Appendix 7A: Fitting probability distributions to Service Component data

2023-27 Transmission Revenue Reset

PUBLIC

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Contents

1   Service Component Parameters

This Appendix sets out the information used to calculate AusNet Services' proposed Service Component caps and collars, as presented in section 7.3.2 of the Revenue Proposal. This information was obtained using the @RISK product, a risk analysis and simulation add-in tool for Microsoft Excel.

For each parameter, proposed caps and collars have been set equal to the 5th and 95th percentiles, respectively, of the probability distribution that provides the best fit to the relevant historical data. This approach aligns with that adopted by the AER in AusNet Services' current determination and in recent determinations for ElectraNet, TransGrid and TasNetworks.

For two sub-parameters (loss of supply event frequency (>0.30 system minutes) and incorrect operational isolation of primary or secondary equipment), the IntUniform distribution was found to be the best fit. However, to align with the AER's approach for the current determination, the Poisson distribution has instead been used to set caps and collars for these sub-parameters.

The following table summarises the probability distributions and percentiles underpinning the proposed caps and collars.

Table 1.1: Summary of probability distributions and percentiles

Parameter	Preferred Distribution	5th percentile	95th percentile
Line outage rate (fault)	Normal	0.1160	0.2315
Line outage rate (forced)	Normal	0.0192	0.2176
Reactive plant outage rate (fault)	InvGauss	0.1548	0.3171
Reactive plant outage rate (forced)	Normal	0.2474	0.3665
Transformer outage rate (fault)	Logistic	0.0663	0.1749
Transformer outage rate (forced)	Laplace	0.0732	0.1612
Number of events >0.05 system minutes	Poisson	0	3
Number of events >0.30 system minutes	Poisson	0	2
Average outage duration	InvGauss	19	159
Failure of protection equipment	Poisson	23	42
Material failure of SCADA system	Poisson	0	2
Incorrect operational isolation of primary or secondary equipment	Poisson	2	11

The remainder of this document sets out the rationale for selecting each distribution and the underlying percentile data as calculated by @RISK.

Appendix 7A: Fitting probability distributions to Service Component data

1.1 Service parameter 1 – Average circuit outage rate

1.1.1 Lines outage rate – fault (continuous)

Findings:

- A-D fit statistic: Normal distribution best fit, standard deviation 0.0351
- K-S fit statistic: Normal distribution best fit, standard deviation 0.0351
- **A-D preferred (Normal) due to data concentrated in middle of distribution**

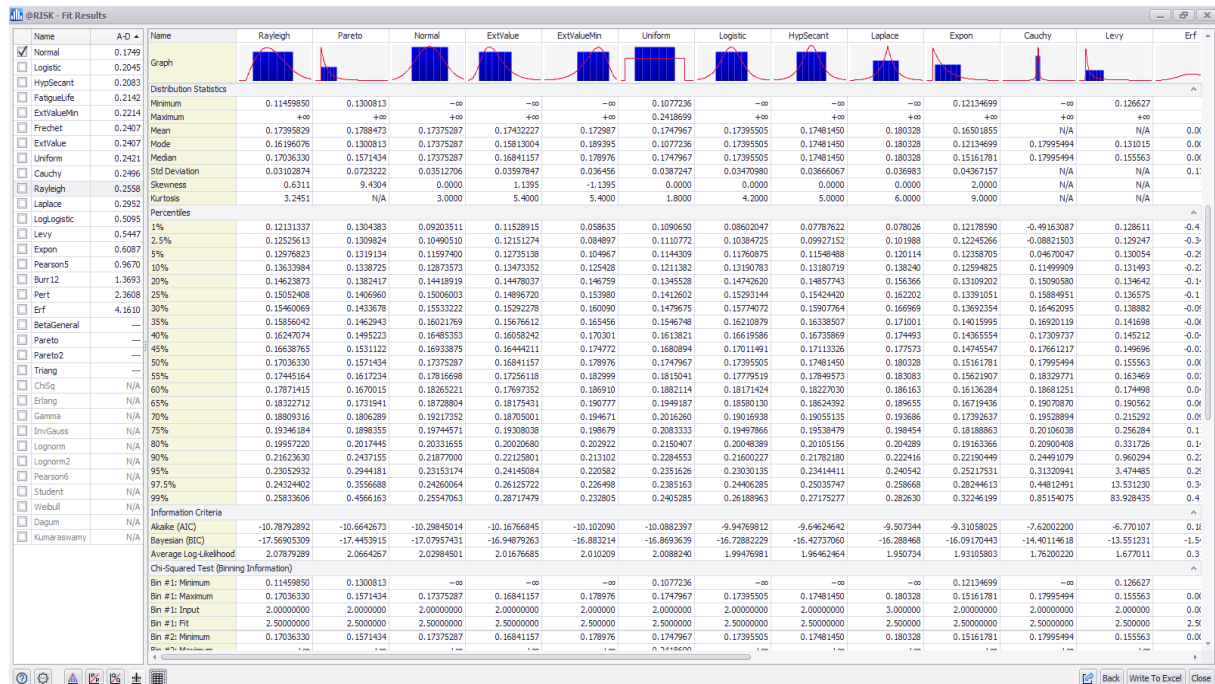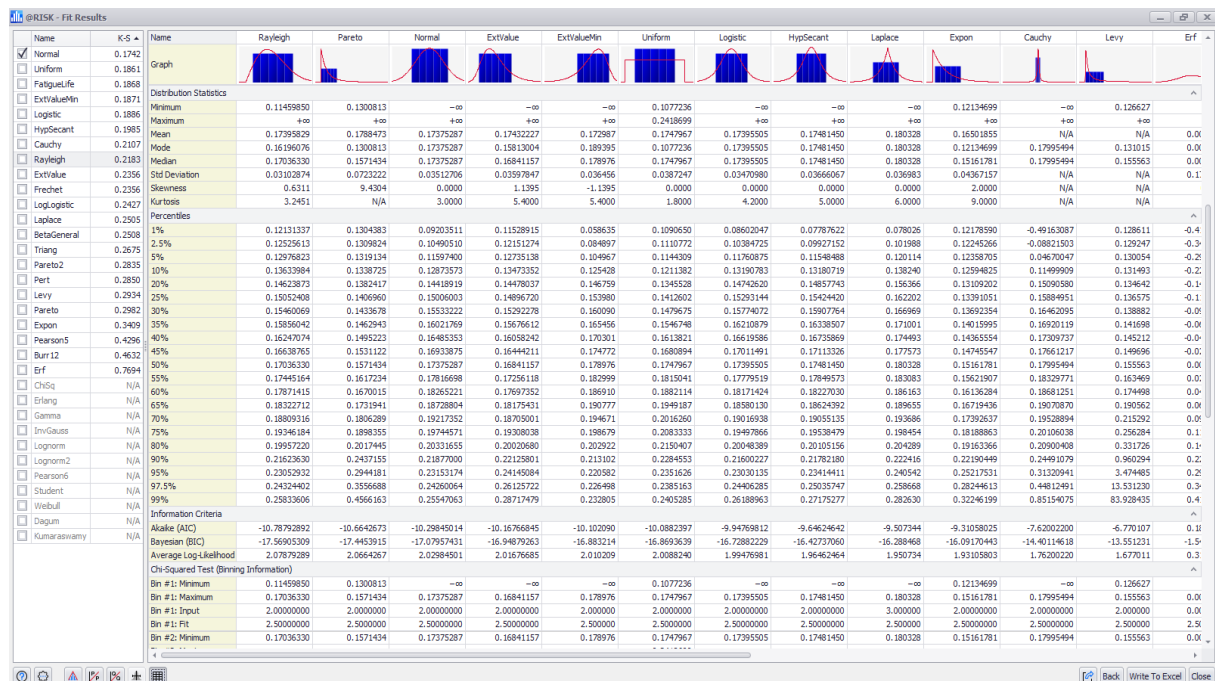## Figure 1-1: Lines outage rate (fault) – distribution fit using A-D

@RISK - Fit Results

Name	A-D
✓ Normal	0.1749
Logistic	0.2045
HypSecant	0.2083
FatigueLife	0.2142
ExtValueMin	0.2214
Frechet	0.2407
ExtValue	0.2407
Uniform	0.2421
Cauchy	0.2496
Rayleigh	0.2558
Laplace	0.2952
LogLogistic	0.5095
Levy	0.5447
Expon	0.6087
Pearson5	0.9670
Burr12	1.3693
Pert	2.3608
Erf	4.1610
BetaGeneral	---
Pareto	---
Pareto2	---
Triang	---
ChiSq	N/A
Erlang	N/A
Gamma	N/A
InvGauss	N/A
Lognorm	N/A
Lognorm2	N/A
Pearson6	N/A
Student	N/A
Weibull	N/A
Dagum	N/A
Kumaraswamy	N/A

Name	Rayleigh	Pareto	Normal	ExtValue	ExtValueMin	Uniform	Logistic	HypSecant	Laplace	Expon	Cauchy	Levy	Erf
Distribution Statistics													
Minimum	0.11459850	0.1300813	-∞	-∞	-∞	0.1077236	-∞	-∞	-∞	0.12134699	-∞	0.126627	
Maximum	+∞	+∞	+∞	+∞	+∞	0.2418699	+∞	+∞	+∞	+∞	+∞	+∞	
Mean	0.17395829	0.1788473	0.17375287	0.17432227	0.172987	0.1747967	0.17395505	0.17481450	0.180328	0.16501855	N/A	N/A	0.00
Mode	0.16196076	0.1300813	0.17375287	0.15813004	0.189395	0.1077236	0.17395505	0.17481450	0.180328	0.12134699	0.17995494	0.131015	0.00
Median	0.17036330	0.1571434	0.17375287	0.16841157	0.178976	0.1747967	0.17395505	0.17481450	0.180328	0.15161781	0.17995494	0.155563	0.00
Std Deviation	0.03102874	0.0723222	0.03512706	0.03597847	0.036456	0.0387247	0.03470980	0.03666067	0.036983	0.04367157	N/A	N/A	0.17
Skewness	0.6311	9.4304	0.0000	1.1395	-1.1395	0.0000	0.0000	0.0000	0.0000	2.0000	N/A	N/A	
Kurtosis	3.2451	N/A	3.0000	5.4000	5.4000	1.8000	4.2000	5.0000	6.0000	9.0000	N/A	N/A	
Percentiles													
1%	0.12131337	0.1304383	0.09203511	0.11528915	0.058635	0.1090650	0.08602047	0.07787622	0.078026	0.12178590	-0.49163087	0.128611	-0.4
2.5%	0.12525613	0.1309824	0.10490510	0.12151274	0.084897	0.1110772	0.10384725	0.09927152	0.101988	0.12245266	-0.08821503	0.129247	-0.3
5%	0.12976823	0.1319134	0.11597400	0.12735138	0.104967	0.1144309	0.11760875	0.11548488	0.120114	0.12358705	0.04670047	0.130054	-0.2
10%	0.13633984	0.1338725	0.12873573	0.13473352	0.125428	0.1211382	0.13190783	0.13180719	0.138240	0.12594825	0.11499909	0.131493	-0.2
20%	0.14623873	0.1382417	0.14418919	0.14478037	0.146759	0.1345528	0.14742620	0.14857743	0.156366	0.13109202	0.15090580	0.134642	-0.1
25%	0.15052408	0.1406960	0.15006003	0.14896720	0.153980	0.1412602	0.15293144	0.15424420	0.162202	0.13391051	0.15884951	0.135575	-0.1
30%	0.15460069	0.1433678	0.15533222	0.15292278	0.160090	0.1479675	0.15774072	0.15907764	0.166969	0.13692354	0.16462095	0.138882	-0.0
35%	0.15856042	0.1462943	0.16021769	0.15676612	0.165456	0.1546748	0.16210879	0.16338507	0.171001	0.14015995	0.16920119	0.141698	-0.0
40%	0.16247074	0.1495223	0.16485353	0.16058242	0.170301	0.1613821	0.16619586	0.16735869	0.174493	0.14365554	0.17309737	0.145212	-0.0
45%	0.16638765	0.1531122	0.16933875	0.16444211	0.174772	0.1680894	0.17011491	0.17113326	0.177573	0.14745547	0.17661217	0.149696	-0.0
50%	0.17036330	0.1571434	0.17375287	0.16841157	0.178976	0.1747967	0.17395505	0.17481450	0.180328	0.15161781	0.17995494	0.155563	0.00
55%	0.17445164	0.1617234	0.17816698	0.17256118	0.182999	0.1815041	0.17779519	0.17849573	0.183083	0.15621907	0.18329771	0.163469	0.00
60%	0.17871415	0.1670015	0.18265221	0.17697352	0.186910	0.1882114	0.18171924	0.18227030	0.186163	0.16136284	0.18681251	0.174498	0.00
65%	0.18322712	0.1731941	0.18728804	0.18175431	0.190777	0.1949187	0.18580130	0.18624392	0.189655	0.16719436	0.19070870	0.190562	0.00
70%	0.18809316	0.1806289	0.19217352	0.18705001	0.194671	0.2016260	0.19016938	0.19055135	0.193686	0.17392637	0.19528894	0.215292	0.09
75%	0.19346184	0.1898355	0.19744571	0.19308038	0.198679	0.2083333	0.19497866	0.19538479	0.198454	0.18188863	0.20106038	0.256284	0.1
80%	0.19957220	0.2017445	0.20331655	0.20020680	0.202922	0.2150407	0.20048389	0.20105156	0.204289	0.19163366	0.20900408	0.331726	0.1
90%	0.21623630	0.2437155	0.21877000	0.22125801	0.213102	0.2284553	0.21600227	0.21782180	0.222416	0.22190449	0.24491079	0.960294	0.2
95%	0.23052932	0.2944181	0.23153174	0.24145084	0.220582	0.2351626	0.23030135	0.23414411	0.240542	0.25217531	0.31320941	3.474485	0.2
97.5%	0.24324402	0.3556688	0.24260064	0.26125722	0.226498	0.2385163	0.24406285	0.25035747	0.258668	0.28244613	0.44812491	13.531230	0.3
99%	0.25833606	0.4566163	0.25547063	0.28717479	0.232805	0.2405285	0.26188963	0.27175277	0.282630	0.32246199	0.85154075	83.928435	0.4
Information Criteria													
Akaike (AIC)	-10.78792892	-10.6642673	-10.29845014	-10.16766845	-10.102090	-10.0882397	-9.94769812	-9.64624642	-9.507344	-9.31058025	-7.62002200	-6.770107	0.18
Bayesian (BIC)	-17.56905309	-17.4453915	-17.07957431	-16.94879263	-16.883214	-16.8693639	-16.72882229	-16.42737060	-16.288468	-16.09170443	-14.40114618	-13.551231	-1.5
Average Log-Likelihood	2.07879289	2.0664267	2.02984501	2.01676685	2.010209	2.0088240	1.99476981	1.96462464	1.950734	1.93105803	1.76200220	1.677011	0.3
Chi-Squared Test (Binning Information)													
Bin #1: Minimum	0.11459850	0.1300813	-∞	-∞	-∞	0.1077236	-∞	-∞	-∞	0.12134699	-∞	0.126627	
Bin #1: Maximum	0.17036330	0.1571434	0.17375287	0.16841157	0.178976	0.1747967	0.17395505	0.17481450	0.180328	0.15161781	0.17995494	0.155563	0.00
Bin #1: Input	2.00000000	2.0000000	2.00000000	2.00000000	2.000000	2.0000000	2.00000000	2.00000000	3.000000	2.00000000	2.00000000	2.000000	0.00
Bin #1: Fit	2.50000000	2.5000000	2.50000000	2.50000000	2.500000	2.5000000	2.50000000	2.50000000	2.500000	2.50000000	2.50000000	2.500000	2.50
Bin #2: Minimum	0.17036330	0.1571434	0.17375287	0.16841157	0.178976	0.1747967	0.17395505	0.17481450	0.180328	0.15161781	0.17995494	0.155563	0.00

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Figure 1-2: Lines outage rate (fault) – distribution fit using K-S

@RISK - Fit Results

Name	K-S
✓ Normal	0.1742
Uniform	0.1861
FatigueLife	0.1868
ExtValueMin	0.1871
Logistic	0.1886
HypSecant	0.1985
Cauchy	0.2107
Rayleigh	0.2183
ExtValue	0.2356
Frechet	0.2356
LogLogistic	0.2427
Laplace	0.2505
BetaGeneral	0.2508
Triang	0.2675
Pareto2	0.2835
Pert	0.2850
Levy	0.2934
Pareto	0.2982
Expon	0.3409
Pearson5	0.4296
Burr12	0.4632
Erf	0.7694
ChiSq	N/A
Erlang	N/A
Gamma	N/A
InvGauss	N/A
Lognorm	N/A
Lognorm2	N/A
Pearson6	N/A
Student	N/A
Weibull	N/A
Dagum	N/A
Kumaraswamy	N/A

Name	Rayleigh	Pareto	Normal	ExtValue	ExtValueMin	Uniform	Logistic	HypSecant	Laplace	Expon	Cauchy	Levy	Erf
Distribution Statistics													
Minimum	0.11459850	0.1300813	-∞	-∞	-∞	0.1077236	-∞	-∞	-∞	0.12134699	-∞	0.126627	
Maximum	+∞	+∞	+∞	+∞	+∞	0.2418699	+∞	+∞	+∞	+∞	+∞	+∞	
Mean	0.17395829	0.1788473	0.17375287	0.17432227	0.172987	0.1747967	0.17395505	0.17481450	0.180328	0.16501855	N/A	N/A	0.00
Mode	0.16196076	0.1300813	0.17375287	0.15813004	0.189395	0.1077236	0.17395505	0.17481450	0.180328	0.12134699	0.17995494	0.131015	0.00
Median	0.17036330	0.1571434	0.17375287	0.16841157	0.178976	0.1747967	0.17395505	0.17481450	0.180328	0.15161781	0.17995494	0.155563	0.00
Std Deviation	0.03102874	0.0723222	0.03512706	0.03597847	0.036456	0.0387247	0.03470980	0.03666067	0.036983	0.04367157	N/A	N/A	0.17
Skewness	0.6311	9.4304	0.0000	1.1395	-1.1395	0.0000	0.0000	0.0000	0.0000	2.0000	N/A	N/A	
Kurtosis	3.2451	N/A	3.0000	5.4000	5.4000	1.8000	4.2000	5.0000	6.0000	9.0000	N/A	N/A	
Percentiles													
1%	0.12131337	0.1304383	0.09203511	0.11528915	0.058635	0.1090650	0.08602047	0.07787622	0.078026	0.12178590	-0.49163087	0.128611	-0.4
2.5%	0.12525613	0.1309824	0.10490510	0.12151274	0.084897	0.1110772	0.10384725	0.09927152	0.101988	0.12245266	-0.08821503	0.129247	-0.3
5%	0.12976823	0.1319134	0.11597400	0.12735138	0.104967	0.1144309	0.11760875	0.11548488	0.120114	0.12358705	0.04670047	0.130054	-0.2
10%	0.13633984	0.1338725	0.12873573	0.13473352	0.125428	0.1211382	0.13190783	0.13180719	0.138240	0.12594825	0.11499909	0.131493	-0.2
20%	0.14623873	0.1382417	0.14418919	0.14478037	0.146759	0.1345528	0.14742620	0.14857743	0.156366	0.13109202	0.15090580	0.134642	-0.1
25%	0.15052408	0.1406960	0.15006003	0.14896720	0.153980	0.1412602	0.15293144	0.15424420	0.162202	0.13391051	0.15884951	0.135575	-0.1
30%	0.15460069	0.1433678	0.15533222	0.15292278	0.160090	0.1479675	0.15774072	0.15907764	0.166969	0.13692354	0.16462095	0.138882	-0.0
35%	0.15856042	0.1462943	0.16021769	0.15676612	0.165456	0.1546748	0.16210879	0.16338507	0.171001	0.14015995	0.16920119	0.141698	-0.0
40%	0.16247074	0.1495223	0.16485353	0.16058242	0.170301	0.1613821	0.16619586	0.16735869	0.174493	0.14365554	0.17309737	0.145212	-0.0
45%	0.16638765	0.1531122	0.16933875	0.16444211	0.174772	0.1680894	0.17011491	0.17113326	0.177573	0.14745547	0.17661217	0.149696	-0.0
50%	0.17036330	0.1571434	0.17375287	0.16841157	0.178976	0.1747967	0.17395505	0.17481450	0.180328	0.15161781	0.17995494	0.155563	0.00
55%	0.17445164	0.1617234	0.17816698	0.17256118	0.182999	0.1815041	0.17779519	0.17849573	0.183083	0.15621907	0.18329771	0.163469	0.00
60%	0.17871415	0.1670015	0.18265221	0.17697352	0.186910	0.1882114	0.18171924	0.18227030	0.186163	0.16136284	0.18681251	0.174498	0.00
65%	0.18322712	0.1731941	0.18728804	0.18175431	0.190777	0.1949187	0.18580130	0.18624392	0.189655	0.16719436	0.19070870	0.190562	0.00
70%	0.18809316	0.1806289	0.19217352	0.18705001	0.194671	0.2016260	0.19016938	0.19055135	0.193686	0.17392637	0.19528894	0.215292	0.09
75%	0.19346184	0.1898355	0.19744571	0.19308038	0.198679	0.2083333	0.19497866	0.19538479	0.198454	0.18188863	0.20106038	0.256284	0.1
80%	0.19957220	0.2017445	0.20331655	0.20020680	0.202922	0.2150407	0.20048389	0.20105156	0.204289	0.19163366	0.20900408	0.331726	0.1
90%	0.21623630	0.2437155	0.21877000	0.22125801	0.213102	0.2284553	0.21600227	0.21782180	0.222416	0.22190449	0.24491079	0.960294	0.2
95%	0.23052932	0.2944181	0.23153174	0.24145084	0.220582	0.2351626	0.23030135	0.23414411	0.240542	0.25217531	0.31320941	3.474485	0.2
97.5%	0.24324402	0.3556688	0.24260064	0.26125722	0.226498	0.2385163	0.24406285	0.25035747	0.258668	0.28244613	0.44812491	13.531230	0.3
99%	0.25833606	0.4566163	0.25547063	0.28717479	0.232805	0.2405285	0.26188963	0.27175277	0.282630	0.32246199	0.85154075	83.928435	0.4
Information Criteria													
Akaike (AIC)	-10.78792892	-10.6642673	-10.29845014	-10.16766845	-10.102090	-10.0882397	-9.94769812	-9.64624642	-9.507344	-9.31058025	-7.62002200	-6.770107	0.18
Bayesian (BIC)	-17.56905309	-17.4453915	-17.07957431	-16.94879263	-16.883214	-16.8693639	-16.72882229	-16.42737060	-16.288468	-16.09170443	-14.40114618	-13.551231	-1.5
Average Log-Likelihood	2.07879289	2.0664267	2.02984501	2.01676685	2.010209	2.0088240	1.99476981	1.96462464	1.950734	1.93105803	1.76200220	1.677011	0.3
Chi-Squared Test (Binning Information)													
Bin #1: Minimum	0.11459850	0.1300813	-∞	-∞	-∞	0.1077236	-∞	-∞	-∞	0.12134699	-∞	0.126627	
Bin #1: Maximum	0.17036330	0.1571434	0.17375287	0.16841157	0.178976	0.1747967	0.17395505	0.17481450	0.180328	0.15161781	0.17995494	0.155563	0.00
Bin #1: Input	2.00000000	2.0000000	2.00000000	2.00000000	2.000000	2.0000000	2.00000000	2.00000000	3.000000	2.00000000	2.00000000	2.000000	0.00
Bin #1: Fit	2.50000000	2.5000000	2.50000000	2.50000000	2.500000	2.5000000	2.50000000	2.50000000	2.500000	2.50000000	2.50000000	2.500000	2.50
Bin #2: Minimum	0.17036330	0.1571434	0.17375287	0.16841157	0.178976	0.1747967	0.17395505	0.17481450	0.180328	0.15161781	0.17995494	0.155563	0.00

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Appendix 7A: Fitting probability distributions to Service Component data

1.1.2 Lines outage rate – forced (continuous)

Findings:

- A-D fit statistic: Uniform distribution best fit, standard deviation 0.0540

- A-D fit statistic: Normal distribution second best fit, standard deviation 0.0603

- K-S fit statistic: HypSecant distribution best fit, standard deviation 0.0660

- **A-D preferred (Normal) due to data concentrated closer to the centre and near tails of distribution**

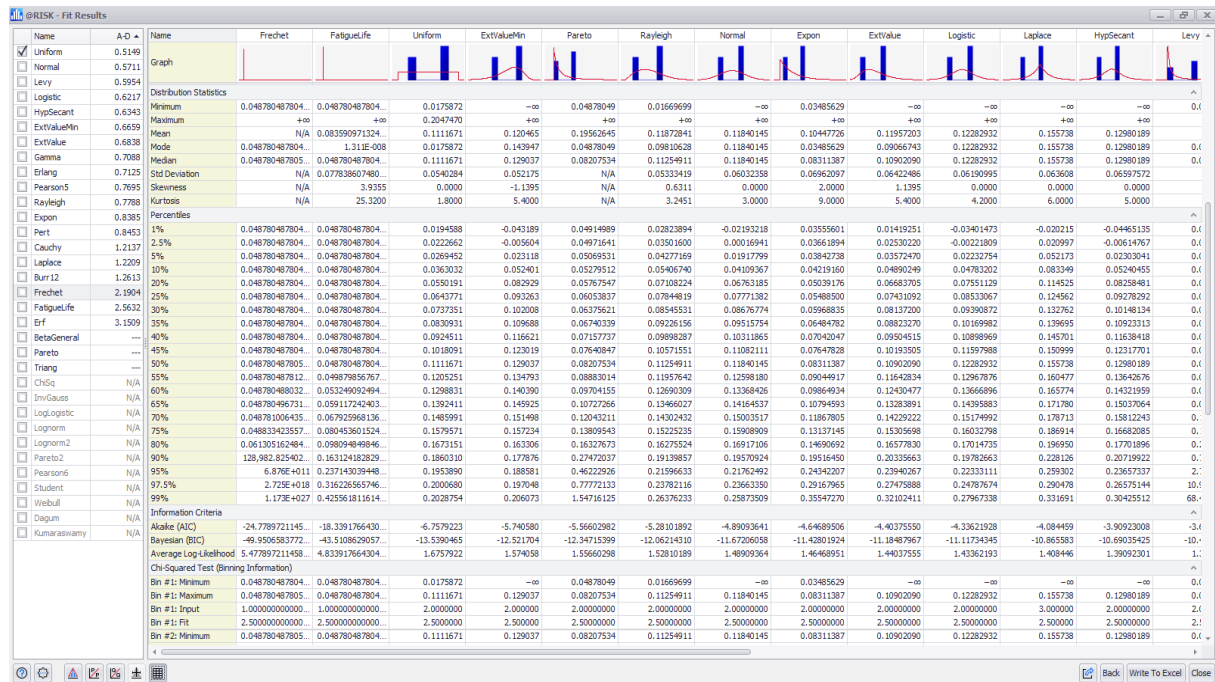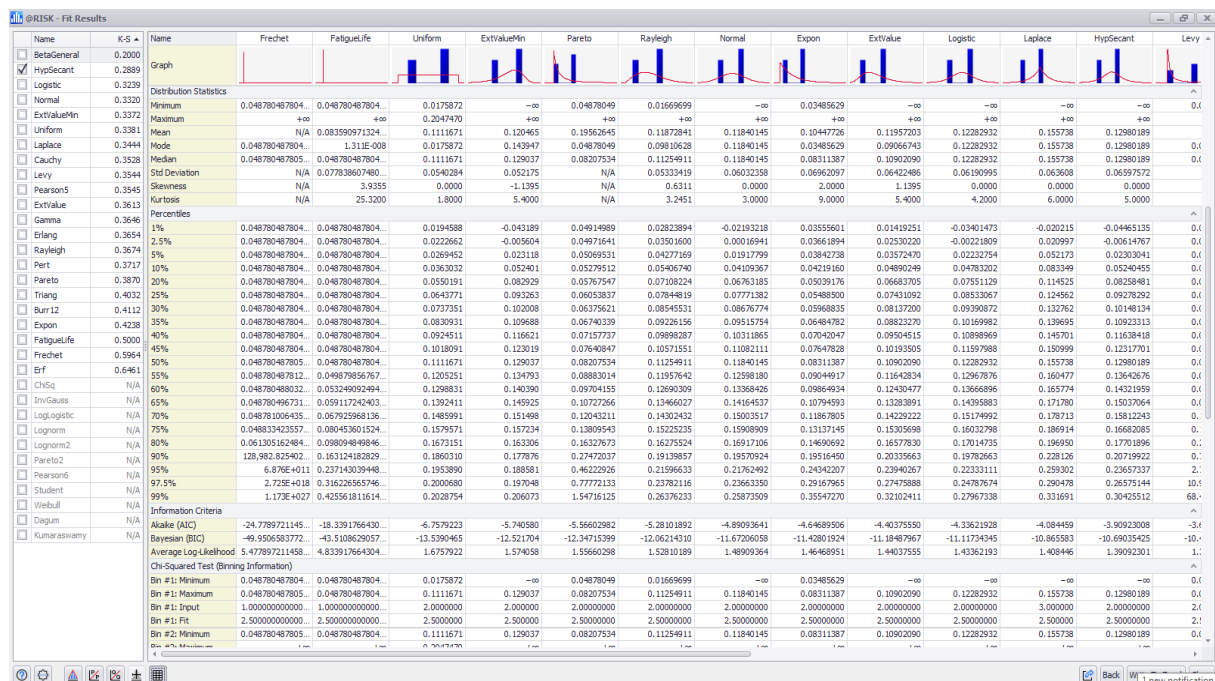**Figure 1-3: Lines outage rate (forced) – distribution fit using A-D**

Figure 1-4: Lines outage rate (forced) – distribution fit using K-S

Appendix 7A: Fitting probability distributions to Service Component data

1.1.3   Reactive plant outage – fault (continuous)

Findings:

- A-D fit statistic: Frechet distribution best fit, however this returns an undefined standard deviation
  - The InvGauss distribution is also a close fit to the data and is close to the Frechet distribution (0.27370 v. 0.2387) and returns a standard deviation of 0.0638

- K-S fit statistic: Frechet distribution best fit, however this returns an undefined standard deviation
  - The InvGauss distribution is also a close fit to the data and is close to the Frechet distribution (0.1976 v. 0.1892) and returns a standard deviation of 0.0638

- **K-S preferred (InvGauss) due to data falling near tails of distribution**

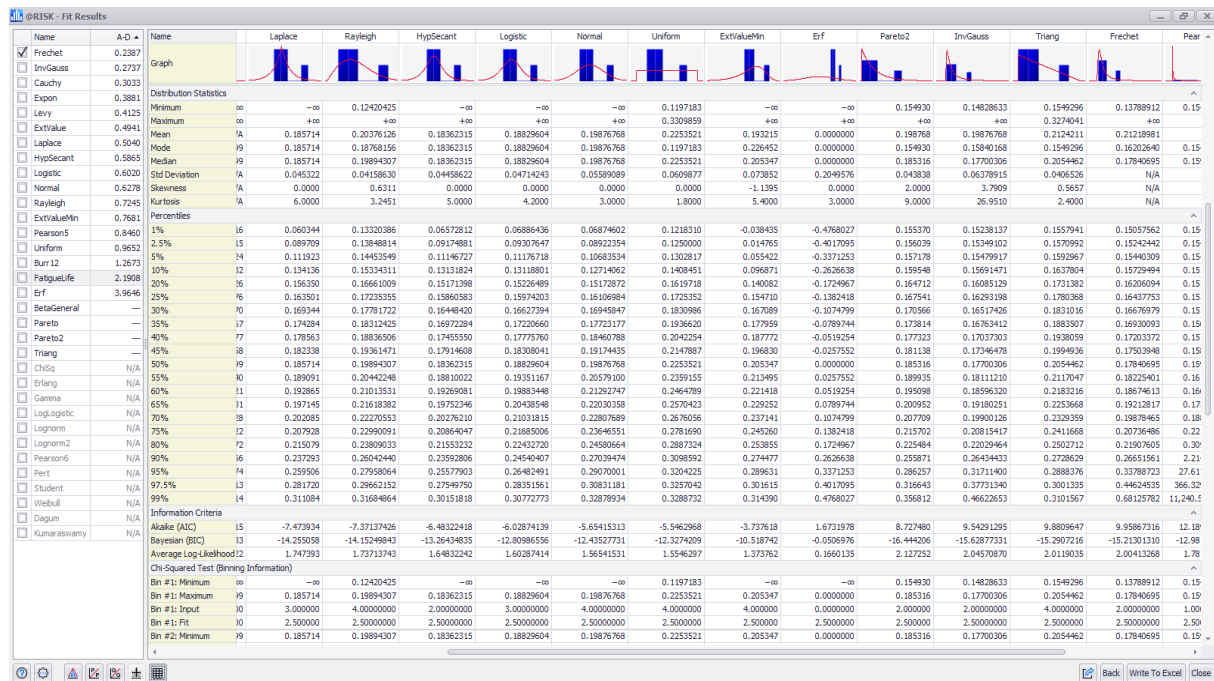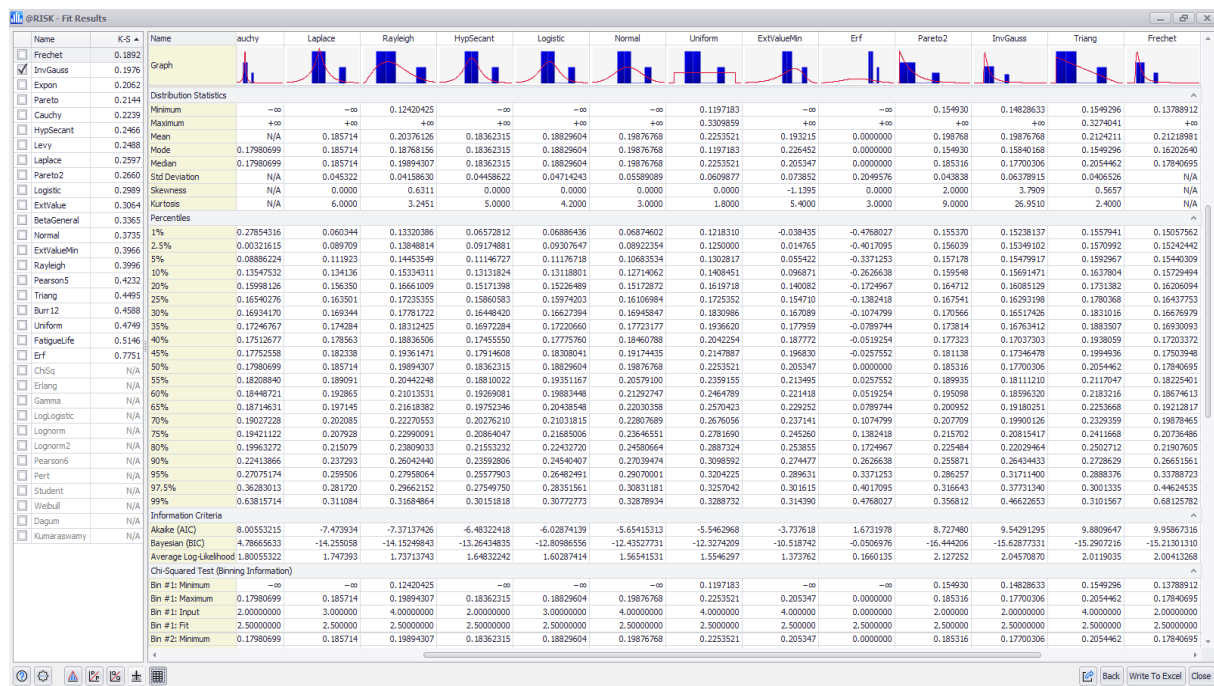**Figure 1-5: Reactive plant outage (fault) – distribution fit using A-D**

Left panel (distribution ranking by A-D statistic):

Name	A-D
Frechet (✓)	0.2387
InvGauss	0.2737
Cauchy	0.3033
Expon	0.3881
Levy	0.4125
ExtValue	0.4941
Laplace	0.5040
HypSecant	0.5865
Logistic	0.6020
Normal	0.6278
Rayleigh	0.7245
ExtValueMin	0.7681
Pearson5	0.8460
Uniform	0.9652
Burr 12	1.2673
FatigueLife	2.1908
Erf	3.9646
BetaGeneral	---
Pareto	---
Pareto2	---
Triang	---
ChiSq	N/A
Erlang	N/A
Gamma	N/A
LogLogistic	N/A
Lognorm	N/A
Lognorm2	N/A
Pearson6	N/A
Pert	N/A
Student	N/A
Weibull	N/A
Dagum	N/A
Kumaraswamy	N/A

Main results panel:

Name	Laplace	Rayleigh	HypSecant	Logistic	Normal	Uniform	ExtValueMin	Erf	Pareto2	InvGauss	Triang	Frechet	Pear
Distribution Statistics													
Minimum	−∞	0.12420425	−∞	−∞	−∞	0.1197183	−∞	−∞	0.154930	0.14828633	0.1549296	0.13788912	0.15
Maximum	+∞	+∞	+∞	+∞	+∞	0.3309859	+∞	+∞	+∞	+∞	0.3274041	+∞	
Mean	0.185714	0.20376126	0.18362315	0.18829604	0.19876768	0.2253521	0.193215	0.0000000	0.198768	0.19876768	0.2124211	0.21218981	
Mode	0.185714	0.18768156	0.18362315	0.18829604	0.19876768	0.1197183	0.226452	0.0000000	0.154930	0.15840168	0.1549296	0.16202640	0.15
Median	0.185714	0.19894307	0.18362315	0.18829604	0.19876768	0.2253521	0.205347	0.0000000	0.185316	0.17700306	0.2054462	0.17840695	0.19
Std Deviation	0.045322	0.04158630	0.04458622	0.04714243	0.05589089	0.0609877	0.073852	0.2049576	0.043838	0.06378915	0.0406526	N/A	
Skewness	0.0000	0.6311	0.0000	0.0000	0.0000	0.0000	−1.1395	0.0000	2.0000	3.7909	0.5657	N/A	
Kurtosis	6.0000	3.2451	5.0000	4.2000	3.0000	1.8000	5.4000	3.0000	9.0000	26.9510	2.4000	N/A	
Percentiles													
1%	0.060344	0.13320386	0.06572812	0.06886436	0.06874602	0.1218310	-0.038435	-0.4768027	0.155370	0.15238137	0.1557941	0.15057562	0.15
2.5%	0.089709	0.13848814	0.09174881	0.09307647	0.08922354	0.1250000	0.014765	-0.4017095	0.156039	0.15349102	0.1570992	0.15242442	0.15
5%	0.111923	0.14453549	0.11146727	0.11176718	0.10683534	0.1302817	0.055422	-0.3371253	0.157178	0.15479917	0.1592967	0.15440309	0.15
10%	0.134136	0.15334311	0.13131824	0.13118801	0.12714062	0.1408451	0.096871	-0.2626638	0.159548	0.15691471	0.1637804	0.15729494	0.15
20%	0.156350	0.16661009	0.15171398	0.15226489	0.15172872	0.1619718	0.140082	-0.1724967	0.164712	0.16085129	0.1731382	0.16206094	0.15
25%	0.163501	0.17235355	0.15860583	0.15974203	0.16106984	0.1725352	0.154710	-0.1382418	0.167541	0.16293198	0.1780368	0.16437753	0.15
30%	0.169344	0.17781722	0.16448420	0.16627394	0.16945847	0.1830986	0.167089	-0.1074799	0.170566	0.16517426	0.1831016	0.16676979	0.15
35%	0.174284	0.18312425	0.16972284	0.17220660	0.17723177	0.1936620	0.177959	-0.0789744	0.173814	0.16763412	0.1883507	0.16930093	0.15
40%	0.178563	0.18836506	0.17455550	0.17775760	0.18460788	0.2042254	0.187772	-0.0519254	0.177323	0.17037303	0.1938059	0.17203372	0.15
45%	0.182338	0.19361471	0.17914608	0.18308041	0.19174435	0.2147887	0.196830	-0.0257552	0.181138	0.17346478	0.1994936	0.17503948	0.15
50%	0.185714	0.19894307	0.18362315	0.18829604	0.19876768	0.2253521	0.205347	0.0000000	0.185316	0.17700306	0.2054462	0.17840695	0.15
55%	0.189091	0.20442248	0.18810022	0.19351167	0.20579100	0.2359155	0.213495	0.0257552	0.189935	0.18111210	0.2117047	0.18225401	0.16
60%	0.192865	0.21013531	0.19269081	0.19883448	0.21292747	0.2464789	0.221418	0.0519254	0.195098	0.18596320	0.2183216	0.18674613	0.16
65%	0.197145	0.21618382	0.19752346	0.20438548	0.22030358	0.2570423	0.229252	0.0789744	0.200952	0.19180251	0.2253668	0.19212817	0.17
70%	0.202085	0.22270553	0.20276210	0.21031815	0.22807689	0.2676056	0.237141	0.1074799	0.207709	0.19900126	0.2329359	0.19878465	0.18
75%	0.207928	0.22990091	0.20864047	0.21685006	0.23646551	0.2781690	0.245260	0.1382418	0.215702	0.20815417	0.2411668	0.20736486	0.22
80%	0.215079	0.23809033	0.21553232	0.22432720	0.24580664	0.2887324	0.253855	0.1724967	0.225484	0.22029464	0.2502712	0.21907605	0.30
90%	0.237293	0.26042440	0.23592806	0.24540407	0.27039474	0.3098592	0.274477	0.2626638	0.255871	0.26434433	0.2728629	0.26651561	2.21
95%	0.259506	0.27958064	0.25577903	0.26482491	0.29070001	0.3204225	0.289631	0.3371253	0.286257	0.31711400	0.2888376	0.33788723	27.61
97.5%	0.281720	0.29662152	0.27549750	0.28351561	0.30831181	0.3257042	0.301615	0.4017095	0.316643	0.37731340	0.3001335	0.44624535	366.32
99%	0.311084	0.31684864	0.30151818	0.30772773	0.32878934	0.3288732	0.314390	0.4768027	0.356812	0.46622653	0.3101567	0.68125782	11,240.5
Information Criteria													
Akaike (AIC)	-7.473934	-7.37137426	-6.48322418	-6.02874139	-5.65415313	-5.5462968	-3.737618	1.6731978	8.727480	9.54291295	9.8809647	9.95867316	12.18
Bayesian (BIC)	-14.255058	-14.15249843	-13.26434835	-12.80986556	-12.43527731	-12.3274209	-10.518742	-0.0506976	-16.444206	-15.62877331	-15.2907216	-15.21301310	-12.98
Average Log-Likelihood	1.747393	1.73713743	1.64832242	1.60287414	1.56541531	1.5546297	1.373762	0.1660135	2.127252	2.04570870	2.0119035	2.00413268	1.78
Chi-Squared Test (Binning Information)													
Bin #1: Minimum	−∞	0.12420425	−∞	−∞	−∞	0.1197183	−∞	−∞	0.154930	0.14828633	0.1549296	0.13788912	0.15
Bin #1: Maximum	0.185714	0.19894307	0.18362315	0.18829604	0.19876768	0.2253521	0.205347	0.0000000	0.185316	0.17700306	0.2054462	0.17840695	0.19
Bin #1: Input	3.000000	4.00000000	2.00000000	3.000000	4.00000000	4.000000	4.000000	0.0000000	2.000000	2.00000000	4.000000	2.000000	1.00
Bin #1: Fit	2.500000	2.50000000	2.50000000	2.50000000	2.50000000	2.500000	2.500000	2.5000000	2.500000	2.50000000	2.500000	2.500000	2.50
Bin #2: Minimum	0.185714	0.19894307	0.18362315	0.18829604	0.19876768	0.2253521	0.205347	0.0000000	0.185316	0.17700306	0.2054462	0.17840695	0.19

Figure 1-6: Reactive plant outage (fault) – distribution fit using K-S

@RISK - Fit Results

Name	K-S ▲
Frechet	0.1892
☑ InvGauss	0.1976
Expon	0.2062
Pareto	0.2144
Cauchy	0.2239
HypSecant	0.2466
Levy	0.2488
Laplace	0.2597
Pareto2	0.2660
Logistic	0.2989
ExtValue	0.3064
BetaGeneral	0.3365
Normal	0.3735
ExtValueMin	0.3966
Rayleigh	0.3996
Pearson5	0.4232
Triang	0.4495
Burr12	0.4588
Uniform	0.4749
FatigueLife	0.5146
Erf	0.7751
ChiSq	N/A
Erlang	N/A
Gamma	N/A
LogLogistic	N/A
Lognorm	N/A
Lognorm2	N/A
Pearson6	N/A
Pert	N/A
Student	N/A
Weibull	N/A
Dagum	N/A
Kumaraswamy	N/A

Name	Cauchy	Laplace	Rayleigh	HypSecant	Logistic	Normal	Uniform	ExtValueMin	Erf	Pareto2	InvGauss	Triang	Frechet
Distribution Statistics													
Minimum	−∞	−∞	0.12420425	−∞	−∞	−∞	0.1197183	−∞	−∞	0.154930	0.14828633	0.1549296	0.13788912
Maximum	+∞	+∞	+∞	+∞	+∞	+∞	0.3309859	+∞	+∞	+∞	+∞	0.3274041	+∞
Mean	N/A	0.185714	0.20376126	0.18362315	0.18829604	0.19876768	0.2253521	0.193215	0.0000000	0.198768	0.19876768	0.2124211	0.21218981
Mode	0.17980699	0.185714	0.18768156	0.18362315	0.18829604	0.19876768	0.1197183	0.226452	0.0000000	0.154930	0.15840168	0.1549296	0.16202640
Median	0.17980699	0.185714	0.19894307	0.18362315	0.18829604	0.19876768	0.2253521	0.205347	0.0000000	0.185316	0.17700306	0.2054462	0.17840695
Std Deviation	N/A	0.045322	0.04158630	0.04458622	0.04714243	0.05589089	0.0609877	0.073852	0.2049576	0.043838	0.06378915	0.0406526	N/A
Skewness	N/A	0.0000	0.6311	0.0000	0.0000	0.0000	0.0000	-1.1395	0.0000	2.0000	3.7909	0.5657	N/A
Kurtosis	N/A	6.0000	3.2451	5.0000	4.2000	3.0000	1.8000	5.4000	3.0000	9.0000	26.9510	2.4000	N/A
Percentiles													
1%	0.27854316	0.060344	0.13320386	0.06572812	0.06886436	0.06874602	0.1218310	-0.038435	-0.4768027	0.155370	0.15238137	0.1557941	0.15057562
2.5%	0.00321615	0.089709	0.13848814	0.09174881	0.09307647	0.08922354	0.1250000	0.014765	-0.4017095	0.156039	0.15349102	0.1570992	0.15242442
5%	0.08886224	0.111923	0.14453549	0.11146727	0.11176718	0.10683534	0.1302817	0.055422	-0.3371253	0.157178	0.15479971	0.1592967	0.15440309
10%	0.13547532	0.134136	0.15334311	0.13131824	0.13118801	0.12714062	0.1408451	0.096871	-0.2626638	0.159548	0.15691471	0.1637804	0.15729494
20%	0.15998126	0.156350	0.1666009	0.15171398	0.15226489	0.15172872	0.1619718	0.140082	-0.1724967	0.164712	0.16085129	0.1731382	0.16206094
25%	0.16540276	0.163501	0.17235355	0.15860583	0.15974203	0.16106984	0.1725352	0.154710	-0.1382418	0.167541	0.16293198	0.1780368	0.16437753
30%	0.16934170	0.169344	0.17781722	0.16448420	0.16627394	0.16945847	0.1830986	0.167089	-0.1074799	0.170566	0.16517426	0.1831016	0.16676979
35%	0.17246767	0.174284	0.18312425	0.16972284	0.17220660	0.17723177	0.1936620	0.177959	-0.0789744	0.173814	0.16763412	0.1883507	0.16930093
40%	0.17512677	0.178563	0.18836506	0.17455550	0.17775760	0.18460788	0.2042254	0.187772	-0.0519254	0.177323	0.17037303	0.1938059	0.17203372
45%	0.17752558	0.182338	0.19361471	0.17914608	0.18308041	0.19174435	0.2147887	0.196830	-0.0257552	0.181138	0.17346478	0.1994936	0.17503948
50%	0.17980699	0.185714	0.19894307	0.18362315	0.18829604	0.19876768	0.2253521	0.205347	0.0000000	0.185316	0.17700306	0.2054462	0.17840695
55%	0.18208840	0.189091	0.20442248	0.18810022	0.19351167	0.20579100	0.2359155	0.213495	0.0257552	0.189935	0.18111210	0.2117047	0.18225401
60%	0.18448721	0.192865	0.21013531	0.19269081	0.19883448	0.21292747	0.2464789	0.221418	0.0519254	0.195098	0.18596320	0.2183216	0.18674613
65%	0.18714631	0.197145	0.21618382	0.19752346	0.20438548	0.22030358	0.2570423	0.229252	0.0789744	0.200952	0.19180251	0.2253668	0.19212817
70%	0.19027228	0.202085	0.22270553	0.20276210	0.21031815	0.22807689	0.2676056	0.237141	0.1074799	0.207709	0.19900126	0.2329359	0.19878465
75%	0.19421122	0.207928	0.22990091	0.20864047	0.21685006	0.23646551	0.2781690	0.245260	0.1382418	0.215702	0.20815417	0.2411668	0.20736486
80%	0.19963272	0.215079	0.23890033	0.21553232	0.22432720	0.24580664	0.2887324	0.253855	0.1724967	0.225484	0.22029464	0.2502712	0.21907605
90%	0.22413866	0.237293	0.26042440	0.23592806	0.24540407	0.27039474	0.3098592	0.274477	0.2626638	0.255871	0.26434433	0.2728629	0.26651561
95%	0.27075174	0.259506	0.27958064	0.25577903	0.26482491	0.29070001	0.3204225	0.289631	0.3371253	0.286257	0.31711400	0.2888376	0.33788723
97.5%	0.36283013	0.281720	0.29662152	0.27549750	0.28351561	0.30831181	0.3257042	0.301615	0.4017095	0.316643	0.37731340	0.3001335	0.44624535
99%	0.63815714	0.311084	0.31684864	0.30151818	0.30772773	0.32878934	0.3288732	0.314390	0.4768027	0.356812	0.46622653	0.3101567	0.68125782
Information Criteria													
Akaike (AIC)	8.00553215	-7.473934	-7.37137426	-6.48322418	-6.02874139	-5.65415313	-5.5462968	-3.737618	1.6731978	8.727480	9.54291295	9.8809647	9.95867316
Bayesian (BIC)	4.78665633	-14.255058	-14.15249843	-13.26434835	-12.80986556	-12.43527731	-12.3274209	-10.518742	-0.0506976	-16.444206	-15.62877331	-15.2907216	-15.21301310
Average Log-Likelihood	1.80055322	1.747393	1.73713743	1.64832242	1.60287414	1.56541531	1.5546297	1.373762	0.1660135	2.127252	2.04570870	2.0119035	2.00413268
Chi-Squared Test (Binning Information)													
Bin #1: Minimum	−∞	−∞	0.12420425	−∞	−∞	−∞	0.1197183	−∞	−∞	0.154930	0.14828633	0.1549296	0.13788912
Bin #1: Maximum	0.17980699	0.185714	0.19894307	0.18362315	0.18829604	0.19876768	0.2253521	0.205347	0.0000000	0.185316	0.17700306	0.2054462	0.17840695
Bin #1: Input	2.00000000	3.00000000	4.00000000	2.00000000	3.00000000	4.00000000	4.000000	4.0000000	0.0000000	2.000000	2.00000000	4.000000	2.00000000
Bin #1: Fit	2.50000000	2.500000	2.50000000	2.50000000	2.50000000	2.50000000	2.500000	2.5000000	2.5000000	2.500000	2.50000000	2.500000	2.50000000
Bin #2: Minimum	0.17980699	0.185714	0.19894307	0.18362315	0.18829604	0.19876768	0.2253521	0.205347	0.0000000	0.185316	0.17700306	0.2054462	0.17840695

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1.1.4 Reactive plant outage – forced (continuous)

Findings:

- A-D fit statistic: Cauchy distribution best fit, however this returns an undefined standard deviation
  - The Normal distribution is also a close fit to the data and is close to the Cauchy distribution (0.2663 v. 0.2564) and returns a standard deviation of 0.0326

- K-S fit statistic: Cauchy distribution best fit, however this returns an undefined standard deviation
  - The Normal distribution is also a close fit to the data and is close to the Cauchy distribution (0.2050 v. 0.2015) and returns a standard deviation of 0.0326

- **K-S preferred (Normal) due to data falling in the middle and near tails of distribution**

Appendix 7A: Fitting probability distributions to Service Component data

**Figure 1-7: Reactive plant outage (forced) – distribution fit using A-D**

Name	A-D
✓ Cauchy	0.2564
Normal	0.2663
HypSecant	0.2810
Logistic	0.2857
FatigueLife	0.3114
ExtValueMin	0.3200
Laplace	0.3310
Frechet	0.3579
ExtValue	0.3583
Rayleigh	0.3956
Uniform	0.4013
Gamma	0.5732
Levy	0.7343
Expon	0.9020
Pearson5	1.1074
Burr12	1.4664
Pert	1.6531
Erf	4.5504
BetaGeneral	---
Erlang	---
Pareto	---
Pareto2	---
Triang	---
ChiSq	N/A
InvGauss	N/A
LogLogistic	N/A
Lognorm	N/A
Lognorm2	N/A
Pearson6	N/A
Student	N/A
Weibull	N/A
Dagum	N/A
Kumaraswamy	N/A

Name	ExtValueMin	Uniform	Normal	Rayleigh	Logistic	HypSecant	Laplace	ExtValue	Pareto	Cauchy	Expon	Levy	Erf
Distribution Statistics													
Minimum	−∞	0.2311871	−∞	0.23864204	−∞	−∞	−∞	−∞	0.2535211	−∞	0.24284420	0.248463	
Maximum	+∞	0.3651911	+∞	+∞	+∞	+∞	+∞	+∞	+∞	+∞	+∞	+∞	
Mean	0.307398	0.2981891	0.30690578	0.30559901	0.30897623	0.30952809	0.304348	0.30879331	0.3111776	0.29622885	N/A	0.29622885	0.00
Mode	0.322247	0.2311871	0.30690578	0.29206597	0.30897623	0.30952809	0.304348	0.29009581	0.2535211	0.30777290	0.24284420	0.254911	0.00
Median	0.312818	0.2981891	0.30690578	0.30154391	0.30897623	0.30952809	0.304348	0.30196811	0.2882640	0.30777290	0.27984762	0.290980	0.30
Std Deviation	0.032995	0.0386836	0.0361990	0.03499996	0.03508248	0.03677326	0.037219	0.04154509	0.0726731	N/A	0.05338466	N/A	0.30
Skewness	−1.1395	0.0000	0.0000	0.6311	0.0000	0.0000	0.0000	1.1395	4.2345	N/A	2.0000	N/A	
Kurtosis	5.4000	1.8000	3.0000	3.2451	4.2000	5.0000	6.0000	5.4000	53.4425	N/A	9.0000	N/A	
Percentiles													
1%	0.203903	0.2325272	0.22269432	0.24621632	0.22009749	0.21229210	0.201392	0.24062653	0.2539937	−0.38464764	0.24338073	0.251378	−0.7
2.5%	0.227671	0.2345372	0.23595705	0.25066368	0.23811568	0.23375311	0.225506	0.24781305	0.2547132	0.03128345	0.24419578	0.252313	−0.60
5%	0.245835	0.2378873	0.24736373	0.25575327	0.25202494	0.25001626	0.243749	0.25455505	0.2559420	0.17038446	0.24558247	0.253498	−0.50
10%	0.264354	0.2445875	0.26051490	0.26316595	0.26647755	0.26638870	0.261991	0.26307935	0.2585189	0.24080192	0.24846883	0.255612	−0.3
20%	0.283659	0.2579879	0.27643994	0.27433175	0.28216255	0.28321044	0.280233	0.27468067	0.2642227	0.27782257	0.25475664	0.260240	−0.2
25%	0.290195	0.2646881	0.28248993	0.27916557	0.28772689	0.28889461	0.286106	0.27951529	0.2674012	0.28601271	0.25820200	0.263080	−0.2
30%	0.295725	0.2713883	0.28792301	0.28376391	0.29258781	0.29374290	0.290904	0.28408288	0.2708414	0.29196320	0.26188516	0.266470	−0.1
35%	0.300582	0.2780885	0.29295757	0.28823044	0.29700279	0.29806356	0.294961	0.28852086	0.2745860	0.29668553	0.26584139	0.270608	−0.1
40%	0.304966	0.2847887	0.29773487	0.29264122	0.30113373	0.30204938	0.298475	0.29292762	0.2786887	0.30070259	0.27011445	0.275770	−0.0
45%	0.309013	0.2914889	0.30235697	0.29705944	0.30509486	0.30583554	0.301575	0.29738448	0.2832181	0.30432643	0.27475952	0.282358	−0.0
50%	0.312818	0.2981891	0.30690578	0.30154391	0.30897623	0.30952809	0.304348	0.30196811	0.2882640	0.30777290	0.27984762	0.290980	0.00
55%	0.316458	0.3048893	0.31145460	0.30615550	0.31285760	0.31322063	0.307121	0.30675975	0.2939467	0.31121938	0.28547225	0.302595	0.0
60%	0.319998	0.3115895	0.31607669	0.31096355	0.31681873	0.31700679	0.310220	0.31185477	0.3004321	0.31484322	0.29176006	0.318800	0.0
65%	0.323498	0.3182897	0.32085400	0.31605411	0.32094968	0.32099261	0.313735	0.31737525	0.3079579	0.31886027	0.29888859	0.342403	0.1
70%	0.327023	0.3249899	0.32588856	0.32154293	0.32536466	0.32531327	0.317792	0.32349030	0.3168806	0.32358261	0.30711787	0.378739	0.1
75%	0.330650	0.3316901	0.33132164	0.32759872	0.33022558	0.33016156	0.322590	0.33045369	0.3277681	0.32953309	0.31685104	0.438969	0.2
80%	0.334490	0.3383903	0.33737163	0.33449112	0.33578992	0.33584573	0.328463	0.33868272	0.3416037	0.33772324	0.32876348	0.549816	0.2
90%	0.343704	0.3517907	0.35329667	0.35328798	0.35147492	0.35266747	0.346705	0.36299099	0.3884176	0.37474389	0.36576691	1.473373	0.3
95%	0.350474	0.3584909	0.36644784	0.36941029	0.36592753	0.36903991	0.364947	0.38630807	0.4416468	0.44516135	0.40277033	5.167483	0.5
97.5%	0.355828	0.3618410	0.37785452	0.38375228	0.37983679	0.38530306	0.383189	0.40917891	0.5021707	0.58426236	0.43977376	19.943893	0.6
99%	0.361536	0.3638511	0.39111725	0.40077588	0.39785498	0.40676407	0.407304	0.43910647	0.5950912	1.00019344	0.48868962	123.378754	0.7
Information Criteria													
Akaike (AIC)	−10.639126	−10.0988545	−9.99785288	−9.86435397	−9.74562390	−9.51745957	−9.443585	−9.10880848	−8.7288512	−7.58319809	−7.30231920	−4.069356	5.70
Bayesian (BIC)	−17.420250	−16.8799787	−16.77897706	−16.64547815	−16.52674808	−16.29858375	−16.224709	−15.88993266	−15.5099754	−14.36432226	−14.08344337	−10.850480	4.0-
Average Log-Likelihood	2.063913	2.0098854	1.99978529	1.98643540	1.97456239	1.95174596	1.944358	1.91088085	1.8728851	1.75831981	1.73023192	1.406936	−0.2
Chi-Squared Test (Binning Information)													
Bin #1: Minimum	−∞	0.2311871	−∞	0.23864204	−∞	−∞	−∞	−∞	0.2535211	−∞	0.24284420	0.248463	
Bin #1: Maximum	0.312818	0.2981891	0.30690578	0.30154391	0.30897623	0.30952809	0.304348	0.30196811	0.2882640	0.30777290	0.27984762	0.290980	0.00
Bin #1: Input	3.000000	2.0000000	3.00000000	2.00000000	3.000000	3.000000	3.000000	2.000000	1.0000000	3.000000	1.000000	1.000000	0.00
Bin #1: Fit	2.500000	2.5000000	2.50000000	2.50000000	2.500000	2.500000	2.500000	2.500000	2.5000000	2.500000	2.500000	2.500000	2.50
Bin #2: Minimum	0.312818	0.2981891	0.30690578	0.30154391	0.30897623	0.30952809	0.304348	0.30196811	0.2882640	0.30777290	0.27984762	0.290980	0.00

Figure 1-8: Reactive plant outage (forced) – distribution fit using K-S

Name	K-S
✓ Cauchy	0.2015
Normal	0.2050
HypSecant	0.2168
Logistic	0.2179
FatigueLife	0.2318
Frechet	0.2319
ExtValue	0.2321
Rayleigh	0.2355
ExtValueMin	0.2422
Laplace	0.2609
BetaGeneral	0.2691
Uniform	0.2820
Pert	0.2913
Triang	0.3166
Gamma	0.3184
Erlang	0.3468
Levy	0.3492
Pareto	0.3648
Expon	0.4290
Pearson5	0.4772
Pareto2	0.4817
Burr12	0.4911
Erf	0.7943
ChiSq	N/A
InvGauss	N/A
LogLogistic	N/A
Lognorm	N/A
Lognorm2	N/A
Pearson6	N/A
Student	N/A
Weibull	N/A
Dagum	N/A
Kumaraswamy	N/A

Name	ExtValueMin	Uniform	Normal	Rayleigh	Logistic	HypSecant	Laplace	ExtValue	Pareto	Cauchy	Expon	Levy	Erf
Distribution Statistics													
Minimum	−∞	0.2311871	−∞	0.23864204	−∞	−∞	−∞	−∞	0.2535211	−∞	0.24284420	0.248463	
Maximum	+∞	0.3651911	+∞	+∞	+∞	+∞	+∞	+∞	+∞	+∞	+∞	+∞	
Mean	0.307398	0.2981891	0.30690578	0.30559901	0.30897623	0.30952809	0.304348	0.30879331	0.3111776	0.29622885	N/A	0.29622885	0.00
Mode	0.322247	0.2311871	0.30690578	0.29206597	0.30897623	0.30952809	0.304348	0.29009581	0.2535211	0.30777290	0.24284420	0.254911	0.00
Median	0.312818	0.2981891	0.30690578	0.30154391	0.30897623	0.30952809	0.304348	0.30196811	0.2882640	0.30777290	0.27984762	0.290980	0.00
Std Deviation	0.032995	0.0386836	0.0361990	0.03499996	0.03508248	0.03677326	0.037219	0.04154509	0.0726731	N/A	0.05338466	N/A	0.30
Skewness	−1.1395	0.0000	0.0000	0.6311	0.0000	0.0000	0.0000	1.1395	4.2345	N/A	2.0000	N/A	
Kurtosis	5.4000	1.8000	3.0000	3.2451	4.2000	5.0000	6.0000	5.4000	53.4425	N/A	9.0000	N/A	
Percentiles													
1%	0.203903	0.2325272	0.22269432	0.24621632	0.22009749	0.21229210	0.201392	0.24062653	0.2539937	−0.38464764	0.24338073	0.251378	−0.7
2.5%	0.227671	0.2345372	0.23595705	0.25066368	0.23811568	0.23375311	0.225506	0.24781305	0.2547132	0.03128345	0.24419578	0.252313	−0.60
5%	0.245835	0.2378873	0.24736373	0.25575327	0.25202494	0.25001626	0.243749	0.25455505	0.2559420	0.17038446	0.24558247	0.253498	−0.50
10%	0.264354	0.2445875	0.26051490	0.26316595	0.26647755	0.26638870	0.261991	0.26307935	0.2585189	0.24080192	0.24846883	0.255612	−0.3
20%	0.283659	0.2579879	0.27643994	0.27433175	0.28216255	0.28321044	0.280233	0.27468067	0.2642227	0.27782257	0.25475664	0.260240	−0.2
25%	0.290195	0.2646881	0.28248993	0.27916557	0.28772689	0.28889461	0.286106	0.27951529	0.2674012	0.28601271	0.25820200	0.263080	−0.2
30%	0.295725	0.2713883	0.28792301	0.28376391	0.29258781	0.29374290	0.290904	0.28408288	0.2708414	0.29196320	0.26188516	0.266470	−0.1
35%	0.300582	0.2780885	0.29295757	0.28823044	0.29700279	0.29806356	0.294961	0.28852086	0.2745860	0.29668553	0.26584139	0.270608	−0.1
40%	0.304966	0.2847887	0.29773487	0.29264122	0.30113373	0.30204938	0.298475	0.29292762	0.2786887	0.30070259	0.27011445	0.275770	−0.0
45%	0.309013	0.2914889	0.30235697	0.29705944	0.30509486	0.30583554	0.301575	0.29738448	0.2832181	0.30432643	0.27475952	0.282358	−0.0
50%	0.312818	0.2981891	0.30690578	0.30154391	0.30897623	0.30952809	0.304348	0.30196811	0.2882640	0.30777290	0.27984762	0.290980	0.00
55%	0.316458	0.3048893	0.31145460	0.30615550	0.31285760	0.31322063	0.307121	0.30675975	0.2939467	0.31121938	0.28547225	0.302595	0.0
60%	0.319998	0.3115895	0.31607669	0.31096355	0.31681873	0.31700679	0.310220	0.31185477	0.3004321	0.31484322	0.29176006	0.318800	0.0
65%	0.323498	0.3182897	0.32085400	0.31605411	0.32094968	0.32099261	0.313735	0.31737525	0.3079579	0.31886027	0.29888859	0.342403	0.1
70%	0.327023	0.3249899	0.32588856	0.32154293	0.32536466	0.32531327	0.317792	0.32349030	0.3168806	0.32358261	0.30711787	0.378739	0.1
75%	0.330650	0.3316901	0.33132164	0.32759872	0.33022558	0.33016156	0.322590	0.33045369	0.3277681	0.32953309	0.31685104	0.438969	0.2
80%	0.334490	0.3383903	0.33737163	0.33449112	0.33578992	0.33584573	0.328463	0.33868272	0.3416037	0.33772324	0.32876348	0.549816	0.2
90%	0.343704	0.3517907	0.35329667	0.35328798	0.35147492	0.35266747	0.346705	0.36299099	0.3884176	0.37474389	0.36576691	1.473373	0.3
95%	0.350474	0.3584909	0.36644784	0.36941029	0.36592753	0.36903991	0.364947	0.38630807	0.4416468	0.44516135	0.40277033	5.167483	0.5
97.5%	0.355828	0.3618410	0.37785452	0.38375228	0.37983679	0.38530306	0.383189	0.40917891	0.5021707	0.58426236	0.43977376	19.943893	0.6
99%	0.361536	0.3638511	0.39111725	0.40077588	0.39785498	0.40676407	0.407304	0.43910647	0.5950912	1.00019344	0.48868962	123.378754	0.7
Information Criteria													
Akaike (AIC)	−10.639126	−10.0988545	−9.99785288	−9.86435397	−9.74562390	−9.51745957	−9.443585	−9.10880848	−8.7288512	−7.58319809	−7.30231920	−4.069356	5.70
Bayesian (BIC)	−17.420250	−16.8799787	−16.77897706	−16.64547815	−16.52674808	−16.29858375	−16.224709	−15.88993266	−15.5099754	−14.36432226	−14.08344337	−10.850480	4.0-
Average Log-Likelihood	2.063913	2.0098854	1.99978529	1.98643540	1.97456239	1.95174596	1.944358	1.91088085	1.8728851	1.75831981	1.73023192	1.406936	−0.2
Chi-Squared Test (Binning Information)													
Bin #1: Minimum	−∞	0.2311871	−∞	0.23864204	−∞	−∞	−∞	−∞	0.2535211	−∞	0.24284420	0.248463	
Bin #1: Maximum	0.312818	0.2981891	0.30690578	0.30154391	0.30897623	0.30952809	0.304348	0.30196811	0.2882640	0.30777290	0.27984762	0.290980	0.00
Bin #1: Input	3.000000	2.0000000	3.00000000	2.00000000	3.000000	3.000000	3.000000	2.000000	1.0000000	3.000000	1.000000	1.000000	0.00
Bin #1: Fit	2.500000	2.5000000	2.50000000	2.50000000	2.500000	2.500000	2.500000	2.500000	2.5000000	2.500000	2.500000	2.500000	2.50
Bin #2: Minimum	0.312818	0.2981891	0.30690578	0.30154391	0.30897623	0.30952809	0.304348	0.30196811	0.2882640	0.30777290	0.27984762	0.290980	0.00

1.1.5 Transformers outage – fault (continuous)

Findings:

- A-D fit statistic: ExtValueMin distribution best fit, standard deviation 0.0295

- K-S fit statistic: Logistic distribution best fit, standard deviation 0.0334

- **K-S preferred (Logistic) due to data concentrated closer to the centre and near tails of distribution**

Appendix 7A: Fitting probability distributions to Service Component data

Figure 1-9: Transformers outage (fault) – distribution fit using A-D
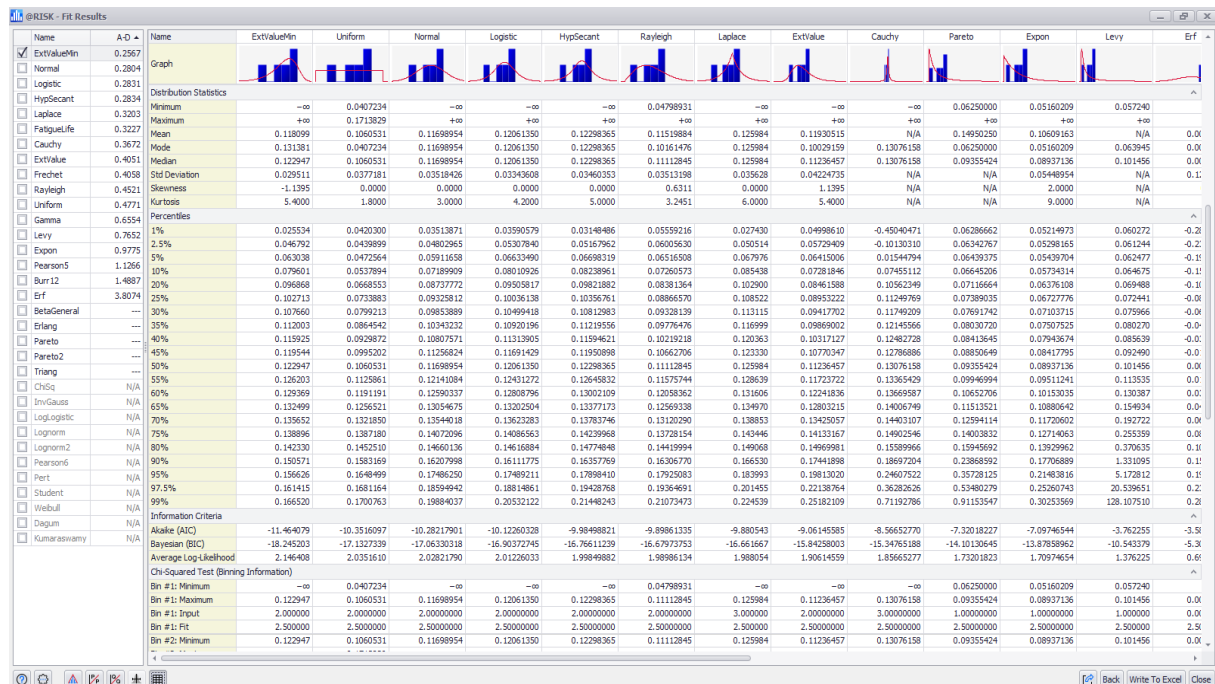
Figure 1-10: Transformers outage (fault) – distribution fit using K-S
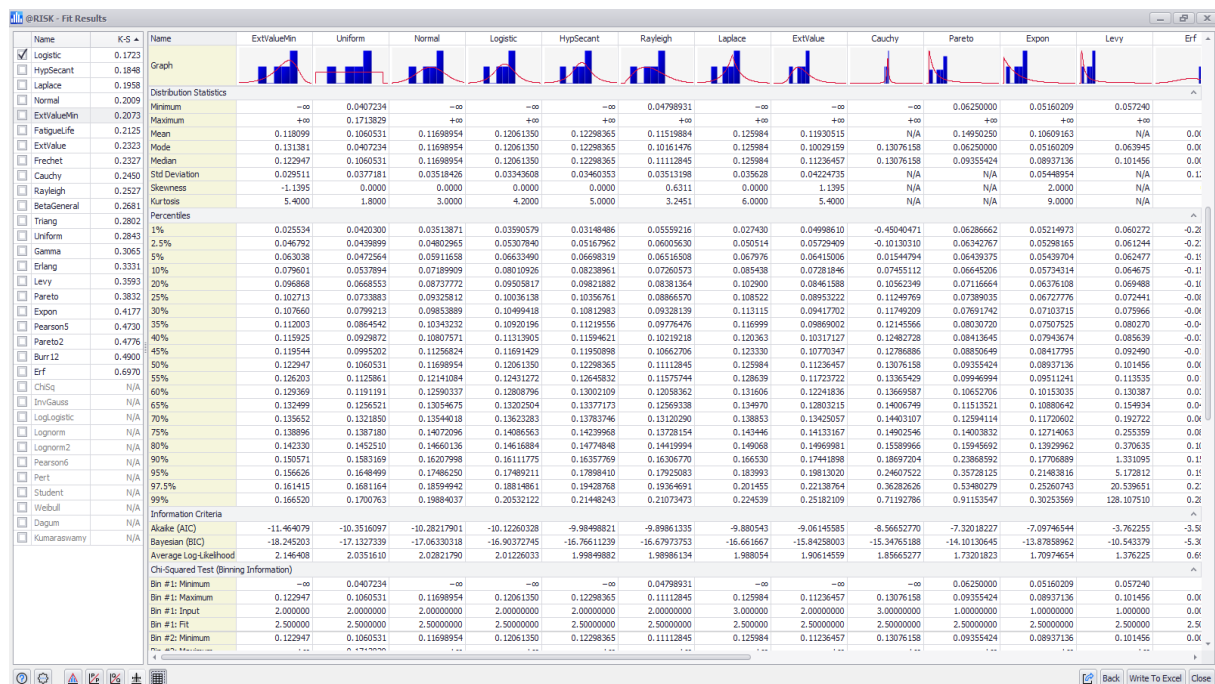
1.1.6 Transformers outage – forced (continuous)

Findings:

- A-D fit statistic: Cauchy distribution best fit, however this returns an undefined standard deviation

  - The Laplace distribution is also a close fit to the data and is close to the Cauchy distribution (0.1875 v. 0.1409) and returns a standard deviation of 0.0271

Appendix 7A: Fitting probability distributions to Service Component data

- K-S fit statistic: Cauchy distribution best fit, however this returns an undefined standard deviation

  o The Laplace distribution is also a close fit to the data and is close to the Cauchy distribution (0.1639 v. 0.1349) and returns a standard deviation of 0.0271

- **K-S preferred (Laplace) due to data falling in the middle and near tails of distribution**

Figure 1-11: Transformers outage (forced) – distribution fit using A-D
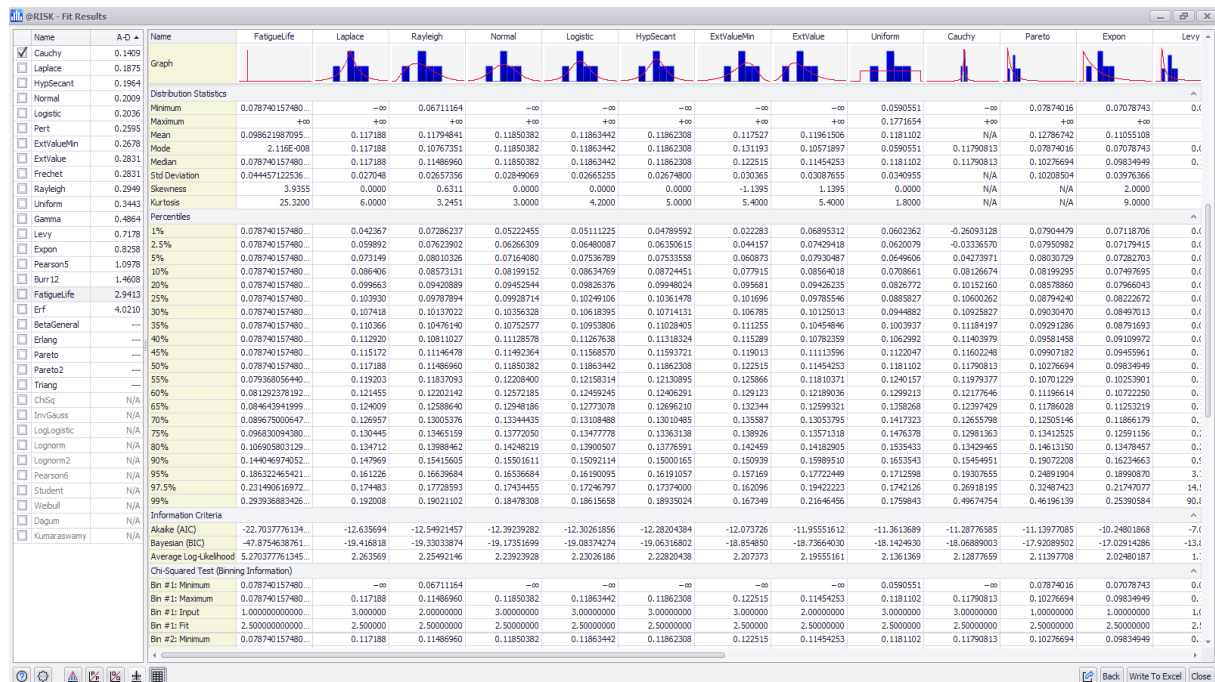
Figure 1-12: Transformers outage (forced) – distribution fit using K-S
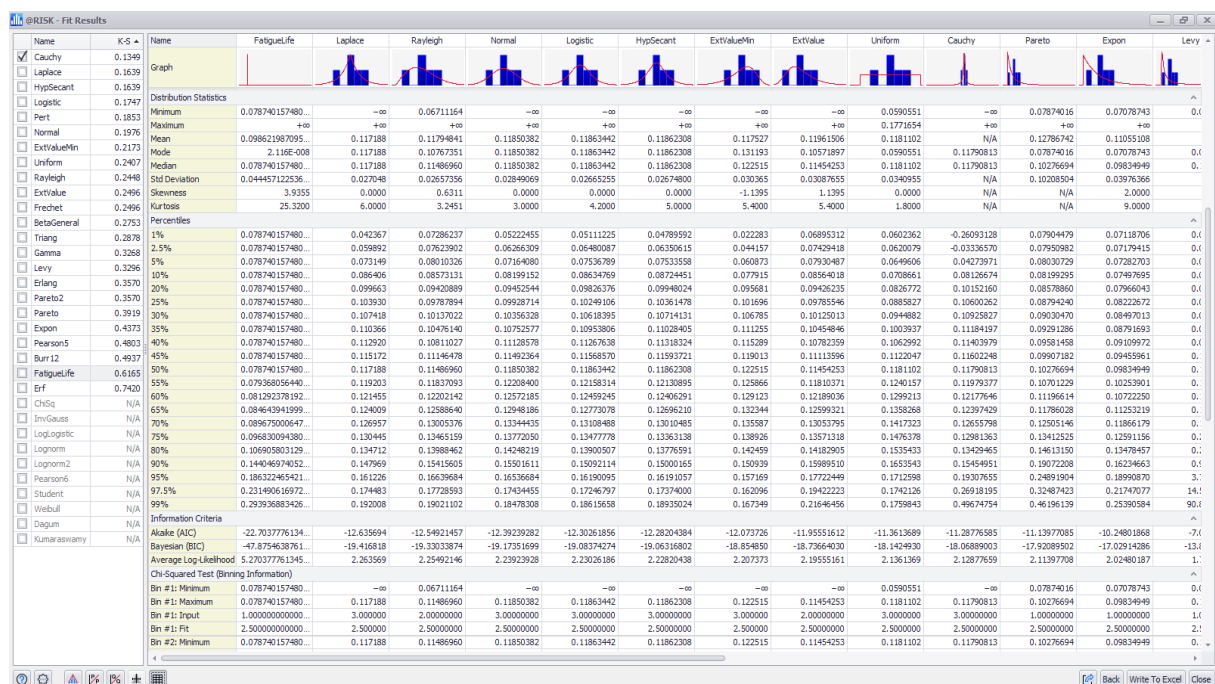
1.2 Service parameter 2 – loss of supply event frequency

1.2.1 Number of events > 0.05 system minutes (discrete)

Findings:

- Akaike information criterion (AIC) fit statistic: Poisson distribution best fit, standard deviation 1.0954

- Bayesian information criterion (BIC) fit statistic: Poisson distribution best fit, standard deviation 1.0954

- Large variance in standard deviations of better fitting distributions

- **Best fit distribution (Poisson) preferred**

Figure 1-13: Number of events >0.05 system minutes – AIC distribution

Name	AIC
Poisson	18.1153
Geomet	18.4915
IntUniform	23.8629
NegBin	24.7166
HyperGeo	44.8066
Binomial	N/A

Name	Poisson	Geomet	IntUniform	NegBin	HyperGeo
Distribution Statistics					
Minimum	0.000000	0.000000	0.000000	0.000000	0.000000
Maximum	+∞	+∞	3.000000	+∞	38.000000
Mean	1.200000	1.200000	1.500000	1.200000	1.192114
Mode	1.000000	0.000000	0.000000	0.000000	1.000000
Median	1.000000	1.000000	1.000000	1.000000	1.000000
Std Deviation	1.095445	1.624808	1.118034	1.219836	1.073944
Skewness	0.9129	2.0926	0.0000	1.2133	0.8707
Kurtosis	3.8333	9.3788	1.6400	4.8720	3.7038
Percentiles					
1%	0.000000	0.000000	0.000000	0.000000	0.000000
2.5%	0.000000	0.000000	0.000000	0.000000	0.000000
5%	0.000000	0.000000	0.000000	0.000000	0.000000
10%	0.000000	0.000000	0.000000	0.000000	0.000000
20%	0.000000	0.000000	0.000000	0.000000	0.000000
25%	0.000000	0.000000	0.000000	0.000000	0.000000
30%	0.000000	0.000000	1.000000	0.000000	1.000000
35%	1.000000	0.000000	1.000000	1.000000	1.000000
40%	1.000000	0.000000	1.000000	1.000000	1.000000
45%	1.000000	0.000000	1.000000	1.000000	1.000000
50%	1.000000	1.000000	1.000000	1.000000	1.000000
55%	1.000000	1.000000	2.000000	1.000000	1.000000
60%	1.000000	1.000000	2.000000	1.000000	1.000000
65%	1.000000	1.000000	2.000000	1.000000	1.000000
70%	2.000000	1.000000	2.000000	2.000000	2.000000
75%	2.000000	2.000000	2.000000	2.000000	2.000000
80%	2.000000	2.000000	3.000000	2.000000	2.000000
90%	3.000000	3.000000	3.000000	3.000000	3.000000
95%	3.000000	4.000000	3.000000	4.000000	3.000000
97.5%	4.000000	6.000000	3.000000	4.000000	4.000000
99%	4.000000	7.000000	3.000000	4.000000	4.000000
Information Criteria					
Akaike (AIC)	18.115288	18.491537	23.862944	24.716629	44.806571
Bayesian (BIC)	16.391393	16.767641	17.081819	17.935505	19.634885
Average Log-Likelihood	-1.478195	-1.515820	-1.386294	-1.471663	-1.480657
Chi-Squared Test (Binning Information)					
Bin #1: Minimum	0.000000	0.000000	0.000000	0.000000	0.000000
Bin #1: Maximum	+∞	+∞	3.000000	+∞	38.000000
Bin #1: Input	5.000000	5.000000	5.000000	5.000000	5.000000
Bin #1: Fit	5.000000	5.000000	5.000000	5.000000	5.000000
Chi-Squared Test - [* Values unavailable without running a bootstrap]					
Statistic	0.000000	0.000000	0.000000	0.000000	0.000000

Appendix 7A: Fitting probability distributions to Service Component data

Figure 1-14: Number of events >0.05 system minutes – BIC distribution

Name	BIC ▲
☑ Poisson	16.3914
☐ Geomet	16.7676
☐ IntUniform	17.0818
☐ NegBin	17.9355
☐ HyperGeo	19.6349
☐ Binomial	N/A

Name	Poisson	Geomet	IntUniform	NegBin	HyperGeo
Distribution Statistics					
Minimum	0.000000	0.000000	0.000000	0.000000	0.000000
Maximum	+∞	+∞	3.000000	+∞	38.000000
Mean	1.200000	1.200000	1.500000	1.200000	1.192114
Mode	1.000000	0.000000	0.000000	0.000000	1.000000
Median	1.000000	1.000000	1.000000	1.000000	1.000000
Std Deviation	1.095445	1.624808	1.118034	1.219836	1.073944
Skewness	0.9129	2.0926	0.0000	1.2133	0.8707
Kurtosis	3.8333	9.3788	1.6400	4.8720	3.7038
Percentiles					
1%	0.000000	0.000000	0.000000	0.000000	0.000000
2.5%	0.000000	0.000000	0.000000	0.000000	0.000000
5%	0.000000	0.000000	0.000000	0.000000	0.000000
10%	0.000000	0.000000	0.000000	0.000000	0.000000
20%	0.000000	0.000000	0.000000	0.000000	0.000000
25%	0.000000	0.000000	0.000000	0.000000	0.000000
30%	0.000000	0.000000	1.000000	0.000000	1.000000
35%	1.000000	0.000000	1.000000	1.000000	1.000000
40%	1.000000	0.000000	1.000000	1.000000	1.000000
45%	1.000000	0.000000	1.000000	1.000000	1.000000
50%	1.000000	1.000000	1.000000	1.000000	1.000000
55%	1.000000	1.000000	2.000000	1.000000	1.000000
60%	1.000000	1.000000	2.000000	1.000000	1.000000
65%	1.000000	1.000000	2.000000	1.000000	1.000000
70%	2.000000	1.000000	2.000000	2.000000	2.000000
75%	2.000000	2.000000	2.000000	2.000000	2.000000
80%	2.000000	2.000000	3.000000	2.000000	2.000000
90%	3.000000	3.000000	3.000000	3.000000	3.000000
95%	3.000000	4.000000	3.000000	4.000000	3.000000
97.5%	4.000000	6.000000	3.000000	4.000000	4.000000
99%	4.000000	7.000000	3.000000	5.000000	4.000000
Information Criteria					
Akaike (AIC)	18.115288	18.491537	23.862944	24.716629	44.806571
Bayesian (BIC)	16.391393	16.767641	17.081819	17.935505	19.634885
Average Log-Likelihood	-1.478195	-1.515820	-1.386294	-1.471663	-1.480657
Chi-Squared Test (Binning Information)					
Bin #1: Minimum	0.000000	0.000000	0.000000	0.000000	0.000000
Bin #1: Maximum	+∞	+∞	3.000000	+∞	38.000000
Bin #1: Input	5.000000	5.000000	5.000000	5.000000	5.000000
Bin #1: Fit	5.000000	5.000000	5.000000	5.000000	5.000000
Chi-Squared Test - [* Values unavailable without running a bootstrap]					
Statistic	0.000000	0.000000	0.000000	0.000000	0.000000

1.2.2 Number of events > 0.30 system minutes (discrete)

Findings:

- Akaike information criterion (AIC) fit statistic: Poisson distribution best fit, standard deviation 0.7746

- Bayesian information criterion (BIC) fit statistic: Binomial distribution best fit, standard deviation 0.4899

- **Best fit distribution (Poisson) preferred**

Figure 1-15: Number of events >0.30 system minutes – AIC distribution

Name	AIC ▲
☑ Poisson	12.3983
☐ Geomet	13.9183
☐ Binomial	16.7301
☐ IntUniform	16.9315
☐ HyperGeo	36.7301
☐ NegBin	N/A

Name	Poisson	Geomet	Binomial	IntUniform	HyperGeo
Distribution Statistics					
Minimum	0.000000	0.000000	0.000000	0.000000	0.000000
Maximum	+∞	+∞	1.000000	1.000000	1.000000
Mean	0.600000	0.600000	0.600000	0.500000	0.600000
Mode	0.000000	0.000000	1.000000	0.000000	1.000000
Median	0.000000	0.000000	1.000000	0.000000	1.000000
Std Deviation	0.774597	0.979796	0.489898	0.500000	0.489898
Skewness	1.2910	2.2454	-0.4082	0.0000	-0.4082
Kurtosis	4.6667	10.0417	1.1667	1.0000	1.1667
Percentiles					
1%	0.000000	0.000000	0.000000	0.000000	0.000000
2.5%	0.000000	0.000000	0.000000	0.000000	0.000000
5%	0.000000	0.000000	0.000000	0.000000	0.000000
10%	0.000000	0.000000	0.000000	0.000000	0.000000
20%	0.000000	0.000000	0.000000	0.000000	0.000000
25%	0.000000	0.000000	0.000000	0.000000	0.000000
30%	0.000000	0.000000	0.000000	0.000000	0.000000
35%	0.000000	0.000000	0.000000	0.000000	0.000000
40%	0.000000	0.000000	0.000000	0.000000	0.000000
45%	0.000000	0.000000	1.000000	0.000000	1.000000
50%	0.000000	0.000000	1.000000	0.000000	1.000000
55%	1.000000	0.000000	1.000000	1.000000	1.000000
60%	1.000000	0.000000	1.000000	1.000000	1.000000
65%	1.000000	1.000000	1.000000	1.000000	1.000000
70%	1.000000	1.000000	1.000000	1.000000	1.000000
75%	1.000000	1.000000	1.000000	1.000000	1.000000
80%	1.000000	1.000000	1.000000	1.000000	1.000000
90%	2.000000	2.000000	1.000000	1.000000	1.000000
95%	2.000000	3.000000	1.000000	1.000000	1.000000
97.5%	2.000000	3.000000	1.000000	1.000000	1.000000
99%	3.000000	4.000000	1.000000	1.000000	1.000000
Information Criteria					
Akaike (AIC)	12.398287	13.918345	16.730117	16.931472	36.730117
Bayesian (BIC)	10.674392	12.194450	9.948992	10.150348	11.558430
Average Log-Likelihood	-0.906495	-1.058501	-0.673012	-0.693147	-0.673012
Chi-Squared Test (Binning Information)					
Bin #1: Minimum	0.000000	0.000000	0.000000	0.000000	0.000000
Bin #1: Maximum	+∞	+∞	1.000000	1.000000	1.000000
Bin #1: Input	5.000000	5.000000	5.000000	5.000000	5.000000
Bin #1: Fit	5.000000	5.000000	5.000000	5.000000	5.000000
Chi-Squared Test - [* Values unavailable without running a bootstrap]					
Statistic	0.000000	0.000000	0.000000	0.000000	0.000000

Figure 1-16: Number of events >0.30 system minutes – BIC distribution

1.3 Service parameter 3 – average outage duration

1.3.1 Average outage duration (continuous)

Findings:

- A-D fit statistic: Frechet distribution best fit, however this returns an undefined standard deviation

  - The InvGauss distribution is also a close fit to the data and is close to the Cauchy distribution (0.3861 v. 0.3367) and returns a standard deviation of 60.73

- K-S fit statistic: Frechet distribution best fit, however this returns an undefined standard deviation

  - The InvGauss distribution is also a close fit to the data and is close to the Frechet distribution (0.2624 v. 0.2000) and returns a standard deviation of 60.73

- **K-S is preferred (InvGauss) due to data concentrated in the middle and at the tail end of the curve**

Appendix 7A: Fitting probability distributions to Service Component data

Figure 1-17: Average outage duration – distribution fit using A-D
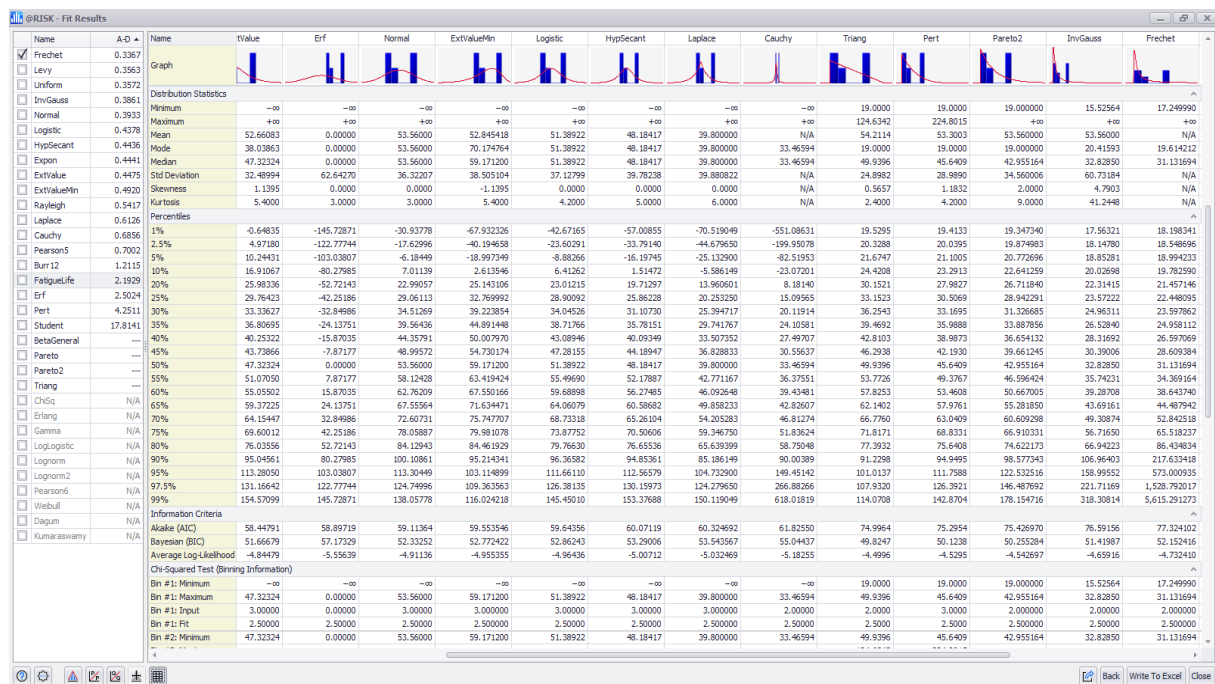
Figure 1-18: Average outage duration – distribution fit using K-S
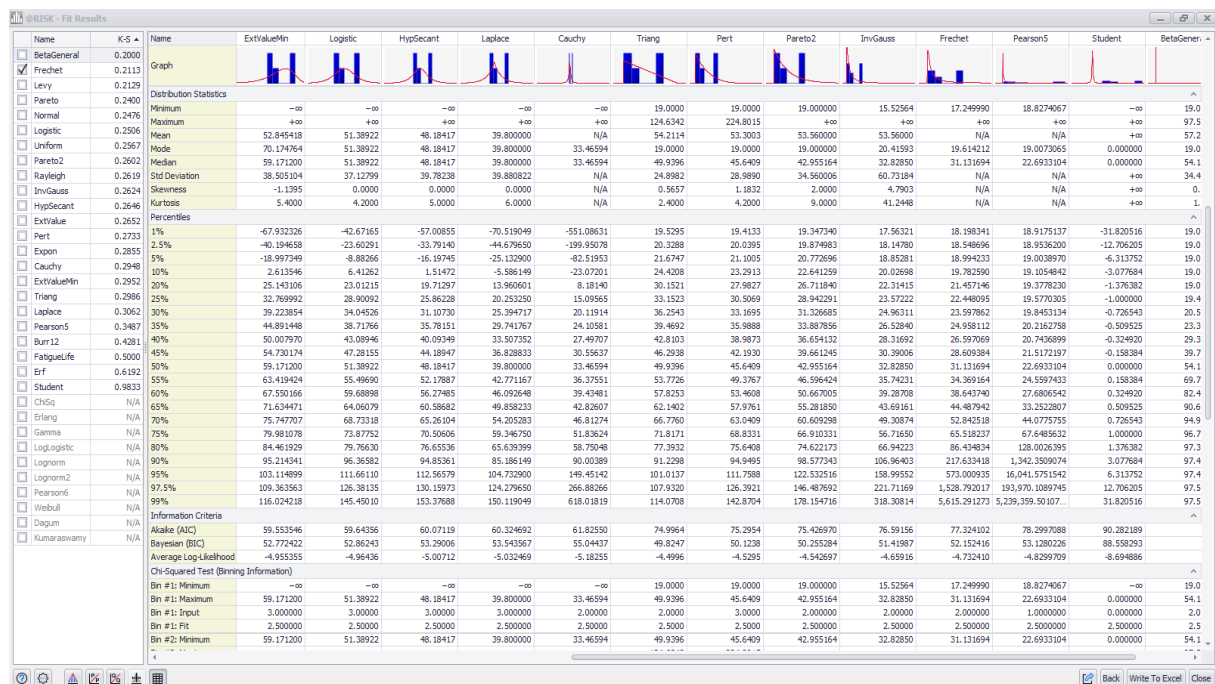
1.4 Service parameter 4 – proper operation of equipment

1.4.1 Failure of protection system (discrete)

Findings:

- Akaike information criterion (AIC) fit statistic: Poisson distribution best fit, standard deviation 5.6570

- Bayesian information criterion (BIC) fit statistic: IntUniform distribution best fit, standard deviation 6.9220

- **Best fit distribution (Poisson) preferred**

Figure 1-19: Failure of protection system – AIC distribution
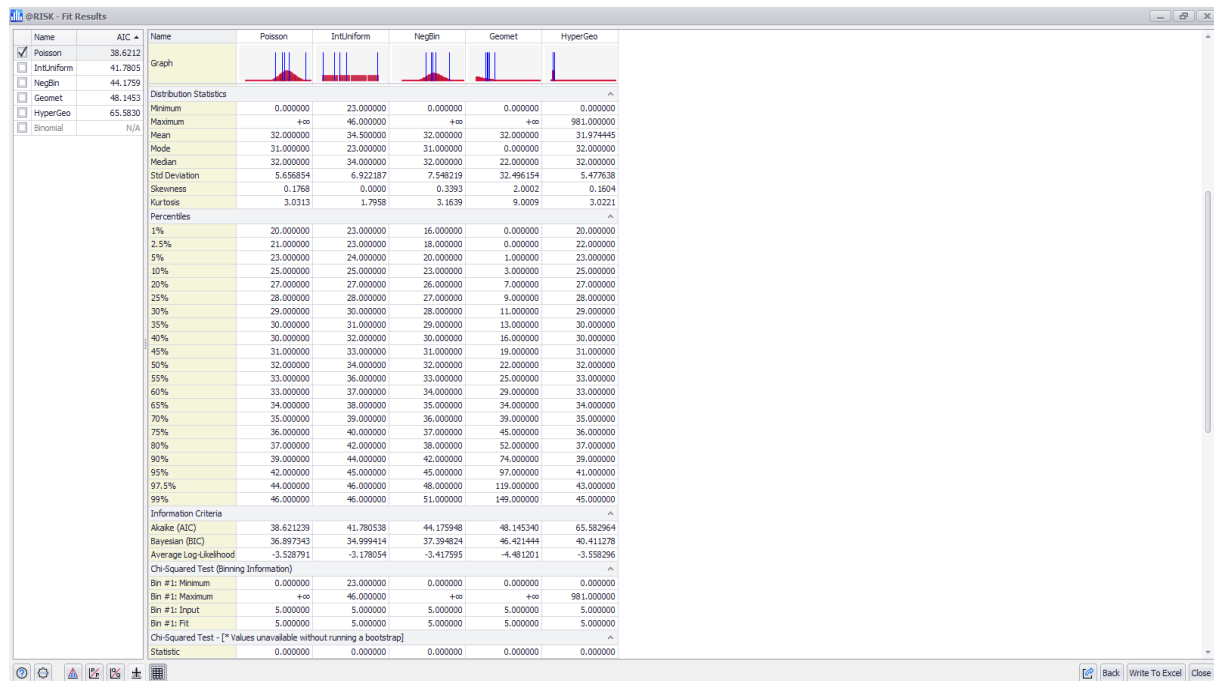
Figure 1-20: Failure of protection system – BIC distribution
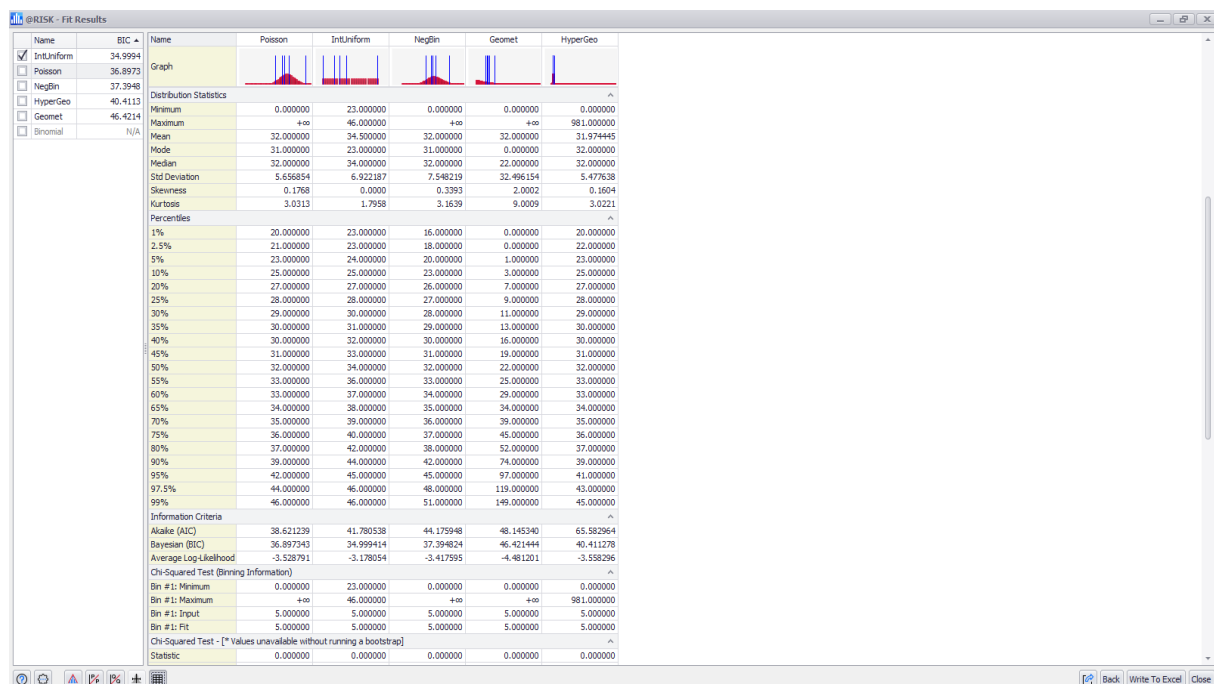
1.4.2   Material failure of SCADA system (discrete)

Findings:

- Akaike information criterion (AIC) fit statistic: Geometric distribution best fit, standard deviation 1.200

- Akaike information criterion (AIC) fit statistic: Poisson distribution best fit, standard deviation 0.8944

- Bayesian information criterion (BIC) fit statistic: Geometric distribution best fit, standard deviation 1.200

- **Best fit distribution (Poisson) preferred**

Figure 1-21: Material failure of SCADA system – AIC distribution
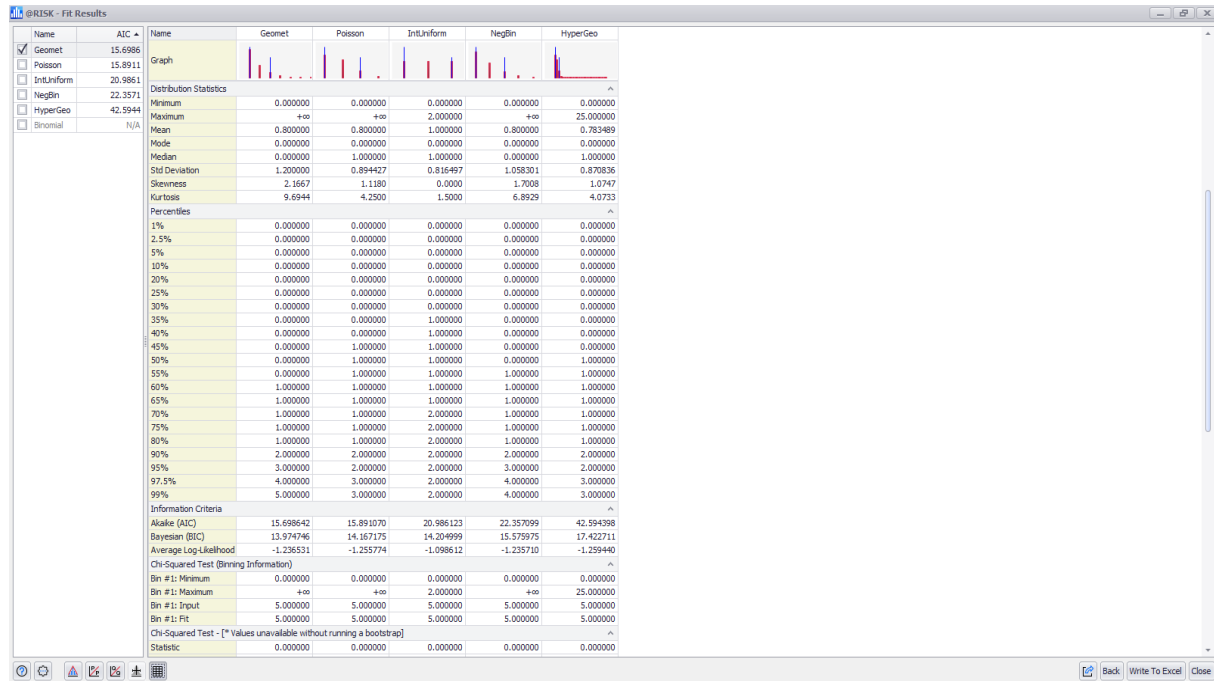
Figure 1-22: Material failure of SCADA system – BIC distribution
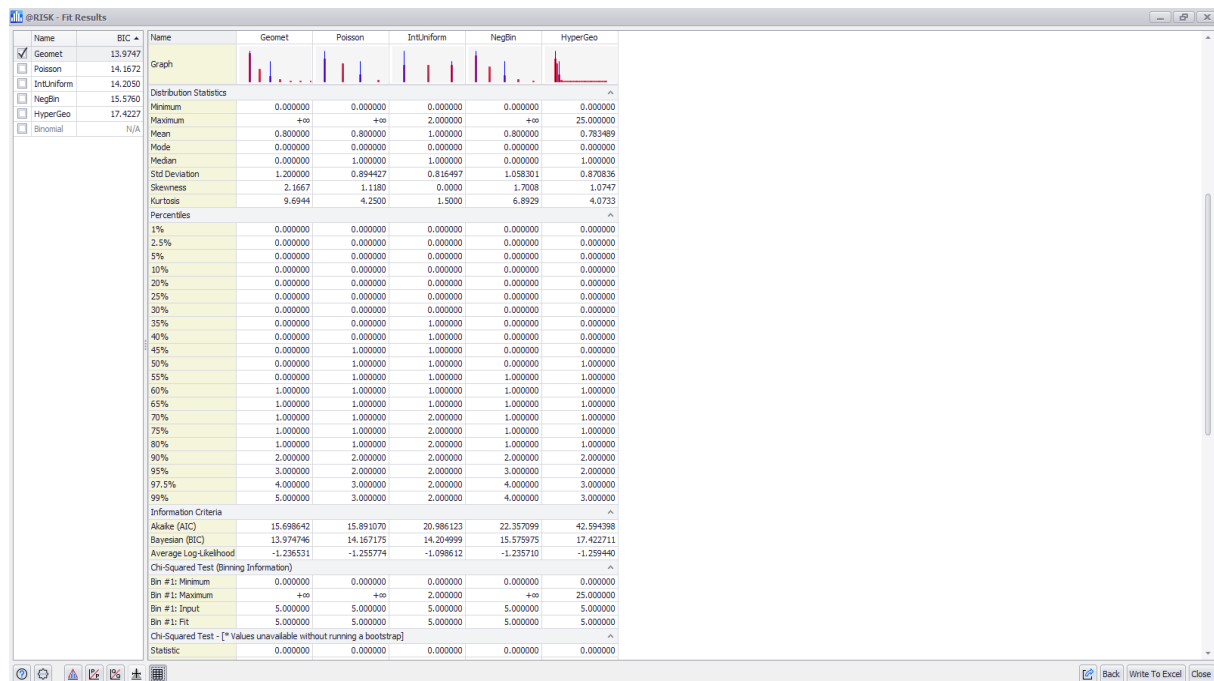
1.4.3 Incorrect operational isolation of primary or secondary equipment (discrete)

Findings:

- Akaike information criterion (AIC) fit statistic: Poisson distribution best fit, standard deviation 2.490

- Akaike information criterion (AIC) fit statistic: IntUniform distribution best fit, standard deviation 3.452

- Bayesian information criterion (BIC) fit statistic: Poisson distribution best fit, standard deviation 2.490

- **Best fit distribution (Poisson) preferred**

Figure 1-23: Incorrect operational isolation of equipment – AIC distribution
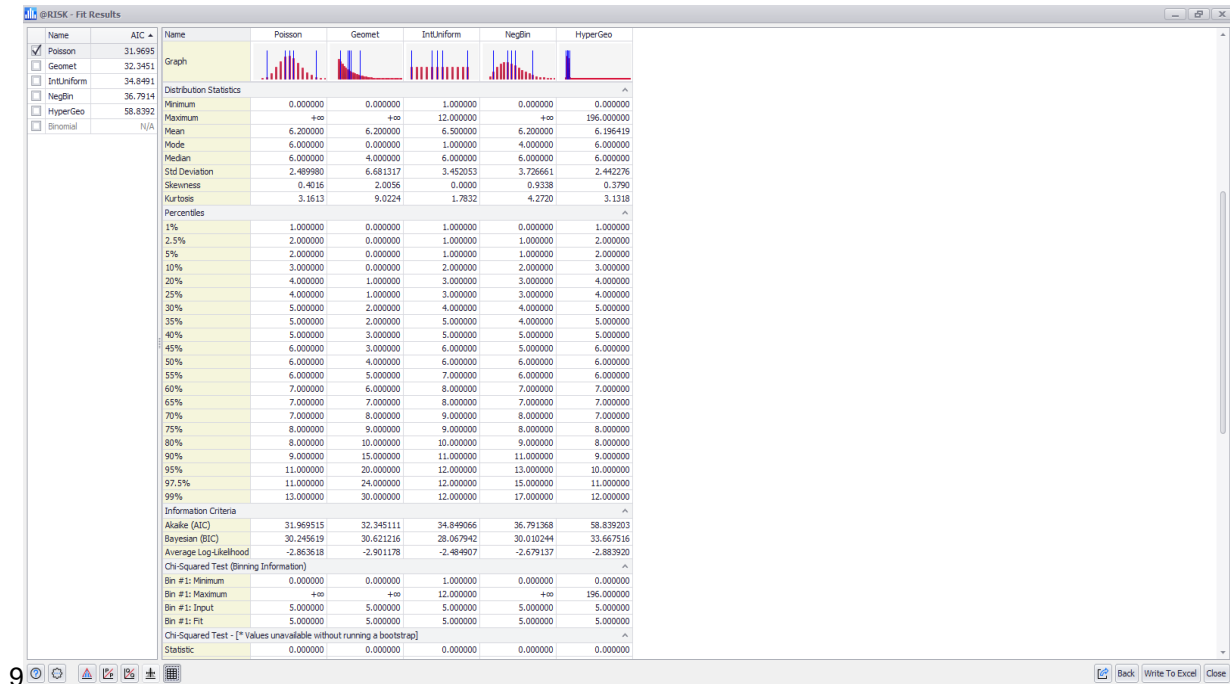
Figure 1-24: Incorrect operational isolation of equipment – BIC distribution