

Appendix T:

SPI PowerNet Pty Ltd

**Transmission Revenue Reset
(TRR)
2014/15 – 2016/17**

**Fitting Probability
Distributions for SP AusNet
Reliability Data for STPIS
Submission - Parsons
Brinkerhoff**

SP AusNet

Fitting probability distributions for SP AusNet reliability data for STPIS Submission

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1. Introduction

Parsons Brinckerhoff has been engaged by SP AusNet to assist with the determination of suitable targets and other attributes for the parameters of its service target performance incentive scheme (STIPS).

The service component of SP AusNet's STIPS will measure performance against the following parameters:

- Average outage duration (1 sub-parameter)
- Loss of supply event frequency (2 sub-parameters)
- Average circuit outage rates (6 sub-parameters).

Parsons Brinckerhoff determined a curve of best fit to SP AusNet's reliability data from the past five years 2008-2012 for each of the sub-parameters and calculated the standard deviation on which proposed caps and collars for this scheme are based.

1.1 Approach

Parsons Brinckerhoff used the @RISK product, a risk analysis and simulation add-in tool for Microsoft Excel, to determine the types of probability distribution that best fit the reliability data.

Recognising the need to present the best fit distribution curve based on the nature of the reliability data, the following distribution parameters were chosen for this exercise.

- Average outage duration data are fitted using continuous probability distributions bounded at a lower limit of zero
- Loss of supply event frequency are fitted with discrete probability distributions
- Availability rates are fitted with continuous probability distributions bounded at a lower limit of zero.

Three key fit statistics were used to measure how well the probability distribution functions fit the input data. For discrete probability distributions, the Chi Squared (ChiSq) fit statistic was used. For non-discrete distributions, the Kolmogorov-Smirnov (K-S) and the Anderson-Darling (A-D) fit statistics were used.

The K-S fit statistic focuses on the differences between the middle of the fitted distribution and the input data. The A-D fit statistic focuses on the difference between the tails of fitted distribution and input data. Where the input data was concentrated around the middle of a distribution curve the K-S fit statistic was used and where the data was near the tails the A-D fit statistic was used. The results from both were compared in each case. Where the input data was both in the middle and the tails of a distribution, the result from the A-D fit statistic was favoured, because the best fit of the data and the distribution curve at the tails improves the calculation of the scheme measures (caps and collars at one or two standard deviations).

Once the probability distribution function of best fit was determined for each sub-parameter the standard deviation of the probability distribution functions were calculated.

Because a probability distribution is being fitted to a dataset of five values only for each sub-parameter, the fit statistics are typically low in value and the curve of best fit is sensitive to small changes in any of the five values. The curve of second best fit was examined to test for any large variations in the calculated standard deviation that might indicate that the curve of best fit should not be used.

2. Results of distribution fitting

2.1 Average outage duration

The average outage duration is a measure of the response time to outages. The optimal performance limit is close to zero, which represents an immediate response; as such a lower limit of zero is set for fitting curves to the data.

The best fit using the A-D fit statistic is the Exponential distribution curve (figure 1), where the duration data is spread across the middle and tails of the distribution. Table 1 shows the statistical results using other distributions to fit the duration data using the A-D fit statistic, where it can be seen the Erlang distribution curve exhibits the second best fit.

Figure 1 Average outage duration – continuous distribution fit comparison using A-D

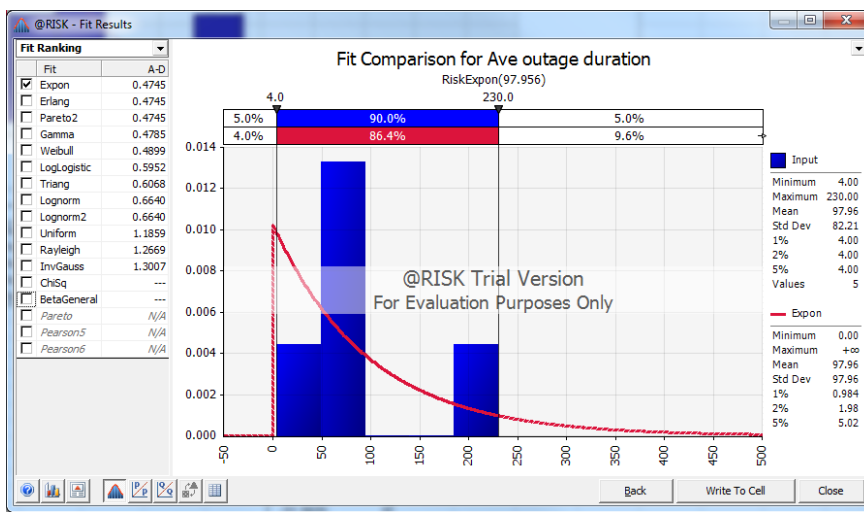


Table 1 Average outage duration – statistics table for A-D

Fit Ranking	Fit	A-D	Input	Expon	Erlang	Pareto2	Gamma	Weibull
Distribution Statistics								
	Minimum		4.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Maximum		230.0000	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
	Mean		97.9556	97.9556	97.9556	97.9556	97.9556	97.3162
	Mode		88.7500 [e..]	0.0000	0.0000	0.0000	3.1732	12.8495
	Median		91.7780	67.8976	67.8976	67.8976	68.7736	72.7936
	Std. Deviation		82.2058	97.9556	97.9556	97.9556	96.3559	87.6454
	Skewness		1.0950	2.0000	2.0000	2.0000	1.9673	1.7059
	Kurtosis		5.4675	9.0000	9.0000	9.0000	8.8056	7.2023
Percentiles								
	5%		4.0000	5.0245	5.0245	5.0245	5.4470	7.0024
	10%		4.0000	10.3207	10.3207	10.3207	10.9567	13.3774
	15%		4.0000	15.9196	15.9196	15.9196	16.6993	19.7531
	20%		4.0000	21.8582	21.8582	21.8582	22.7372	26.2690
	25%		71.5000	28.1801	28.1801	28.1801	29.1247	33.0109
	30%		71.5000	34.9383	34.9383	34.9383	35.9202	40.0508
	35%		71.5000	42.1976	42.1976	42.1976	43.1910	47.4610
	40%		71.5000	50.0382	50.0382	50.0382	51.0182	55.3216
	45%		91.7780	58.5615	58.5615	58.5615	59.5028	63.7269
	50%		91.7780	67.8976	67.8976	67.8976	68.7736	72.7936
	55%		91.7780	78.2183	78.2183	78.2183	78.9992	82.6715
	60%		92.5000	89.7558	89.7558	89.7558	90.4073	93.5599
	65%		92.5000	102.8360	102.8360	102.8360	103.3166	105.7352
	70%		92.5000	117.9359	117.9359	117.9359	118.1933	119.5986
	75%		92.5000	135.7953	135.7953	135.7953	135.7955	135.7674
	80%		92.5000	157.6535	157.6535	157.6535	157.2240	155.2687
	85%		230.0000	185.8335	185.8335	185.8335	184.8521	180.0151
	90%		230.0000	225.5511	225.5511	225.5511	223.7269	214.2668
	95%		230.0000	293.4488	293.4488	293.4488	290.0582	271.4739

The best fit using the K-S fit statistic is the Triangle distribution curve (figure 2). Table 2 illustrates other distribution curves fitting the outage duration data using the K-S statistics, the LogLogistic distribution curve exhibits the second best fit for the outage duration data.

Figure 2 Average outage duration – continuous distribution fit comparison using K-S

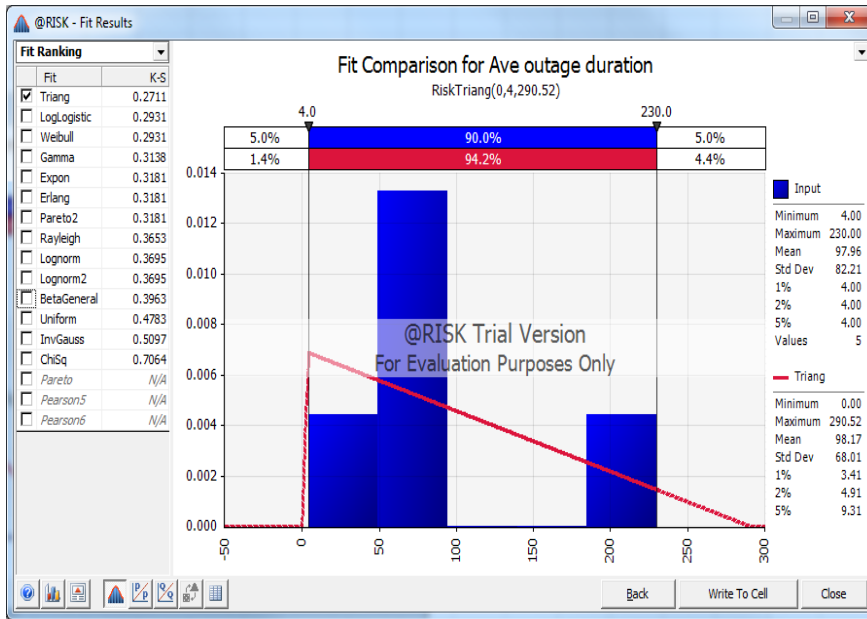


Table 2 Average outage duration – statistics table for K-S

	Input	Triang	LogLogistic	Weibull	Gamma	Expon
Distribution Statistics						
Minimum	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	230.0000	290.5189	+Infinity	+Infinity	+Infinity	+Infinity
Mean	97.9556	98.1730	219.4410	97.3162	97.9556	97.9556
Mode	88.7500 [e..]	4.0000	19.1694	12.8495	3.1732	0.0000
Median	91.7780	86.5101	72.9474	72.7936	68.7736	67.8976
Std. Deviation	82.2058	68.0095	+Infinity	87.6454	96.3559	97.9556
Skewness	1.0905	0.5653	+Infinity	1.7059	1.9673	2.0000
Kurtosis	5.4675	2.4000	+Infinity	7.2023	8.8056	9.0000
Percentiles						
5%	4.0000	9.3122	8.6013	7.0024	5.4470	5.0245
10%	4.0000	16.8124	14.7971	13.3774	10.9567	10.3207
15%	4.0000	24.5240	20.7039	19.7531	16.6993	15.9196
20%	4.0000	32.4660	26.6613	26.2690	22.7372	21.8582
25%	71.5000	40.6602	32.8544	33.0109	29.1247	28.1801
30%	71.5000	49.1325	39.4311	40.0508	35.9202	34.9383
35%	71.5000	57.9131	46.5386	47.4610	43.1910	42.1976
40%	71.5000	67.0385	54.3448	55.3216	51.0182	50.0382
45%	91.7780	76.5527	63.0571	63.7269	59.5028	58.5615
50%	91.7780	86.5101	72.9474	72.7936	68.7736	67.8976
55%	91.7780	96.9792	84.3890	82.6715	78.9992	78.2183
60%	92.5000	108.0479	97.9179	93.5599	90.4073	89.7558
65%	92.5000	119.8329	114.3422	105.7352	103.3166	102.8360
70%	92.5000	132.4944	134.9527	119.5986	118.1933	117.9359
75%	92.5000	146.2629	161.9670	135.7674	135.7595	135.7595
80%	92.5000	161.4925	199.5900	155.2687	157.2240	157.6535
85%	230.0000	178.7787	257.0204	180.0151	184.8521	185.8335
90%	230.0000	199.2834	359.6192	214.2668	223.7269	225.5511
95%	230.0000	226.0057	618.6654	271.4739	290.0582	293.4488

As the data concentrates about both the middle and tails of the distribution, the A-D fit has been selected and the curve of best fit determined as Exponential. The curve of second best fit is the Erlang curve. The standard deviations of the two curves are the same (97.96).

In comparison, the standard deviation of the best K-S fit curve (Triangle) is significantly less at 68.01. The upper limit of the Triangle curve, however, is bounded at 290.5, which is counter intuitive to the possible performance outcomes. Hence the adoption of this curve to represent the data is inappropriate.

2.2 Loss of supply event frequency

Losses of supply events represent discrete occurrences of failure. In order to best fit the loss of supply events data, discrete distribution curves are used with equal interval binning.

Number of events > 0.05 system minutes

Figure 3 shows the NegBin discrete distribution curve is the best fit for the loss of supply events greater than 0.05 systems. Table 3 is provided to show the variation in statistics for other discrete distribution curves.

Noting that the Chi Squared fit statistics are similar for the top three curves of best fit, and that the standard deviations vary widely, the curve of second best fit (Geometric) and the curve of third best fit (Poisson) were also examined. The standard deviations are 2.45, 2.00 and 1.41 respectively. The relatively high variation in standard deviations indicates some uncertainty in the curve fitting.

The average of the three values (2.45, 2.00, 1.41) is 1.95, close to the standard deviation for the curve of best fit. This indicates that the standard deviation of 2.000 for the curve of best fit (NegBin) is an appropriate value to use in setting caps and collars.

Figure 3 No. of events > 0.05 system minutes – best discrete distribution fit - NegBin

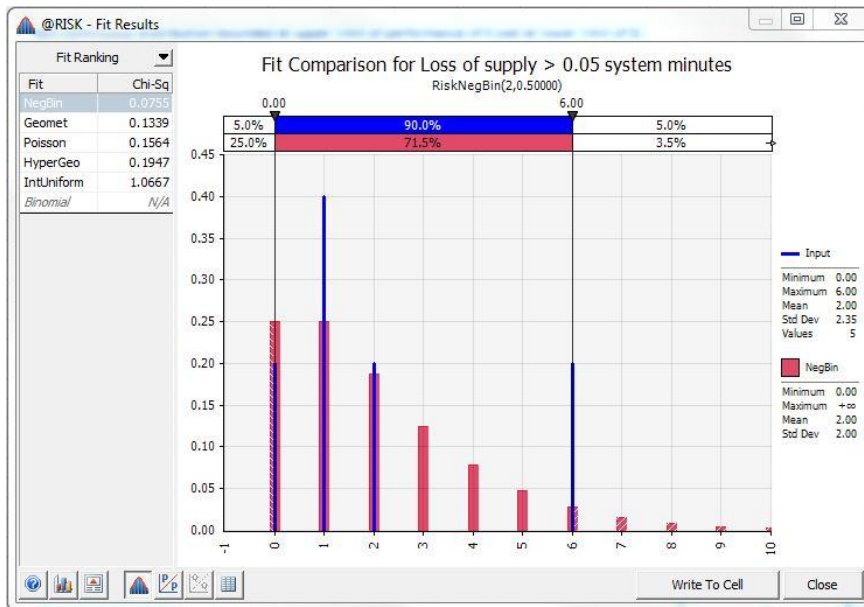


Table 3 No. of events > 0.05 system minutes – discrete distributions statistics table

The screenshot shows the @RISK - Fit Results window. It contains a table with the following data:

Fit Ranking	Chi-Sq	Function	Input	NegBin	Geomet	Poisson	HyperGeo	IntUnifo..
NegBin	0.0755							
Geomet	0.1339							
Poisson	0.1564							
HyperGeo	0.1947							
IntUniform	1.0667							
Binomial	N/A							
		Function	=RiskNegBi..	=RiskGeom..	=RiskPoisso..	=RiskHyper..	=RiskInt..	
		- Distribution Statistics						
		Minimum	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		Maximum	6.0000	+Infinity	+Infinity	+Infinity	63.0000	6.0000
		Mean	2.0000	2.0000	2.0000	2.0000	1.9801	3.0000
		Mode	1.0000	0.0000	0.0000	1.0000	2.0000	0.0000
		Median	1.0000	1.0000	1.0000	2.0000	2.0000	3.0000
		Std. Deviation	2.3452	2.0000	2.4495	1.4142	1.3836	2.0000
		Skewness	1.7444	1.5000	2.0412	0.7071	0.6748	0.0000
		Kurtosis	6.3223	6.2500	9.1667	3.5000	3.4219	1.7500
		- Percentiles						
		5%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		10%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		15%	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
		20%	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000
		25%	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000
		30%	1.0000	1.0000	0.0000	1.0000	1.0000	2.0000
		35%	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000
		40%	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000
		45%	1.0000	1.0000	1.0000	2.0000	2.0000	3.0000
		50%	1.0000	1.0000	1.0000	2.0000	2.0000	3.0000
		55%	1.0000	2.0000	1.0000	2.0000	2.0000	3.0000
		60%	1.0000	2.0000	2.0000	2.0000	2.0000	4.0000
		65%	2.0000	2.0000	2.0000	2.0000	2.0000	4.0000
		70%	2.0000	3.0000	2.0000	3.0000	3.0000	4.0000
		75%	2.0000	3.0000	3.0000	3.0000	3.0000	5.0000
		80%	2.0000	3.0000	3.0000	3.0000	3.0000	5.0000
		85%	6.0000	4.0000	4.0000	3.0000	3.0000	5.0000
		90%	6.0000	5.0000	5.0000	4.0000	4.0000	6.0000
		95%	6.0000	6.0000	7.0000	5.0000	4.0000	6.0000

Number of events > 0.30 system minutes

The discrete distribution of best fit for the loss of supply events greater than 0.30 system minutes is the IntUniform curve, giving a standard deviation of 0.816. Table 4 is provided to show the statistics for other discrete distribution curves.

The curve of second best fit (Binomial) has a significantly worse fit statistic – 7.2 compared to 1.6 for the curve of best fit – hence it has not been considered.

Figure 4 No. of event > 0.30 system minutes – best discrete distribution fit – IntUniform

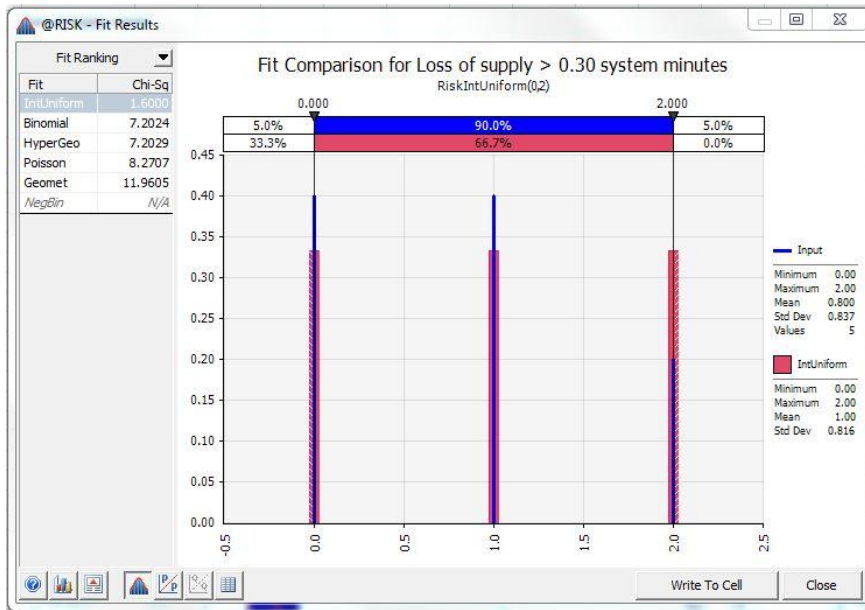


Table 4 No. of events > 0.30 system minutes – discrete distributions statistics table

Fit	Chi-Sq	Function	Input	IntUniform	Binomial	HyperGeo	Poisson	Geomet
IntUniform	1.6000	=RiskIntUni..						
Binomial	7.2024	=RiskBinomi..						
HyperGeo	7.2029	=RiskHyper..						
Poisson	8.2707	=RiskPoisso..						
Geomet	11.9605	=RiskGeomet(0.55556)						
NegBin	N/A							
- Distribution Statistics								
Minimum		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum		2.0000	2.0000	2.0000	2.0000	2.0000	+Infinity	+Infinity
Mean		0.8000	1.0000	0.8000	0.8000	0.8000	0.8000	0.8000
Mode		0.0000	0.0000	1.0000	1.0000	0.0000	0.0000	0.0000
Median		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000
Std. Deviation		0.8367	0.8165	0.6928	0.6928	0.8944	1.2000	1.2000
Skewness		0.5122	0.0000	0.2887	0.2887	1.1180	2.1667	2.1667
Kurtosis		2.3878	1.5000	2.0833	2.0834	4.2500	9.6944	9.6944
- Percentiles								
5%		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10%		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15%		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20%		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
25%		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30%		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
35%		0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
40%		0.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000
45%		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000
50%		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000
55%		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000
60%		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
65%		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
70%		1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000
75%		1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000
80%		1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000
85%		2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000
90%		2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000
95%		2.0000	2.0000	2.0000	2.0000	2.0000	3.0000	3.0000

2.3 Average circuit outage rate

Average circuit outage rates represent measures of availability for components of transmission circuits. The optimal performance limit is 0%, which represents total availability for the component for the year; as such a lower limit of zero is set for fitting non-continuous curves to the data.

The availability rate measures are presented based on the components and nature of availability in the following categories.

Lines outage rate – fault performance

The K-S fit statistic has the Weibull distribution curve delivering the best fit (figure 5), while using the A-D fit statistic, the LogLogistic curve is best fitting (figure 6). As most of the data congregate near the two tails, the A-D fit statistic is preferred (LogLogistic), giving a standard deviation of 0.090.

Tables 5 and 6 present the variation in statistical fit by other distribution curves for K-S and A-D respectively. The standard deviations for the curve of second best fit (Pearson5) and the Weibull are 0.080 and 0.072, being slightly lower than for the preferred curve.

Figure 5 Lines - fault non-continuous distribution comparison using K-S

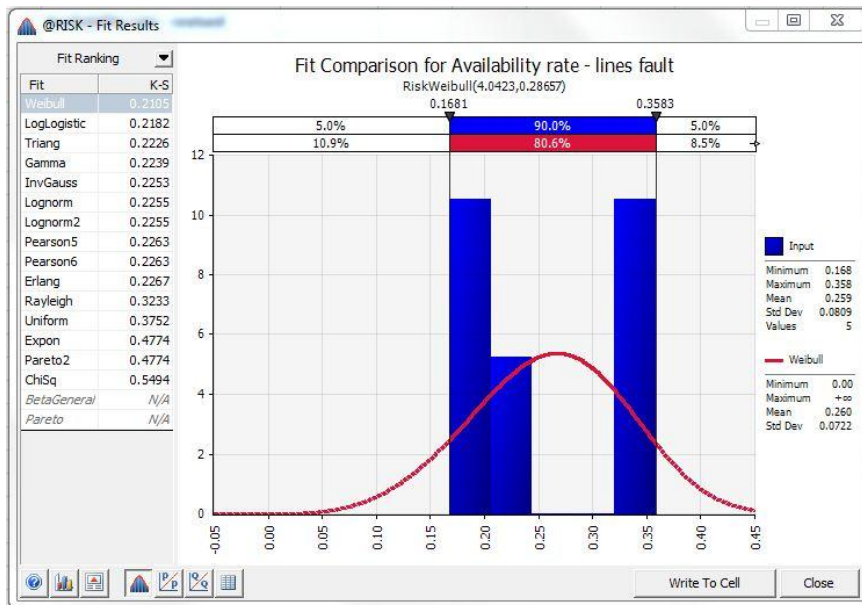


Table 5 Lines – fault non-continuous distribution statistics table for K-S

Fit	K-S
Weibull	0.2105
LogLogistic	0.2182
Triang	0.2226
Gamma	0.2239
InvGauss	0.2253
Lognorm	0.2255
Lognorm2	0.2255
Pearson5	0.2263
Pearson6	0.2263
Erlang	0.2267
Rayleigh	0.3233
Uniform	0.3752
Expon	0.4774
Pareto2	0.4774
ChiSq	0.5494
BetaGeneral	N/A
Pareto	N/A

Function	=RiskWeibu..	=RiskLogLo..	=RiskTriang..	=RiskGamm..	=RiskInvGa..	=RiskLogno..
Minimum	0.1681	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.3583	+Infinity	+Infinity	0.3583	+Infinity	+Infinity
Mean	0.2590	0.2599	0.2622	0.2389	0.2590	0.2592
Mode	0.1728 [est]	0.2671	0.2335	0.3583	0.2385	0.2294
Median	0.2437	0.2617	0.2488	0.2534	0.2522	0.2487
Std. Deviation	0.0809	0.0722	0.0902	0.0845	0.0729	0.0750
Skewness	0.2398	-0.0957	2.0116	-0.5657	0.5629	0.8977
Kurtosis	0.7325	2.7522	17.9225	2.4000	3.4752	4.4663

Percentiles	0.1681	0.1374	0.1475	0.0801	0.1519	0.1561	0.1557
5%	0.1681	0.1374	0.1475	0.0801	0.1519	0.1561	0.1557
10%	0.1681	0.1642	0.1685	0.1133	0.1711	0.1727	0.1727
15%	0.1681	0.1828	0.1829	0.1388	0.1850	0.1851	0.1852
20%	0.1681	0.1977	0.1946	0.1603	0.1965	0.1956	0.1957
25%	0.2000	0.2106	0.2048	0.1792	0.2069	0.2051	0.2053
30%	0.2000	0.2221	0.2141	0.1963	0.2164	0.2140	0.2143
35%	0.2000	0.2327	0.2229	0.2120	0.2256	0.2227	0.2229
40%	0.2000	0.2427	0.2316	0.2266	0.2345	0.2313	0.2315
45%	0.2437	0.2523	0.2401	0.2404	0.2433	0.2399	0.2401
50%	0.2437	0.2617	0.2488	0.2534	0.2522	0.2487	0.2488
55%	0.2437	0.2711	0.2579	0.2657	0.2613	0.2578	0.2579
60%	0.3250	0.2804	0.2674	0.2776	0.2708	0.2674	0.2675
65%	0.3250	0.2900	0.2777	0.2889	0.2809	0.2777	0.2777
70%	0.3250	0.3000	0.2892	0.2998	0.2917	0.2890	0.2890
75%	0.3250	0.3107	0.3024	0.3103	0.3038	0.3017	0.3016
80%	0.3250	0.3224	0.3183	0.3205	0.3175	0.3164	0.3163
85%	0.3583	0.3358	0.3386	0.3304	0.3341	0.3345	0.3344
90%	0.3583	0.3522	0.3675	0.3399	0.3557	0.3586	0.3586
95%	0.3583	0.3759	0.4197	0.3493	0.3894	0.3973	0.3977

Figure 6 Lines - fault non-continuous distribution comparison using A-D

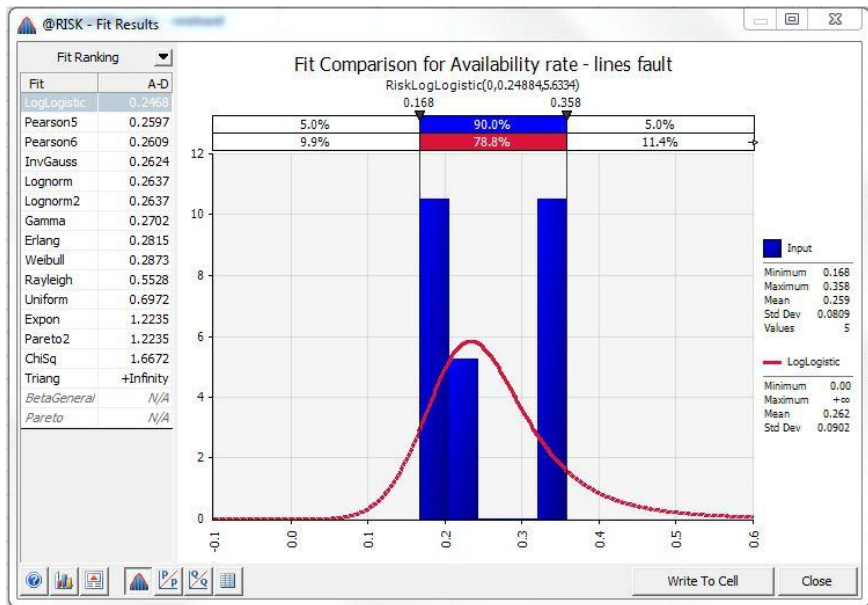


Table 6 Lines – fault non-continuous distribution statistics table for A-D

Fit	Ranking	Function	Input	LogLogistic	Pearson5	Pearson6	InvGauss	Lognorm	Lognorm2
LogLogistic	0.2468	=RiskLogLo..							
Pearson5	0.2597	=RiskPears..							
Pearson6	0.2609	=RiskPears..							
InvGauss	0.2624	=RiskInvGa..							
Lognorm	0.2637	=RiskLogno..							
Lognorm2	0.2637	=RiskLogno..							
Gamma	0.2702								
Erlang	0.2815								
Weibull	0.2873								
Rayleigh	0.5528								
Uniform	0.6972								
Expon	1.2235								
Pareto2	1.2235								
ChiSq	1.6672								
Triang	+Infinity								
BetaGeneral	N/A								
Pareto	N/A								

Statistic	Input	LogLogistic	Pearson5	Pearson6	InvGauss	Lognorm	Lognorm2
Minimum	0.1681	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.3583	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.2590	0.2622	0.2597	0.2595	0.2590	0.2592	0.2592
Mode	0.1728 [est]	0.2335	0.2214	0.2237	0.2285	0.2294	0.2294
Median	0.2437	0.2488	0.2455	0.2464	0.2487	0.2488	0.2488
Std. Deviation	0.0809	0.0902	0.0799	0.0786	0.0750	0.0754	0.0754
Skewness	0.2398	2.0116	1.3598	1.2273	0.8684	0.8977	0.8977
Kurtosis	0.7325	17.9225	6.7989	6.0387	4.2569	4.4663	4.4663

Percentile	Input	LogLogistic	Pearson5	Pearson6	InvGauss	Lognorm	Lognorm2
5%	0.1681	0.1475	0.1588	0.1579	0.1561	0.1557	0.1557
10%	0.1681	0.1685	0.1739	0.1736	0.1727	0.1727	0.1727
15%	0.1681	0.1829	0.1852	0.1852	0.1851	0.1852	0.1852
20%	0.1681	0.1946	0.1949	0.1951	0.1956	0.1957	0.1957
25%	0.2000	0.2048	0.2037	0.2042	0.2051	0.2053	0.2053
30%	0.2000	0.2141	0.2121	0.2128	0.2140	0.2143	0.2143
35%	0.2000	0.2229	0.2204	0.2211	0.2227	0.2229	0.2229
40%	0.2000	0.2316	0.2286	0.2294	0.2313	0.2315	0.2315
45%	0.2437	0.2401	0.2369	0.2378	0.2399	0.2401	0.2401
50%	0.2437	0.2488	0.2455	0.2464	0.2487	0.2488	0.2488
55%	0.2437	0.2579	0.2545	0.2554	0.2578	0.2579	0.2579
60%	0.3250	0.2674	0.2641	0.2650	0.2674	0.2675	0.2675
65%	0.3250	0.2777	0.2746	0.2754	0.2777	0.2777	0.2777
70%	0.3250	0.2892	0.2862	0.2869	0.2890	0.2890	0.2890
75%	0.3250	0.3024	0.2995	0.3000	0.3017	0.3016	0.3016
80%	0.3250	0.3183	0.3152	0.3155	0.3164	0.3163	0.3163
85%	0.3583	0.3386	0.3350	0.3348	0.3345	0.3344	0.3344
90%	0.3583	0.3675	0.3623	0.3612	0.3586	0.3586	0.3586
95%	0.3583	0.4197	0.4083	0.4053	0.3973	0.3977	0.3977

Lines outage rate – forced outage performance

The data for lines forced to be unavailable is spread across the middle and the tails of the distribution curve. The best fit distribution for the lines forced outage performance for both the K-S and A-D fit statistics is the Pearson5 distribution curve (figure 7 and 8) giving a standard deviation of 0.017.

Tables 7 and 8 illustrate the other distribution fit statistics for the lines forced outage performance. The standard deviation for the curve of second best fit (InvGauss) is the same as for the curve of best fit.

Figure 7 Lines - forced non-continuous distribution comparison using K-S

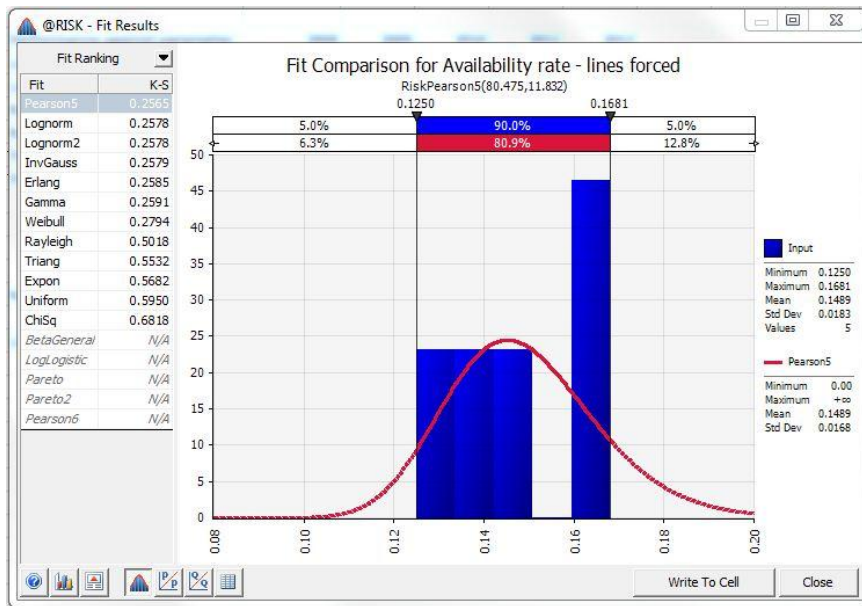


Table 7 Lines – forced non-continuous distribution statistics table for K-S

Fit Ranking	Fit	K-S	Function	Input	Pearson5	Lognorm	Lognorm2	InvGauss	Erlang	Gamma
1	Pearson5	0.2565	=RiskPears..							
2	Lognorm	0.2578	=RiskLogno..							
3	Lognorm2	0.2578	=RiskLogno..							
4	InvGauss	0.2579	=RiskInvGa..							
5	Erlang	0.2585	=RiskErlang..							
6	Gamma	0.2591	=RiskGamm..							
7	Weibull	0.2794								
8	Rayleigh	0.5018								
9	Triang	0.5532								
10	Expon	0.5682								
11	Uniform	0.5950								
12	ChiSq	0.6818								
13	BetaGeneral	N/A								
14	LogLogistic	N/A								
15	Pareto	N/A								
16	Pareto2	N/A								
17	Pearson6	N/A								

Distribution Statistics									
Minimum	0.1250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.1681	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.1489	0.1489	0.1489	0.1489	0.1489	0.1489	0.1489	0.1489	0.1489
Mode	0.1670 [est]	0.1452	0.1461	0.1461	0.1461	0.1461	0.1470	0.1470	
Median	0.1429	0.1476	0.1479	0.1479	0.1479	0.1479	0.1482	0.1482	
Std. Deviation	0.0183	0.0168	0.0166	0.0166	0.0166	0.0166	0.0165	0.0165	
Skewness	-0.0952	0.4574	0.3364	0.3364	0.3348	0.3348	0.2222	0.2216	
Kurtosis	1.2607	3.3963	3.2019	3.2019	3.1868	3.1868	3.0741	3.0737	

Percentiles									
5%	0.1250	0.1235	0.1232	0.1232	0.1232	0.1232	0.1227	0.1228	
10%	0.1250	0.1284	0.1283	0.1283	0.1283	0.1283	0.1281	0.1281	
15%	0.1250	0.1318	0.1318	0.1318	0.1318	0.1318	0.1318	0.1318	
20%	0.1250	0.1346	0.1347	0.1347	0.1347	0.1347	0.1348	0.1348	
25%	0.1417	0.1370	0.1372	0.1372	0.1372	0.1372	0.1374	0.1374	
30%	0.1417	0.1393	0.1395	0.1395	0.1395	0.1395	0.1398	0.1398	
35%	0.1417	0.1415	0.1417	0.1417	0.1417	0.1417	0.1420	0.1420	
40%	0.1417	0.1435	0.1438	0.1438	0.1438	0.1438	0.1441	0.1441	
45%	0.1429	0.1456	0.1459	0.1459	0.1459	0.1459	0.1462	0.1462	
50%	0.1429	0.1476	0.1479	0.1479	0.1479	0.1479	0.1482	0.1482	
55%	0.1429	0.1497	0.1500	0.1500	0.1500	0.1500	0.1503	0.1503	
60%	0.1667	0.1519	0.1522	0.1522	0.1522	0.1522	0.1525	0.1525	
65%	0.1667	0.1542	0.1544	0.1544	0.1544	0.1544	0.1547	0.1547	
70%	0.1667	0.1566	0.1568	0.1568	0.1568	0.1568	0.1571	0.1571	
75%	0.1667	0.1593	0.1595	0.1595	0.1595	0.1595	0.1596	0.1596	
80%	0.1667	0.1624	0.1625	0.1625	0.1625	0.1625	0.1626	0.1626	
85%	0.1681	0.1661	0.1660	0.1660	0.1660	0.1660	0.1660	0.1660	
90%	0.1681	0.1709	0.1706	0.1706	0.1706	0.1706	0.1704	0.1703	
95%	0.1681	0.1784	0.1777	0.1777	0.1776	0.1776	0.1771	0.1770	

Figure 8 Lines - forced non-continuous distribution comparison using A-D

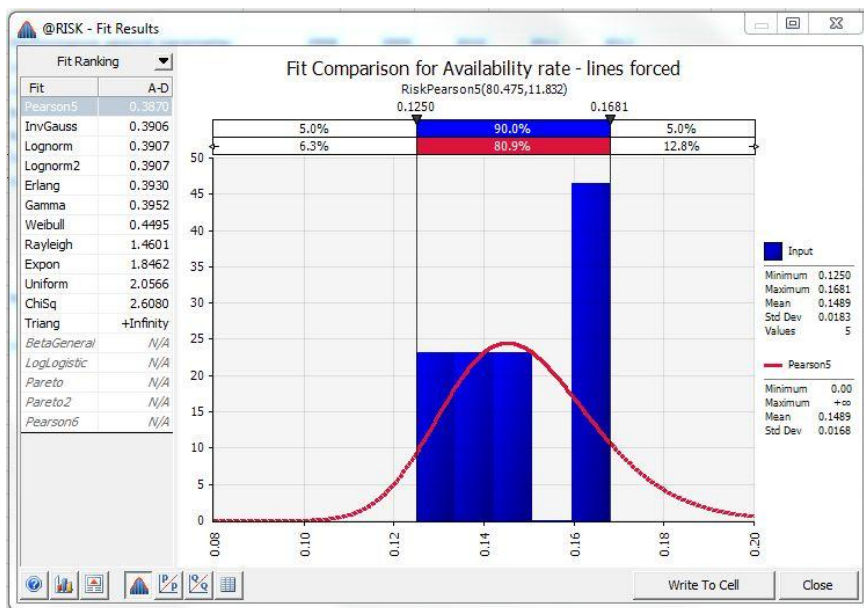


Table 8 Lines – forced non-continuous distribution statistics table for A-D

Fit	A-D	Function	=RiskPears..	=RiskInvGa..	=RiskLogno..	=RiskLogno..	=RiskErlang..	=RiskGamm..
Pearson5	0.3870							
InvGauss	0.3906							
Lognorm	0.3907							
Lognorm2	0.3907							
Erlang	0.3930							
Gamma	0.3952							
Weibull	0.4495							
Rayleigh	1.4601							
Expon	1.8462							
Uniform	2.0566							
ChiSq	2.6080							
Triang	+Infinity							
BetaGeneral	N/A							
LogLogistic	N/A							
Pareto	N/A							
Pareto2	N/A							
Pearson6	N/A							

Minimum	0.1250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.1681	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.1489	0.1489	0.1489	0.1489	0.1489	0.1489	0.1489
Mode	0.1670 [est]	0.1452	0.1461	0.1461	0.1461	0.1470	0.1470
Median	0.1429	0.1476	0.1479	0.1479	0.1479	0.1482	0.1482
Std. Deviation	0.0183	0.0168	0.0166	0.0166	0.0166	0.0165	0.0165
Skewness	-0.0952	0.4574	0.3348	0.3364	0.3364	0.2222	0.2216
Kurtosis	1.2607	3.3963	3.1868	3.2019	3.2019	3.0741	3.0737

Percentiles	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	
5%	0.1250	0.1235	0.1232	0.1232	0.1232	0.1232	0.1227	0.1228												
10%	0.1250	0.1284	0.1283	0.1283	0.1283	0.1283	0.1281	0.1281												
15%	0.1250	0.1318	0.1318	0.1318	0.1318	0.1318	0.1318	0.1318												
20%	0.1250	0.1346	0.1347	0.1347	0.1347	0.1347	0.1348	0.1348												
25%	0.1417	0.1370	0.1372	0.1372	0.1372	0.1372	0.1374	0.1374												
30%	0.1417	0.1393	0.1395	0.1395	0.1395	0.1395	0.1398	0.1398												
35%	0.1417	0.1415	0.1417	0.1417	0.1417	0.1417	0.1420	0.1420												
40%	0.1417	0.1435	0.1438	0.1438	0.1438	0.1438	0.1441	0.1441												
45%	0.1429	0.1456	0.1459	0.1459	0.1459	0.1459	0.1462	0.1462												
50%	0.1429	0.1476	0.1479	0.1479	0.1479	0.1479	0.1482	0.1482												
55%	0.1429	0.1497	0.1500	0.1500	0.1500	0.1500	0.1503	0.1503												
60%	0.1667	0.1519	0.1522	0.1522	0.1522	0.1522	0.1525	0.1525												
65%	0.1667	0.1542	0.1544	0.1544	0.1544	0.1544	0.1547	0.1547												
70%	0.1667	0.1566	0.1568	0.1568	0.1568	0.1568	0.1571	0.1571												
75%	0.1667	0.1593	0.1595	0.1595	0.1595	0.1595	0.1596	0.1596												
80%	0.1667	0.1624	0.1625	0.1625	0.1625	0.1625	0.1626	0.1626												
85%	0.1681	0.1661	0.1660	0.1660	0.1660	0.1660	0.1660	0.1660												
90%	0.1681	0.1709	0.1706	0.1706	0.1706	0.1706	0.1704	0.1703												
95%	0.1681	0.1784	0.1776	0.1776	0.1777	0.1777	0.1771	0.1770												

Reactive plant outage rate – fault performance

Using the K-S fit statistic, the best fit distribution for reactive plant unavailability due to fault is the InvGauss (figure 9), while the A-D fit statistic has the Loglogistic curve as the best fit (figure 10). As the data is spread evenly across the middle and the tails of the distribution curve the A-D fit is preferred (LogLogistic), giving a standard deviation of 0.064.

Tables 9 and 10 are provided to show the variation in fit statistics of other distribution curves. The standard deviation for the curve of second best fit (InvGauss) at 0.058 is not materially different.

Figure 9 Reactive plant – fault non-continuous distribution comparison using K-S

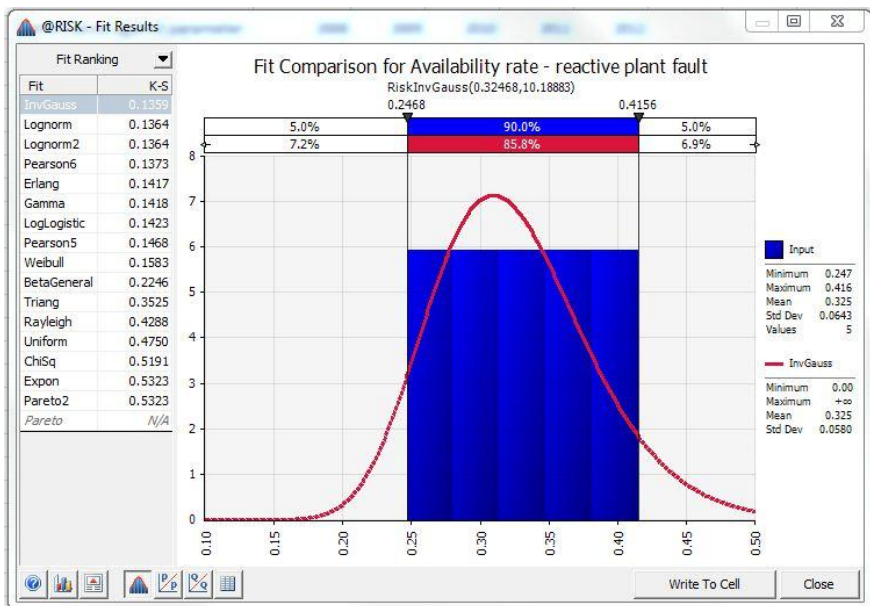


Table 9 Reactive plant – fault non-continuous distribution statistics table for K-S

Fit	K-S	Function	Input	InvGauss	Lognorm	Lognorm2	Pearson6	Erlang	Gamma
InvGauss	0.1359	=RiskInvGa..							
Lognorm	0.1364	=RiskLogno..							
Lognorm2	0.1364	=RiskLogno..							
Pearson6	0.1373	=RiskPears..							
Erlang	0.1417	=RiskErlang..							
Gamma	0.1418	=RiskGamm..							
LogLogistic	0.1423								
Pearson5	0.1468								
Weibull	0.1583								
BetaGeneral	0.2246								
Triang	0.3525								
Rayleigh	0.4288								
Uniform	0.4750								
ChiSq	0.5191								
Expon	0.5323								
Pareto2	0.5323								
Pareto	N/A								

Distribution Statistics									
Minimum	0.2468	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.4156	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.3247	0.3247	0.3247	0.3247	0.3247	0.3247	0.3247	0.3247	0.3247
Mode	0.2510 [est]	0.3095	0.3097	0.3097	0.3090	0.3145	0.3145	0.3145	0.3145
Median	0.3247	0.3196	0.3196	0.3196	0.3193	0.3213	0.3213	0.3213	0.3213
Std. Deviation	0.0643	0.0580	0.0580	0.0580	0.0583	0.0574	0.0574	0.0574	0.0574
Skewness	0.3711	0.5355	0.5420	0.5420	0.5822	0.3536	0.3534	0.3534	0.3534
Kurtosis	2.9009	3.4780	3.5268	3.5268	3.6374	3.1875	3.1873	3.1873	3.1873

Percentiles									
5%	0.2468	0.2389	0.2387	0.2387	0.2391	0.2364	0.2364	0.2364	0.2364
10%	0.2468	0.2546	0.2546	0.2546	0.2548	0.2536	0.2537	0.2537	0.2537
15%	0.2468	0.2659	0.2660	0.2660	0.2660	0.2657	0.2658	0.2658	0.2658
20%	0.2468	0.2752	0.2753	0.2753	0.2753	0.2757	0.2757	0.2757	0.2757
25%	0.2857	0.2835	0.2836	0.2836	0.2835	0.2843	0.2844	0.2844	0.2844
30%	0.2857	0.2912	0.2912	0.2912	0.2911	0.2923	0.2923	0.2923	0.2923
35%	0.2857	0.2984	0.2985	0.2985	0.2983	0.2998	0.2998	0.2998	0.2998
40%	0.2857	0.3055	0.3056	0.3056	0.3053	0.3071	0.3071	0.3071	0.3071
45%	0.3247	0.3125	0.3126	0.3126	0.3123	0.3142	0.3142	0.3142	0.3142
50%	0.3247	0.3196	0.3196	0.3196	0.3193	0.3213	0.3213	0.3213	0.3213
55%	0.3247	0.3268	0.3268	0.3268	0.3265	0.3285	0.3285	0.3285	0.3285
60%	0.3506	0.3343	0.3343	0.3343	0.3340	0.3360	0.3360	0.3360	0.3360
65%	0.3506	0.3423	0.3422	0.3422	0.3419	0.3438	0.3438	0.3438	0.3438
70%	0.3506	0.3508	0.3508	0.3508	0.3505	0.3522	0.3522	0.3522	0.3522
75%	0.3506	0.3603	0.3602	0.3602	0.3600	0.3613	0.3613	0.3613	0.3613
80%	0.3506	0.3712	0.3711	0.3711	0.3709	0.3717	0.3717	0.3717	0.3717
85%	0.4156	0.3842	0.3841	0.3841	0.3841	0.3841	0.3841	0.3841	0.3841
90%	0.4156	0.4012	0.4012	0.4012	0.4014	0.4001	0.4000	0.4000	0.4000
95%	0.4156	0.4278	0.4279	0.4279	0.4286	0.4245	0.4244	0.4244	0.4244

Figure 10 Reactive plant – fault non-continuous distribution comparison using A-D

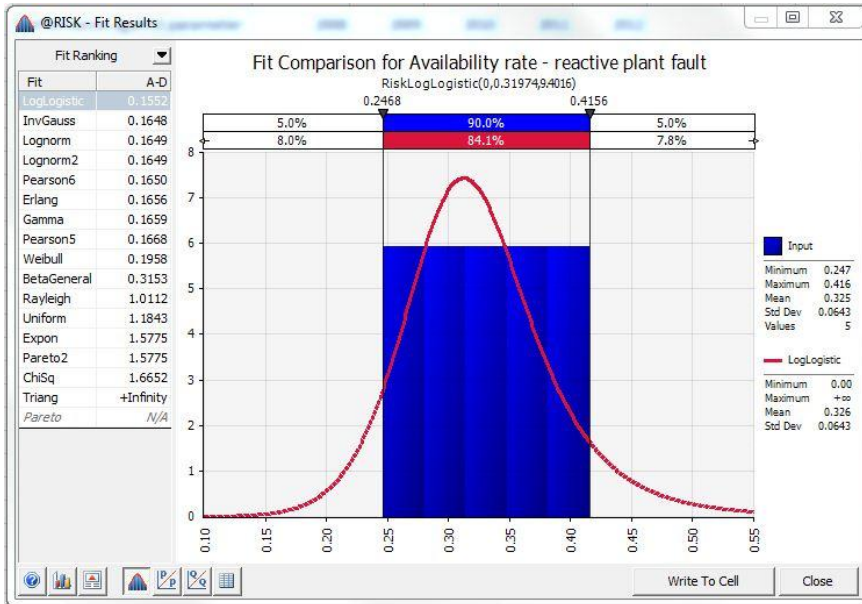


Table 10 Reactive plant – fault non-continuous distribution statistics table for A-D

Fit	A-D	Function	=RiskLogLo..	=RiskInvGa..	=RiskLogno..	=RiskLogno..	=RiskPears..	=RiskErlang..
LogLogistic	0.1952							
InvGauss	0.1648							
Lognorm	0.1649							
Lognorm2	0.1649							
Pearson6	0.1650							
Erlang	0.1656							
Gamma	0.1659							
Pearson5	0.1668							
Weibull	0.1958							
BetaGeneral	0.3153							
Rayleigh	1.0112							
Uniform	1.1843							
Expon	1.5775							
Pareto2	1.5775							
ChiSq	1.6652							
Triang	+Infinity							
Pareto	N/A							

Statistic	0.2468	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Minimum	0.2468	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.4156	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.3247	0.3258	0.3247	0.3247	0.3247	0.3247	0.3247
Mode	0.2510 [est]	0.3126	0.3095	0.3097	0.3097	0.3090	0.3145
Median	0.3247	0.3197	0.3196	0.3196	0.3196	0.3193	0.3213
Std. Deviation	0.0643	0.0643	0.0580	0.0580	0.0580	0.0583	0.0574
Skewness	0.3711	1.0065	0.5355	0.5420	0.5420	0.5822	0.3536
Kurtosis	2.9009	6.8954	3.4780	3.5268	3.5268	3.6374	3.1875

Percentile	0.2468	0.2338	0.2389	0.2387	0.2387	0.2391	0.2364
5%	0.2468	0.2338	0.2389	0.2387	0.2387	0.2391	0.2364
10%	0.2468	0.2531	0.2546	0.2546	0.2546	0.2548	0.2536
15%	0.2468	0.2659	0.2659	0.2660	0.2660	0.2660	0.2657
20%	0.2468	0.2759	0.2752	0.2753	0.2753	0.2753	0.2757
25%	0.2857	0.2845	0.2835	0.2836	0.2836	0.2835	0.2843
30%	0.2857	0.2922	0.2912	0.2912	0.2912	0.2911	0.2923
35%	0.2857	0.2994	0.2984	0.2985	0.2985	0.2983	0.2998
40%	0.2857	0.3062	0.3055	0.3056	0.3056	0.3053	0.3071
45%	0.3247	0.3130	0.3125	0.3126	0.3126	0.3123	0.3142
50%	0.3247	0.3197	0.3196	0.3196	0.3196	0.3193	0.3213
55%	0.3247	0.3266	0.3268	0.3268	0.3268	0.3265	0.3285
60%	0.3506	0.3338	0.3343	0.3343	0.3343	0.3340	0.3360
65%	0.3506	0.3415	0.3423	0.3422	0.3422	0.3419	0.3438
70%	0.3506	0.3499	0.3508	0.3508	0.3508	0.3505	0.3522
75%	0.3506	0.3594	0.3603	0.3602	0.3602	0.3600	0.3613
80%	0.3506	0.3705	0.3712	0.3711	0.3711	0.3709	0.3717
85%	0.4156	0.3845	0.3842	0.3841	0.3841	0.3841	0.3841
90%	0.4156	0.4039	0.4012	0.4012	0.4012	0.4014	0.4001
95%	0.4156	0.4373	0.4278	0.4279	0.4279	0.4286	0.4245

Reactive plant outage rate – forced outage performance

Reactive plant forced unavailability data has a high representation in the middle and right tail of the distribution. The best fit distribution curve for both the K-S and A-D fit statistics is the Rayleigh distribution curve (figures 11 and 12), giving a standard deviation of 0.076.

Tables 11 and 12 are provided to show the variation in fit statistics of other distribution curves. The standard deviation for the curve of second best fit (Erlang) at 0.074 is not materially different.

Figure 11 Reactive plant – forced non-continuous distribution comparison using K-S

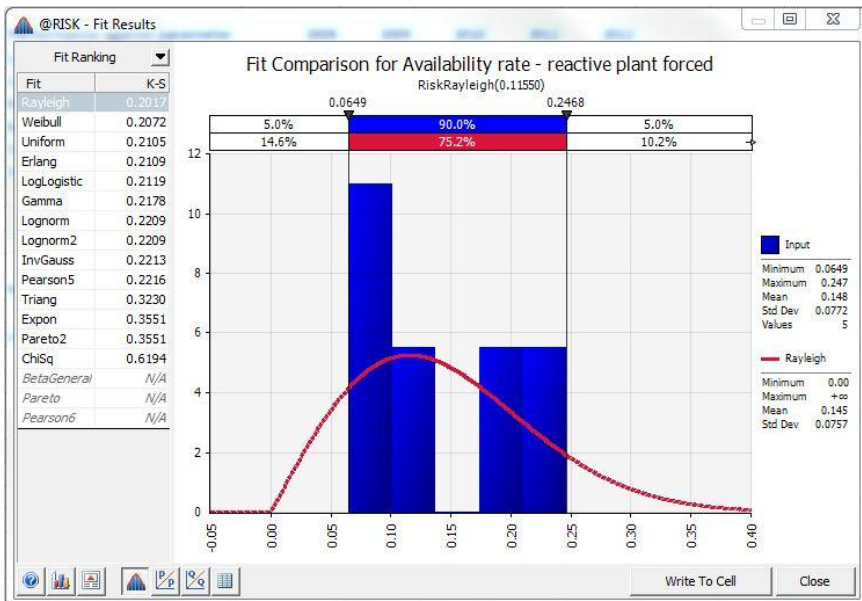


Table 11 Reactive plant – forced non-continuous distribution statistics table for K-S

Fit Ranking	Fit	K-S
1	Rayleigh	0.2017
2	Weibull	0.2072
3	Uniform	0.2105
4	Erlang	0.2109
5	LogLogistic	0.2119
6	Gamma	0.2178
7	Lognorm	0.2209
8	Lognorm2	0.2209
9	InvGauss	0.2213
10	Pearson5	0.2216
11	Triang	0.3230
12	Expon	0.3551
13	Pareto2	0.3551
14	ChiSq	0.6194
15	BetaGeneral	N/A
16	Pareto	N/A
17	Pearson6	N/A

Function	=RiskRaylei..	=RiskWeibu..	=RiskUnifor..	=RiskErlang..	=RiskLogLo..	=RiskGamm..
Minimum	0.0649	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.2468	+Infinity	+Infinity	0.3084	+Infinity	+Infinity
Mean	0.1481	0.1448	0.1489	0.1542	0.1481	0.1556
Mode	0.0695 [est]	0.1155	0.1325	0.0000	0.1110	0.1086
Median	0.1299	0.1360	0.1437	0.1542	0.1359	0.1323
Std. Deviation	0.0772	0.0757	0.0675	0.0890	0.0740	0.1106
Skewness	0.3700	0.6311	0.4323	0.0000	1.0000	14.8754
Kurtosis	0.8587	3.2451	2.9378	1.8000	4.5000	+Infinity

Percentiles	Input	Rayleigh	Weibull	Uniform	Erlang	LogLogistic	Gamma
5%	0.0649	0.0370	0.0473	0.0154	0.0506	0.0532	0.0537
10%	0.0649	0.0530	0.0643	0.0308	0.0646	0.0671	0.0676
15%	0.0649	0.0659	0.0774	0.0463	0.0755	0.0774	0.0783
20%	0.0649	0.0772	0.0886	0.0617	0.0850	0.0862	0.0877
25%	0.0909	0.0876	0.0987	0.0771	0.0938	0.0942	0.0963
30%	0.0909	0.0976	0.1082	0.0925	0.1023	0.1018	0.1045
35%	0.0909	0.1072	0.1173	0.1080	0.1106	0.1092	0.1125
40%	0.0909	0.1167	0.1261	0.1234	0.1189	0.1167	0.1205
45%	0.1299	0.1263	0.1349	0.1388	0.1273	0.1243	0.1286
50%	0.1299	0.1360	0.1437	0.1542	0.1359	0.1323	0.1369
55%	0.1299	0.1460	0.1526	0.1696	0.1450	0.1407	0.1456
60%	0.2078	0.1564	0.1619	0.1851	0.1545	0.1499	0.1548
65%	0.2078	0.1674	0.1715	0.2005	0.1649	0.1601	0.1647
70%	0.2078	0.1792	0.1818	0.2159	0.1763	0.1718	0.1755
75%	0.2078	0.1923	0.1931	0.2313	0.1891	0.1857	0.1878
80%	0.2078	0.2072	0.2058	0.2468	0.2041	0.2030	0.2020
85%	0.2468	0.2250	0.2208	0.2622	0.2226	0.2260	0.2195
90%	0.2468	0.2479	0.2398	0.2776	0.2473	0.2608	0.2429
95%	0.2468	0.2827	0.2683	0.2930	0.2870	0.3285	0.2803

Figure 12 Reactive plant – forced non-continuous distribution comparison using A-D

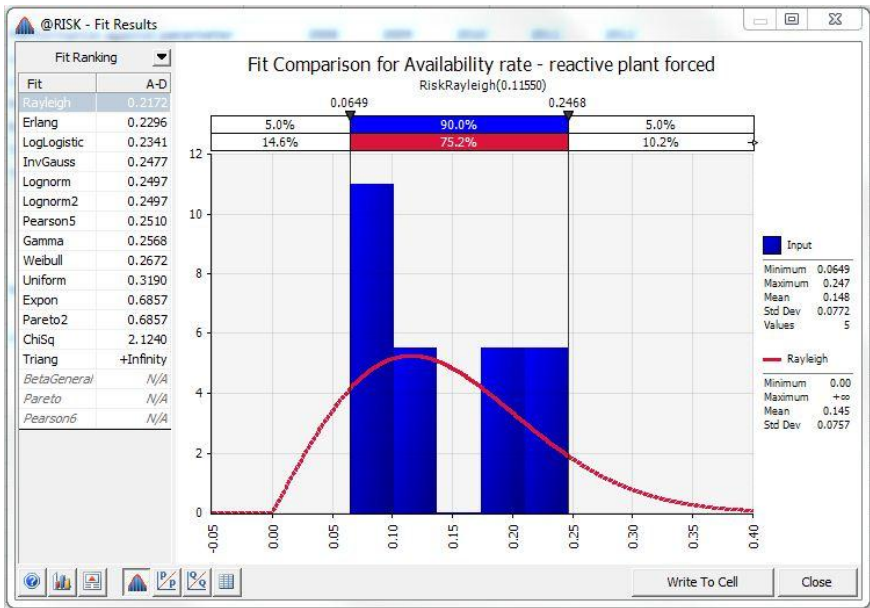


Table 12 Reactive plant – forced non-continuous distribution statistics table for A-D

Fit	A-D	Function	=RiskRaylei...	=RiskErlang...	=RiskLogLo...	=RiskInvGa...	=RiskLogno...	=RiskLogno...
Rayleigh	0.2172							
Erlang	0.2296							
LogLogistic	0.2341							
InvGauss	0.2477							
Lognorm	0.2497							
Lognorm2	0.2497							
Pearson5	0.2510							
Gamma	0.2568							
Weibull	0.2672							
Uniform	0.3190							
Expon	0.6857							
Pareto2	0.6857							
ChiSq	2.1240							
Triang	+Infinity							
BetaGeneral	N/A							
Pareto	N/A							
Pearson6	N/A							

Minimum	0.0649	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.2468	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.1481	0.1448	0.1481	0.1556	0.1481	0.1488	0.1488	0.1488
Mode	0.0695 [est]	0.1155	0.1110	0.1086	0.0995	0.1026	0.1026	0.1026
Median	0.1299	0.1360	0.1359	0.1323	0.1306	0.1315	0.1315	0.1315
Std. Deviation	0.0772	0.0757	0.0740	0.1106	0.0772	0.0790	0.0790	0.0790
Skewness	0.3700	0.6311	1.0000	14.8754	1.5652	1.7407	1.7407	1.7407
Kurtosis	0.8587	3.2451	4.5000	+Infinity	7.0832	8.8303	8.8303	8.8303

Transformers outage rate – fault performance

The best fitting curve for Transformers unavailability caused by fault using the K-S fit statistic is the Pearson5 distribution (figure 13) curve while the A-D fit statistic has the LogLogistic distribution curve as the best fit (figure 14). As the data for Transformers unavailability caused by fault data is concentrated in the middle of the distribution, the K-S fit statistic (Pearson5) is preferred giving a standard deviation of 0.085.

Tables 13 and 14 show the difference in how the K-S and A-D fit statistics rated the distribution curves according their goodness of fit to the data range. The standard deviation for the curve of second best fit (Triang) is lower at 0.069, and for LogLogistic is similar at 0.089.

Figure 13 Transformers – fault non-continuous distribution comparison using K-S

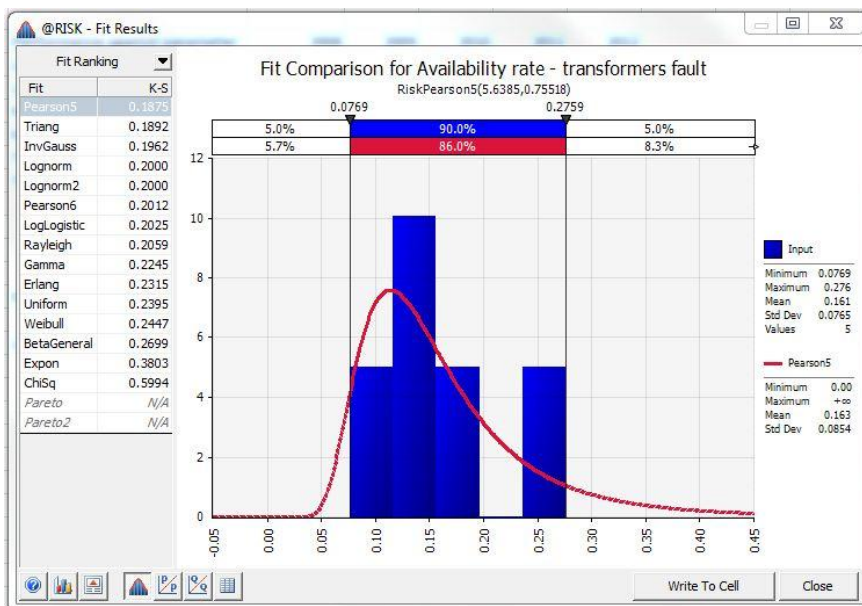


Table 13 Transformers – fault non-continuous distribution statistics table for K-S

Fit Ranking	Fit	K-S	Input	Pearson5	Triang	InvGauss	Lognorm	Lognorm2	Pearson6
1	Pearson5	0.1875							
2	Triang	0.1892							
3	InvGauss	0.1962							
4	Lognorm	0.2000							
5	Lognorm2	0.2000							
6	Pearson6	0.2012							
7	LogLogistic	0.2025							
8	Rayleigh	0.2059							
9	Gamma	0.2245							
10	Erlang	0.2315							
11	Uniform	0.2395							
12	Weibull	0.2447							
13	BetaGeneral	0.2699							
14	Expon	0.3803							
15	ChiSq	0.5994							
16	Pareto	N/A							
17	Pareto2	N/A							

Function	=RiskPears..	=RiskTriang..	=RiskInvGa..	=RiskLogno..	=RiskLogno..	=RiskPears..
Minimum	0.0769	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.2759	+Infinity	0.3334	+Infinity	+Infinity	+Infinity
Mean	0.1607	0.1628	0.1532	0.1607	0.1610	0.1611
Mode	0.0819 [est]	0.1138	0.1261	0.1196	0.1219	0.1229
Median	0.1316	0.1422	0.1475	0.1463	0.1467	0.1468
Std. Deviation	0.0765	0.0854	0.0687	0.0719	0.0726	0.0733
Skewness	0.8432	2.8918	0.2305	1.3421	1.4454	1.5405
Kurtosis	3.3453	26.8605	2.4000	6.0022	6.9311	7.8496

Percentiles	Input	Pearson5	Triang	InvGauss	Lognorm	Lognorm2	Pearson6
5%	0.0769	0.0753	0.0458	0.0728	0.0723	0.0723	0.0721
10%	0.0769	0.0857	0.0648	0.0845	0.0845	0.0845	0.0845
15%	0.0769	0.0938	0.0794	0.0937	0.0939	0.0939	0.0941
20%	0.0769	0.1010	0.0917	0.1017	0.1021	0.1021	0.1023
25%	0.1261	0.1077	0.1025	0.1092	0.1098	0.1098	0.1100
30%	0.1261	0.1144	0.1123	0.1165	0.1171	0.1171	0.1173
35%	0.1261	0.1210	0.1213	0.1237	0.1243	0.1243	0.1245
40%	0.1261	0.1278	0.1297	0.1310	0.1316	0.1316	0.1317
45%	0.1316	0.1348	0.1384	0.1385	0.1390	0.1390	0.1391
50%	0.1316	0.1422	0.1475	0.1463	0.1467	0.1467	0.1468
55%	0.1316	0.1503	0.1570	0.1545	0.1549	0.1549	0.1549
60%	0.1933	0.1590	0.1671	0.1634	0.1636	0.1636	0.1636
65%	0.1933	0.1688	0.1779	0.1731	0.1732	0.1732	0.1731
70%	0.1933	0.1800	0.1894	0.1840	0.1839	0.1839	0.1837
75%	0.1933	0.1931	0.2019	0.1964	0.1962	0.1962	0.1959
80%	0.1933	0.2093	0.2158	0.2112	0.2108	0.2108	0.2105
85%	0.2759	0.2306	0.2316	0.2298	0.2292	0.2292	0.2289
90%	0.2759	0.2614	0.2503	0.2553	0.2547	0.2547	0.2545
95%	0.2759	0.3177	0.2746	0.2979	0.2979	0.2979	0.2982

Figure 14 Transformers – fault non-continuous distribution comparison using A-D

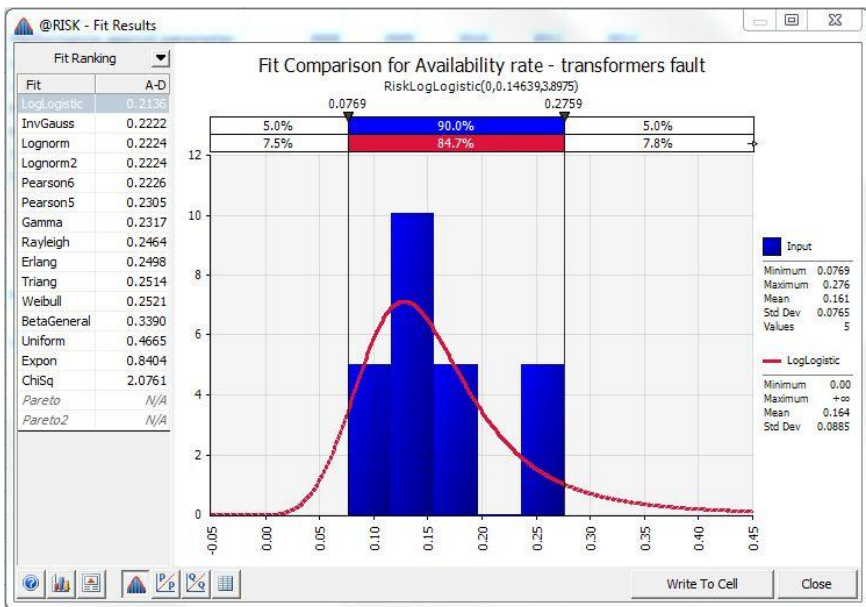


Table 14 Transformers – fault non-continuous distribution statistics table for A-D

Fit	A-D
LogLogistic	0.2135
InvGauss	0.2222
Lognorm	0.2224
Lognorm2	0.2224
Pearson6	0.2226
Pearson5	0.2305
Gamma	0.2317
Rayleigh	0.2464
Erlang	0.2498
Triang	0.2514
Weibull	0.2521
BetaGeneral	0.3390
Uniform	0.4665
Expon	0.8404
ChiSq	2.0761
Pareto	N/A
Pareto2	N/A

Function	=RiskLogLo..	=RiskInvGa..	=RiskLogno..	=RiskLogno..	=RiskPears..	=RiskPears..
Minimum	0.0769	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.2759	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.1607	0.1635	0.1607	0.1610	0.1610	0.1611
Mode	0.0819 [est]	0.1279	0.1196	0.1219	0.1219	0.1138
Median	0.1316	0.1464	0.1463	0.1467	0.1467	0.1468
Std. Deviation	0.0765	0.0885	0.0719	0.0726	0.0726	0.0733
Skewness	0.8432	4.6772	1.3421	1.4454	1.4454	1.5405
Kurtosis	3.3453	+Infinity	6.0022	6.9311	6.9311	7.8496

Percentiles						
5%	0.0769	0.0688	0.0728	0.0723	0.0723	0.0721
10%	0.0769	0.0833	0.0845	0.0845	0.0845	0.0857
15%	0.0769	0.0938	0.0937	0.0939	0.0939	0.0941
20%	0.0769	0.1026	0.1017	0.1021	0.1021	0.1023
25%	0.1261	0.1104	0.1092	0.1098	0.1098	0.1100
30%	0.1261	0.1178	0.1165	0.1171	0.1171	0.1173
35%	0.1261	0.1249	0.1237	0.1243	0.1243	0.1245
40%	0.1261	0.1319	0.1310	0.1316	0.1316	0.1317
45%	0.1316	0.1390	0.1385	0.1390	0.1390	0.1391
50%	0.1316	0.1464	0.1463	0.1467	0.1467	0.1468
55%	0.1316	0.1541	0.1545	0.1549	0.1549	0.1503
60%	0.1933	0.1624	0.1634	0.1636	0.1636	0.1590
65%	0.1933	0.1716	0.1731	0.1732	0.1732	0.1731
70%	0.1933	0.1819	0.1840	0.1839	0.1839	0.1837
75%	0.1933	0.1941	0.1964	0.1962	0.1962	0.1959
80%	0.1933	0.2089	0.2112	0.2108	0.2108	0.2105
85%	0.2759	0.2285	0.2298	0.2292	0.2292	0.2306
90%	0.2759	0.2573	0.2553	0.2547	0.2547	0.2614
95%	0.2759	0.3116	0.2979	0.2979	0.2979	0.3177

Transformers outage rate – forced outage performance

The data for forced unavailability of transformers is best fitted with a BetaGeneral distribution curve (figure 15) according to the K-S fit statistic. The A-D fit statistic has the Weibull distribution curve as the best fit (figure 16). As the data is distributed across both the middle and tails of the distribution, the A-D fit statistic is preferred (Weibull), giving a standard deviation of 0.034.

Tables 15 and 16 presents the variation in the distribution curve statistics between K-S and A-D fit statistics. The standard deviation for the curve of second best fit (Gama) is higher at 0.045 and for BetaGeneral is similar at 0.038.

Figure 15 Transformers – forced non-continuous distribution comparison using K-S

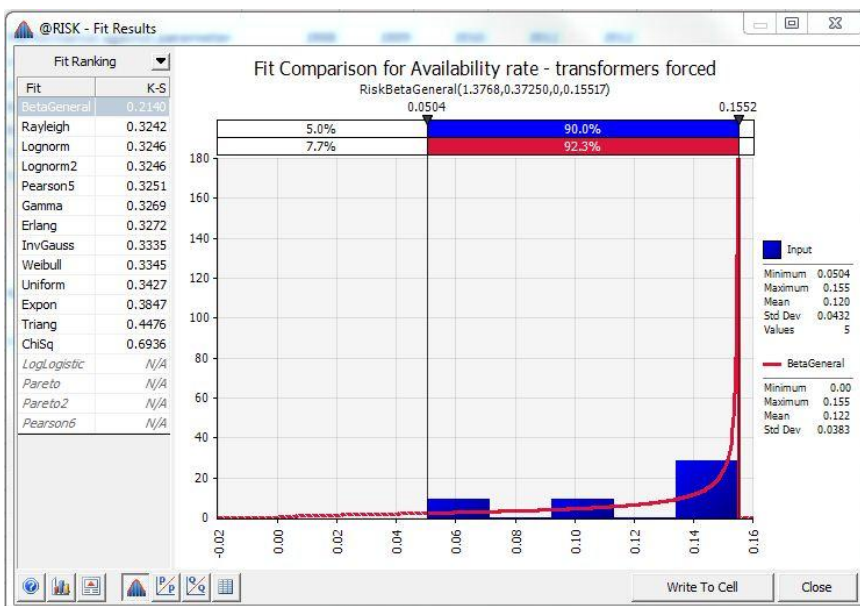


Table 15 Transformers – forced non-continuous distribution statistics table for K-S

Fit	K-S	Function	BetaGeneral	Rayleigh	Lognorm	Lognorm2	Pearson5	Gamma
BetaGeneral	0.2149	=RiskBetaG..						
Rayleigh	0.3242	=RiskRaylei..						
Lognorm	0.3246	=RiskLogno..						
Lognorm2	0.3246	=RiskLogno..						
Pearson5	0.3251	=RiskPears..						
Gamma	0.3269	=RiskGamm..						
Erlang	0.3272							
InvGauss	0.3335							
Weibull	0.3345							
Uniform	0.3427							
Expon	0.3847							
Triang	0.4476							
ChiSq	0.6936							
LogLogistic	N/A							
Pareto	N/A							
Pareto2	N/A							
Pearson5	N/A							

Statistic	BetaGeneral	Rayleigh	Lognorm	Lognorm2	Pearson5	Gamma
Minimum	0.0504	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.1552	0.1552	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.1198	0.1221	0.1116	0.1215	0.1215	0.1250
Mode	0.0530 [est]	0.1552	0.0890	0.0935	0.0935	0.0843
Median	0.1429	0.1386	0.1048	0.1113	0.1113	0.1076
Std. Deviation	0.0432	0.0383	0.0583	0.0531	0.0531	0.0705
Skewness	-1.3663	-1.2404	0.6311	1.3945	1.3945	3.3120
Kurtosis	4.1651	3.5586	3.2451	6.6461	6.6461	39.1476

Percentile	BetaGeneral	Rayleigh	Lognorm	Lognorm2	Pearson5	Gamma
5%	0.0504	0.0380	0.0285	0.0560	0.0560	0.0554
10%	0.0504	0.0598	0.0409	0.0651	0.0651	0.0633
15%	0.0504	0.0767	0.0507	0.0722	0.0722	0.0696
20%	0.0504	0.0906	0.0595	0.0783	0.0783	0.0751
25%	0.1053	0.1022	0.0675	0.0840	0.0840	0.0804
30%	0.1053	0.1121	0.0752	0.0894	0.0894	0.0856
35%	0.1053	0.1204	0.0826	0.0948	0.0948	0.0908
40%	0.1053	0.1275	0.0900	0.1001	0.1001	0.0961
45%	0.1429	0.1335	0.0973	0.1056	0.1056	0.1017
50%	0.1429	0.1386	0.1048	0.1113	0.1113	0.1076
55%	0.1429	0.1428	0.1125	0.1173	0.1173	0.1139
60%	0.1453	0.1462	0.1205	0.1238	0.1238	0.1209
65%	0.1453	0.1489	0.1290	0.1308	0.1308	0.1288
70%	0.1453	0.1511	0.1381	0.1386	0.1386	0.1378
75%	0.1453	0.1527	0.1482	0.1476	0.1476	0.1484
80%	0.1453	0.1538	0.1597	0.1583	0.1583	0.1616
85%	0.1552	0.1545	0.1734	0.1717	0.1717	0.1790
90%	0.1552	0.1550	0.1910	0.1902	0.1902	0.2044
95%	0.1552	0.1551	0.2179	0.2214	0.2214	0.2029

Figure 16 Transformers – forced non-continuous distribution comparison using A-D

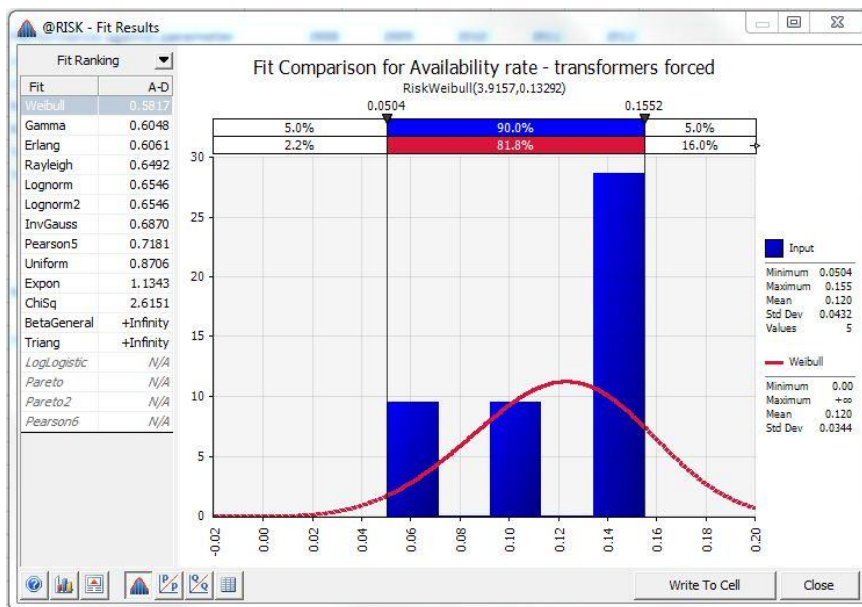


Table 16 Transformers – forced non-continuous distribution statistics table for A-D

Fit Ranking	Input	Weibull	Gamma	Erlang	Rayleigh	Lognorm	Lognorm2
Fit	A-D						
Weibull	0.5817						
Gamma	0.6048						
Erlang	0.6061						
Rayleigh	0.6492						
Lognorm	0.6546						
Lognorm2	0.6546						
InvGauss	0.6870						
Pearson5	0.7181						
Uniform	0.8706						
Expon	1.1343						
ChiSq	2.6151						
BetaGeneral	+Infinity						
Triang	+Infinity						
LogLogistic	N/A						
Pareto	N/A						
Pareto2	N/A						
Pearson6	N/A						
Function =RiskWeibu.. =RiskGamm.. =RiskErlang.. =RiskRaylei.. =RiskLogno.. =RiskLogno..							
Distribution Statistics							
Minimum	0.0504	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.1552	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.1198	0.1203	0.1198	0.1198	0.1116	0.1215	0.1215
Mode	0.0530 [est]	0.1233	0.1026	0.1027	0.0890	0.0935	0.0935
Median	0.1429	0.1210	0.1141	0.1141	0.1048	0.1113	0.1113
Std. Deviation	0.0432	0.0344	0.0454	0.0453	0.0583	0.0531	0.0531
Skewness	-1.3663	-0.0700	0.7575	0.7559	0.6311	1.3945	1.3945
Kurtosis	4.1651	2.7396	3.8607	3.8571	3.2451	6.6461	6.6461
Percentiles							
5%	0.0504	0.0623	0.0561	0.0562	0.0285	0.0560	0.0560
10%	0.0504	0.0748	0.0666	0.0667	0.0409	0.0651	0.0651
15%	0.0504	0.0836	0.0743	0.0744	0.0507	0.0722	0.0722
20%	0.0504	0.0906	0.0809	0.0810	0.0595	0.0783	0.0783
25%	0.1053	0.0967	0.0869	0.0870	0.0675	0.0840	0.0840
30%	0.1053	0.1022	0.0925	0.0926	0.0752	0.0894	0.0894
35%	0.1053	0.1072	0.0980	0.0980	0.0826	0.0948	0.0948
40%	0.1053	0.1120	0.1033	0.1034	0.0900	0.1001	0.1001
45%	0.1429	0.1166	0.1087	0.1087	0.0973	0.1056	0.1056
50%	0.1429	0.1210	0.1141	0.1141	0.1048	0.1113	0.1113
55%	0.1429	0.1255	0.1198	0.1198	0.1125	0.1173	0.1173
60%	0.1453	0.1300	0.1257	0.1257	0.1205	0.1238	0.1238
65%	0.1453	0.1346	0.1320	0.1320	0.1290	0.1308	0.1308
70%	0.1453	0.1394	0.1388	0.1388	0.1381	0.1386	0.1386
75%	0.1453	0.1445	0.1465	0.1465	0.1482	0.1476	0.1476
80%	0.1453	0.1501	0.1554	0.1553	0.1597	0.1583	0.1583
85%	0.1552	0.1565	0.1662	0.1661	0.1734	0.1717	0.1717
90%	0.1552	0.1645	0.1804	0.1803	0.1910	0.1902	0.1902
95%	0.1552	0.1759	0.2029	0.2027	0.2179	0.2214	0.2214

3. Summary of findings

Table 17 summarises the probability distribution functions that have been chosen to best fit the parameter data (table 18). In Parsons Brinckerhoff’s view this approach is robust and does not seem to be sensitive to the choice of distribution function, because the results were close for the next best fit distributions. The approach is also consistent with the Australian Energy Regulator’s previous regulatory decisions to use a curve of best fit approach.

Table 17 Summary of best fit distributions

Parameter	Best fit distribution	Standard Deviation
Average outage duration	Exponential	97.96
No. of events >0.05 system minutes	NegBin	2.000
No. of events >0.30 system minutes	IntUniform	0.816
Lines outage rate - fault	LogLogistic	0.090
Lines outage rate - forced outage	Pearson5	0.017
Reactive plant outage rate - fault	LogLogistic	0.064
Reactive plant outage rate - forced outage	Rayleigh	0.076
Transformers outage rate - fault	Pearson5	0.085
Transformers outage rate - forced outage	Weibull	0.034

Table 18 Reliability Data 2008-2012

Parameter	2008	2009	2010	2011	2012
Average outage duration	71.5	91.8	92.5	4.0	230.0
No. of events >0.05 system minutes	1	6	1	0	2
No. of events >0.30 system minutes	1	2	0	0	1
Lines outage rate - fault	20.0%	35.8%	16.8%	24.4%	32.5%
Lines outage rate - forced outage	16.7%	12.5%	14.3%	16.8%	14.2%
Reactive plant outage rate - fault	28.6%	35.1%	24.7%	32.5%	41.6%
Reactive plant outage rate - forced outage	6.5%	9.1%	13.0%	24.7%	20.8%
Transformers outage rate - fault	13.2%	27.6%	7.7%	12.6%	19.3%
Transformers outage rate - forced outage	10.5%	15.5%	14.5%	5.0%	14.3%