileage failures significantly differ in their distribution from the samples with known mileages. Based on engineering knowledge provided by Polaris, it is reasonable to conclude that the actual mileages of the 926 unknown failures may be even higher than assumed in this report, since the known mileages recorded at failure are from claims presented to Polaris by dealers, either during the one-year warranty period or later, as good will claims. The higher the mileage at failure (after expiration of the one-year warranty period), the less likely it is that the customer or dealer would seek financial contribution from Polaris, and Polaris would not have information about the mileage at failure in these instances. For this reason, it is reasonable to conclude that the table presented above represents a conservative estimate for the BX% life, and there is no basis for assuming that it represents an understatement of the BX% life.

Appendix

Analysis Results of the Data by 10/20/2000

For the data by 10/20/2000, only 5 failures are available. Obviously, many failures are missing. Therefore, using this data only, the analysis results will be very unrealistic. By applying the method described in this report to allocate the suspensions, we get the following table.

Table A.1: Summary of the Warranty Data by 10/20/2000

Mileage Intervals		Failures	Recorded Suspensions	Unknown Suspensions	Total Suspensions
0	2000	0	1314	216	1530
2000	4000	2	817	134	951
4000	6000	1	440	72	512
6000	8000	1	242	40	282
8000	10000	1	140	23	164
10000	12000	0	83	14	96
12000	14000	0	50	8	58
14000	16000	0	31	5	37
16000	18000	0	18	3	21
18000	20000	0	11	2	13
20000	22000	0	7	1	8
22000	24000	0	4	1	5
	Total	5	3157	519	3679

Figure A.1 gives the probability plot for the Weibull distribution found with $\beta = 1.7$ and $\eta = 249350$.

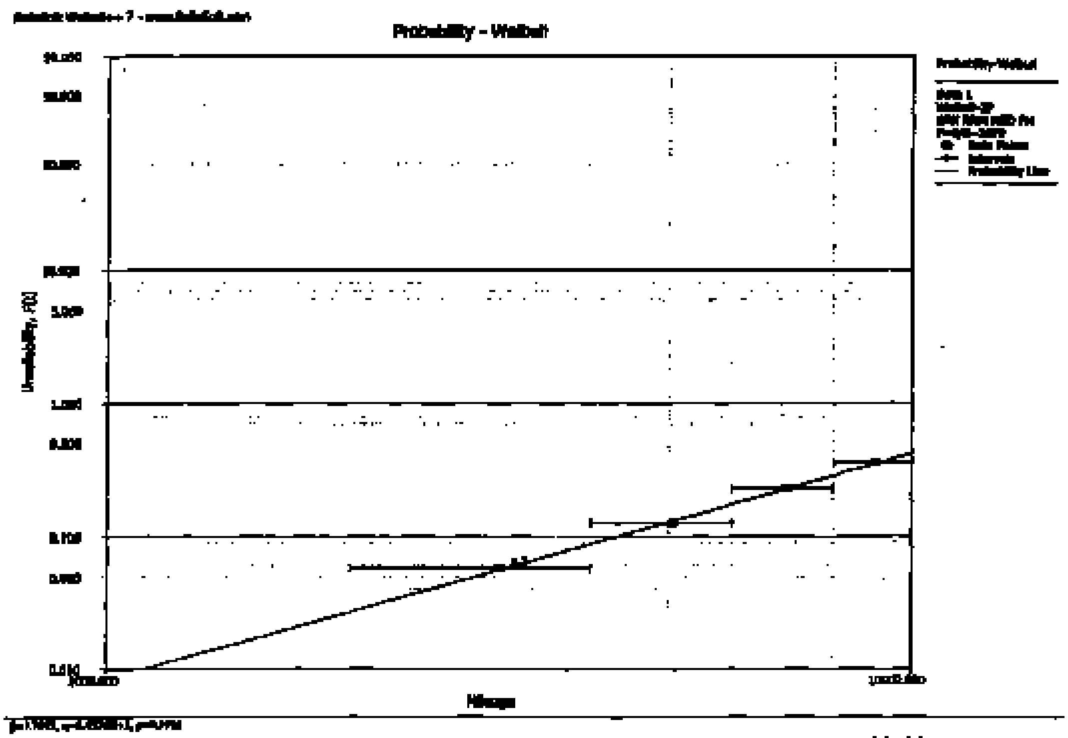


Figure A.1: Probability Plot of the Lift Distribution for the Data by 10/20/2000