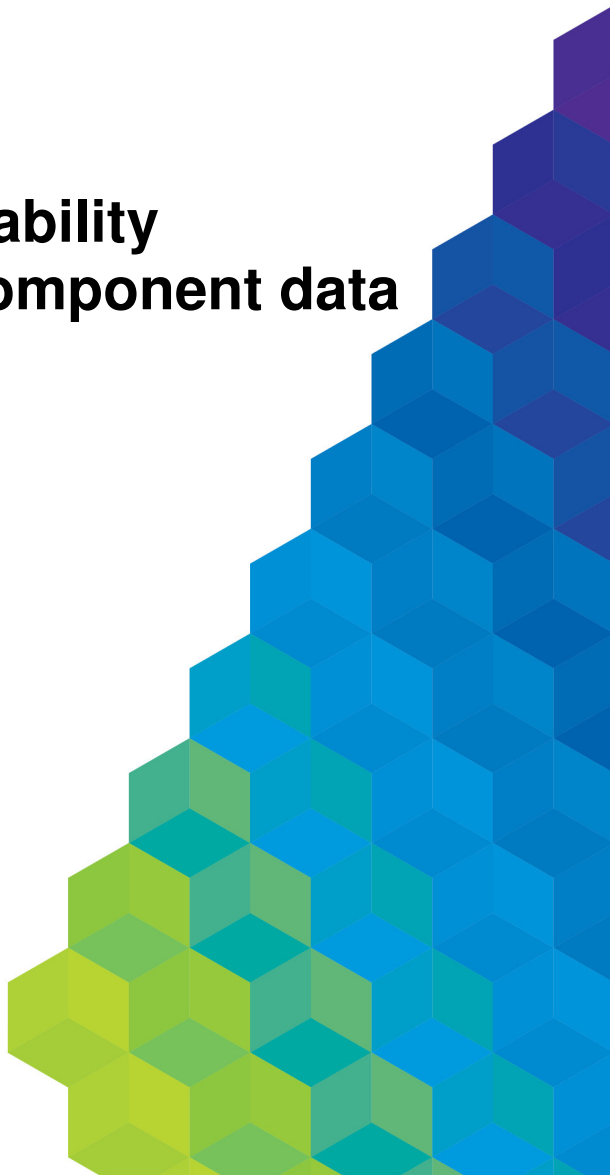
AusNet Transmission Group Pty Ltd

Transmission Revenue Review 2017-2022

Revised Revenue Proposal

Appendix 8A: Fitting probability distributions to Service Component data

Submitted: 21 September 2016



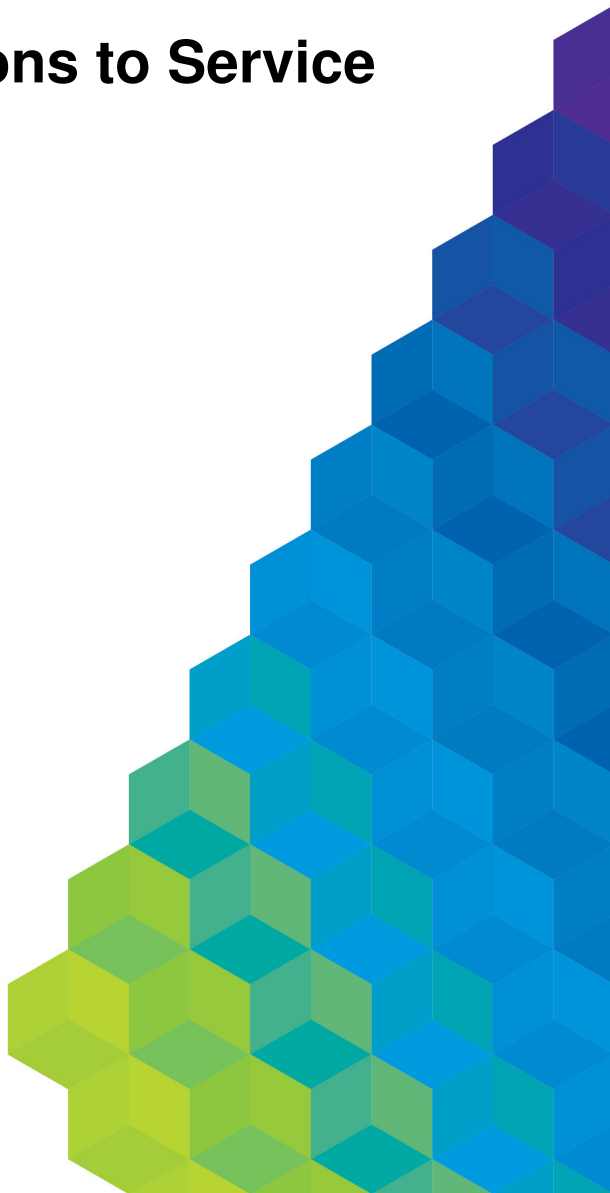
AusNet Transmission Group Pty Ltd

Transmission Revenue Review 2017-2022

Fitting probability distributions to Service Component data

Updated for 2015 data

Submitted: 21 September 2016



ISSUE/AMENDMENT STATUS

Issue Number	Date	Description	Author	Approved by
1	14/08/2015	Initial issue	Rob Ball	Tom Hallam
2	9/9/2016	Revised for Revised Revenue Proposal	Rob Ball	Tom Hallam

Disclaimer

Contact

This document is the responsibility of the Regulation and Network Strategy Division of AusNet Services. Please contact the undersigned or author with any inquiries.

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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 8.3 of the Revised 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 the Draft Decision and in recent determinations for TransGrid and TasNetworks. The distributions and caps and collars have been revised since the AusNet Services' Revenue Proposal to take account of 2015 actual data, which was unavailable at the time. Consistent with the requirements of the STPIS, the caps and collars set out in this document are based on the five most recent years of performance data (2011-15).

In the Draft Decision, the AER disagreed with AusNet Services' preference to adopt distributions based on the Anderson-Daring (A-D) fit statistics test where the data was more skewed to the tails of the preferred distribution. Instead, the AER relied solely on the Kolmogorov-Smirnov (K-S) method of fitting probability distributions. For this Revised Revenue Proposal, AusNet Services has followed the AER's preferred method of using only the K-S method to determine the most appropriate distribution.

For the loss of supply event frequency parameters (>0.05 and >0.30 system minutes) performance data is not conducive to statistical analysis. This is due to the small number of events usually, but not always, recorded in any one year of a five year data series. To align with the Draft Decision and to ensure consistency between the two indicators, the Poisson distribution has been used to set caps and collars for these sub-parameters.

Similarly, caps and collars for the proper operation of equipment sub-parameters have been derived using the Poisson distribution. This is again due to the nature of the performance data not lending itself well to fitting probability distributions. As these are all indicators with discrete values, AusNet Services has adopted the Poisson distribution which has been used for the other discrete distributions in the Service Component (the loss of supply event frequency distributions).

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)	Weibull	0.1597	0.3381
Line outage rate (forced)	Weibull	0.1233	0.1705
Reactive plant outage rate (fault)	Pearson5	0.1840	0.6117
Reactive plant outage rate (forced)	Weibull	0.1989	0.4068
Transformer outage rate (fault)	Weibull	0.0916	0.3177
Transformer outage rate (forced)	Weibull	0.0610	0.1440
Number of events >0.05 system minutes	Poisson	0.0000	5.0000
Number of events >0.30 system minutes	Poisson	0.0000	2.0000
Average outage duration	Lognormal	3.3786	334.2004
Failure of protection equipment	Poisson	23.0000	42.0000
Material failure of SCADA system	Poisson	0.0000	4.0000
Incorrect operational isolation of primary or secondary equipment	Poisson	2.0000	10.0000

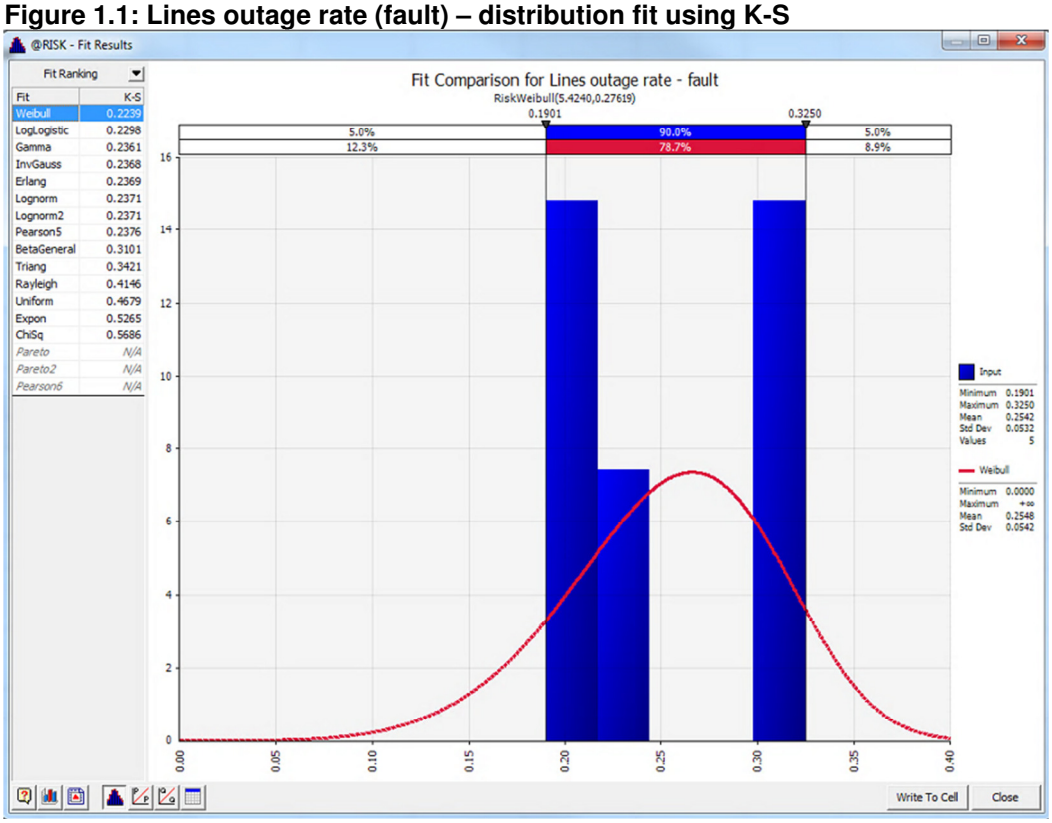
The remainder of this document sets out the underlying data which supports AusNet Services' proposed distributions, caps and collars.

1.1 Service parameter 1 – Average circuit outage rate

1.1.1 Lines outage rate – fault (continuous)

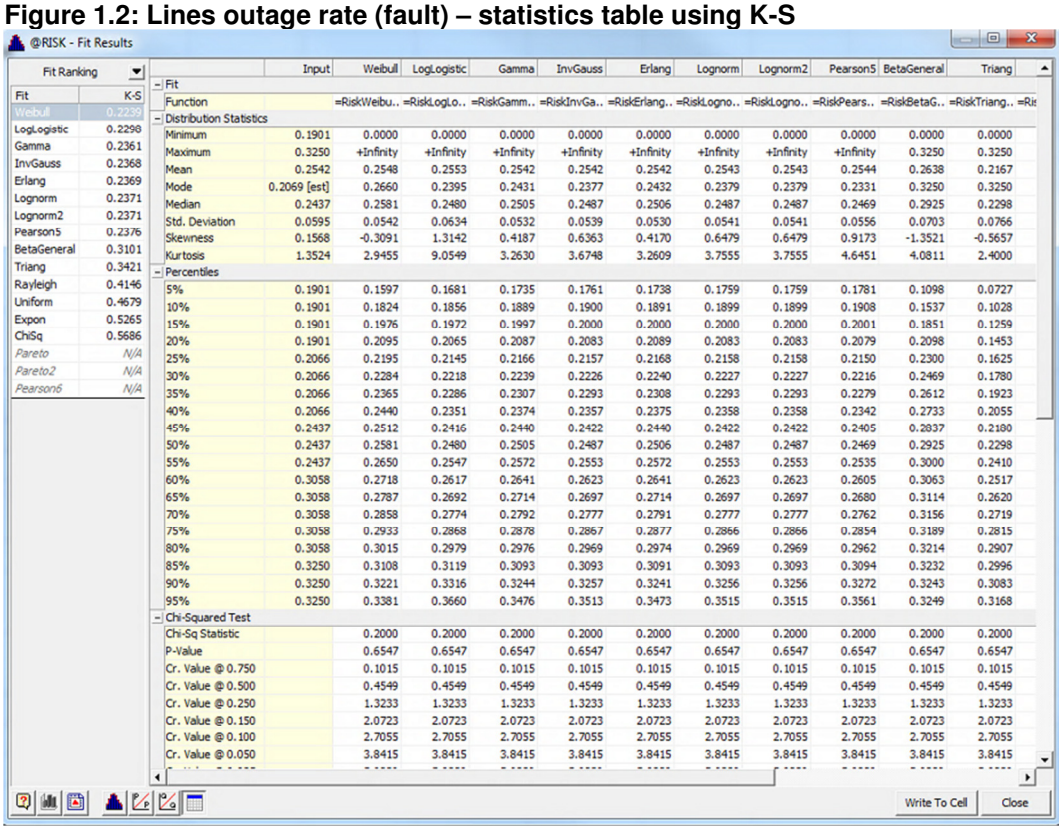
The @RISK software found that the Weibull distribution is the most appropriate fit.

Figure 1.1: Lines outage rate (fault) – distribution fit using K-S



Fit	K-S
Weibull	0.2239
LogLogistic	0.2298
Gamma	0.2361
InvGauss	0.2368
Erlang	0.2369
Lognorm	0.2371
Lognorm2	0.2371
Pearson5	0.2376
BetaGeneral	0.3101
Triang	0.3421
Rayleigh	0.4146
Uniform	0.4679
Expon	0.5265
ChiSq	0.5686
Pareto	*N/A*
Pareto2	*N/A*
Pearson6	*N/A*

Figure 1.2: Lines outage rate (fault) – statistics table using K-S



1.1.2 Lines outage rate – forced (continuous)

The @RISK software found that the Weibull distribution is the most appropriate fit.

Figure 1.3: Lines outage rate (forced) – distribution fit using K-S

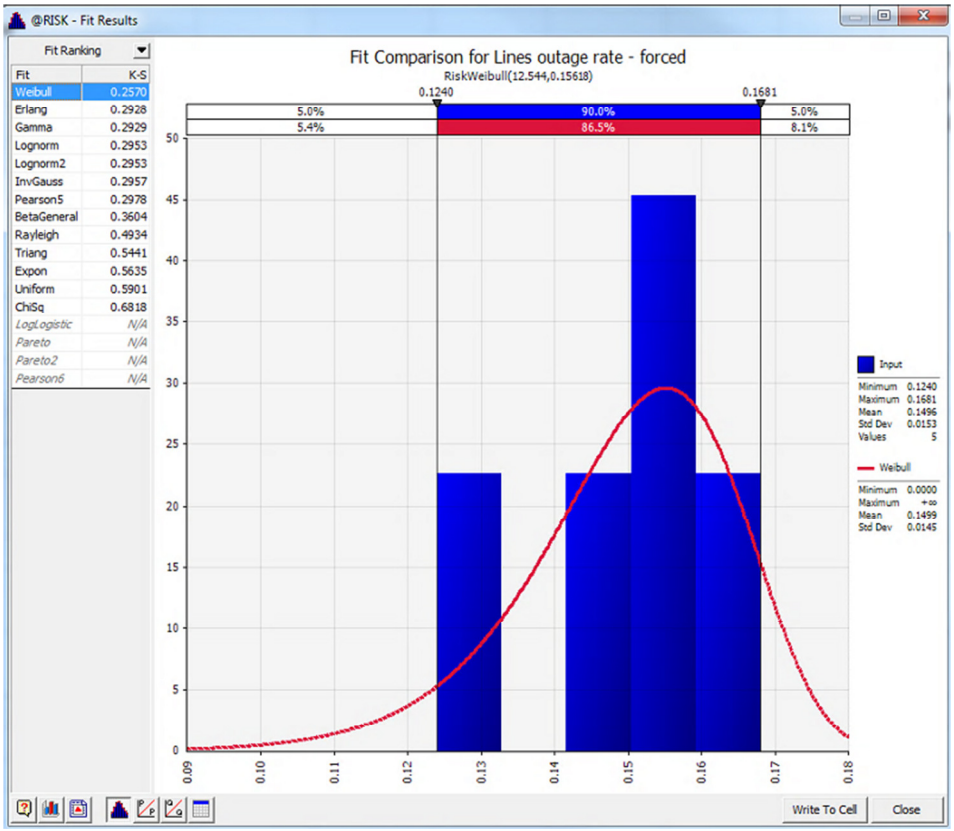
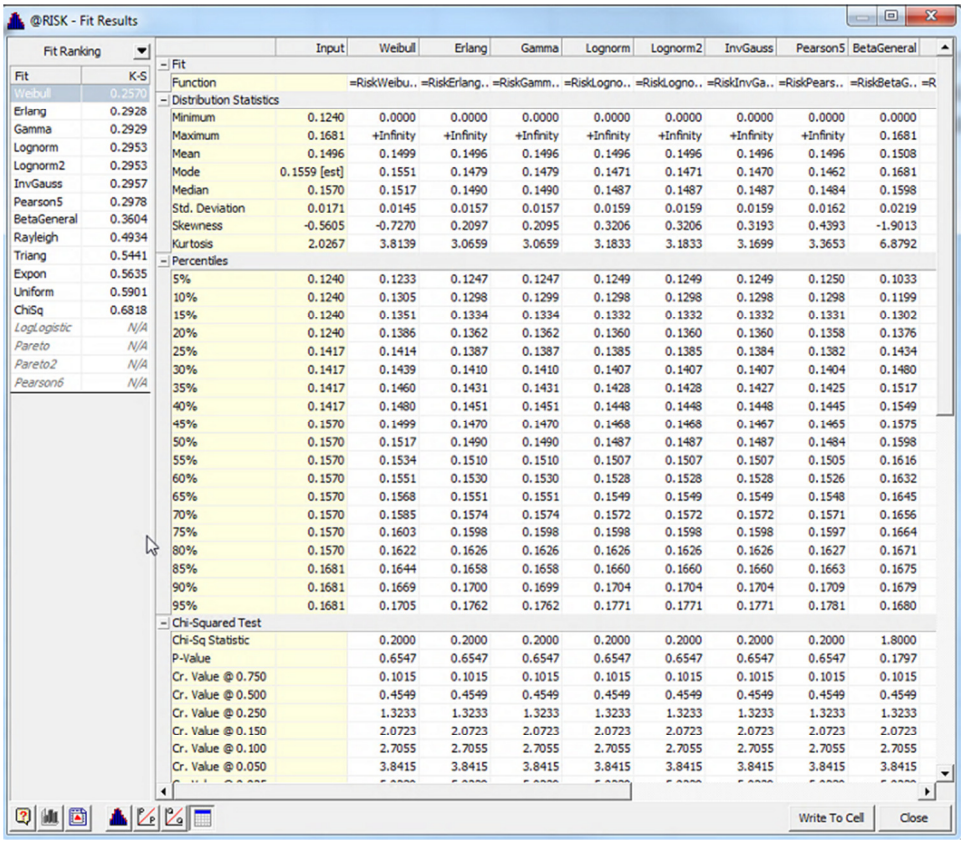


Figure 1.4: Lines outage rate (forced) – statistics table using K-S



1.1.3 Reactive plant outage – fault (continuous)

The @RISK software found the Pearson5 distribution is the most appropriate fit.

Figure 1.5: Reactive plant outage (fault) – distribution fit using K-S

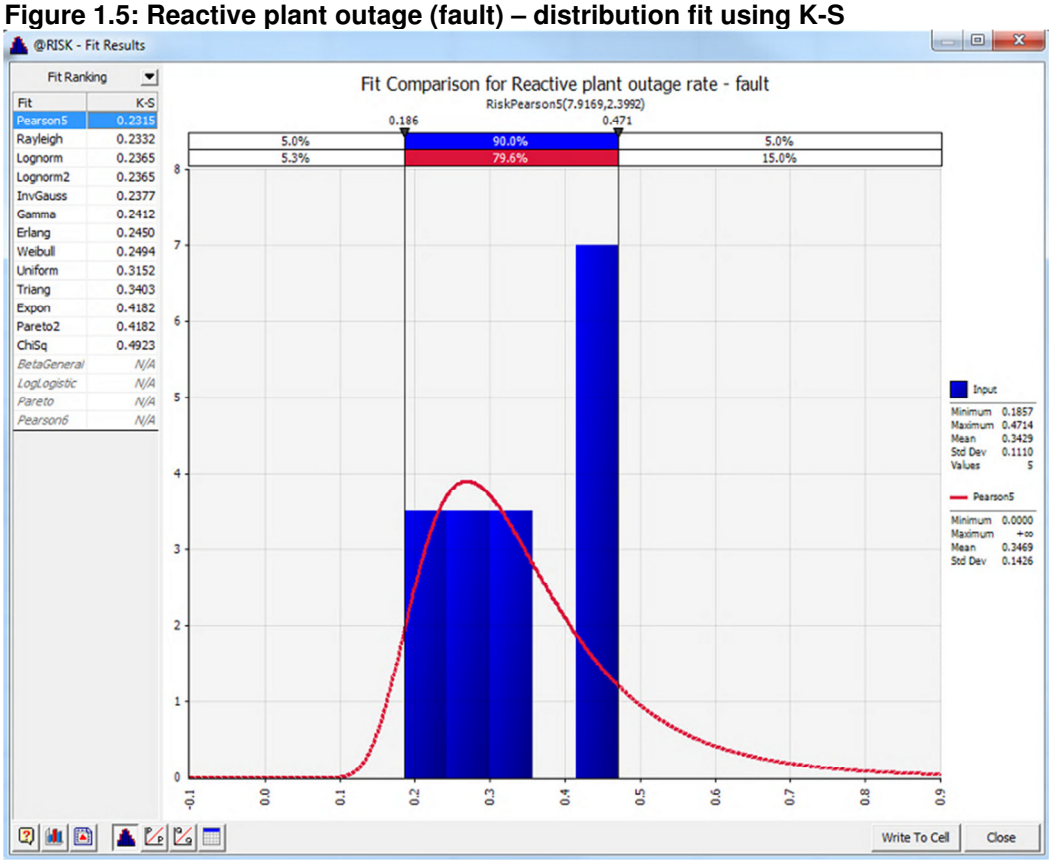
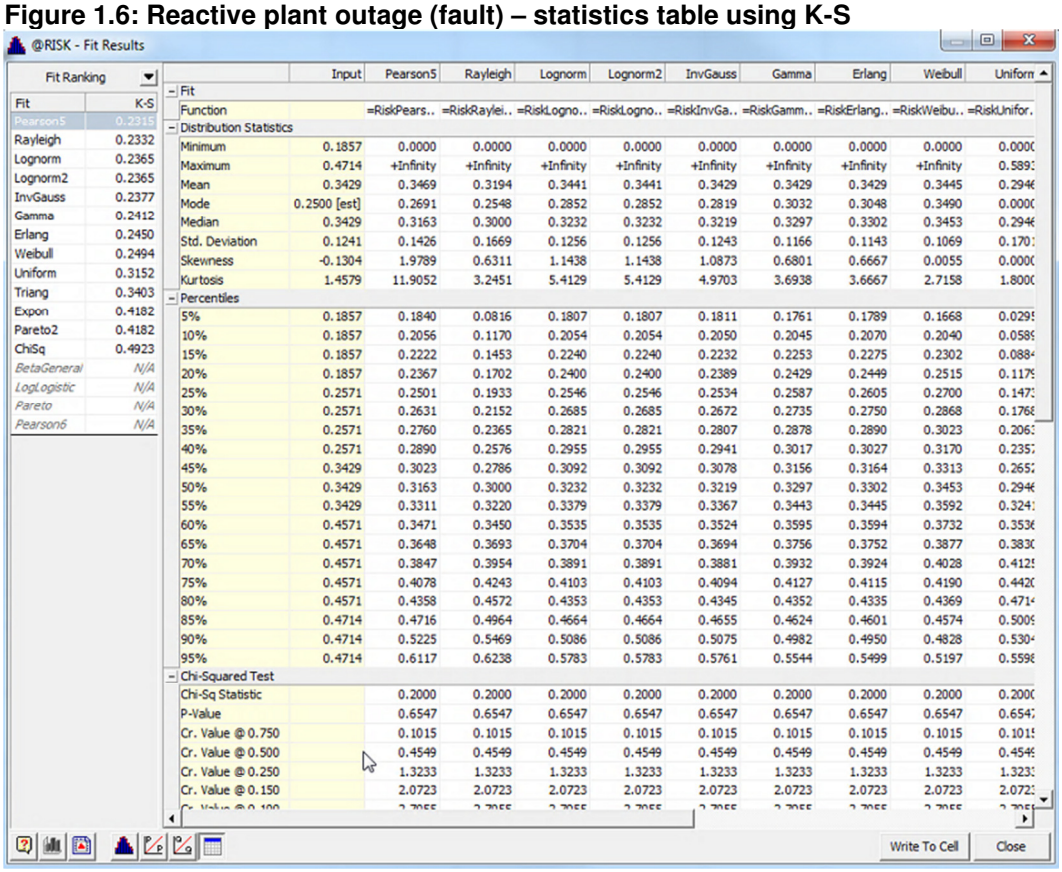


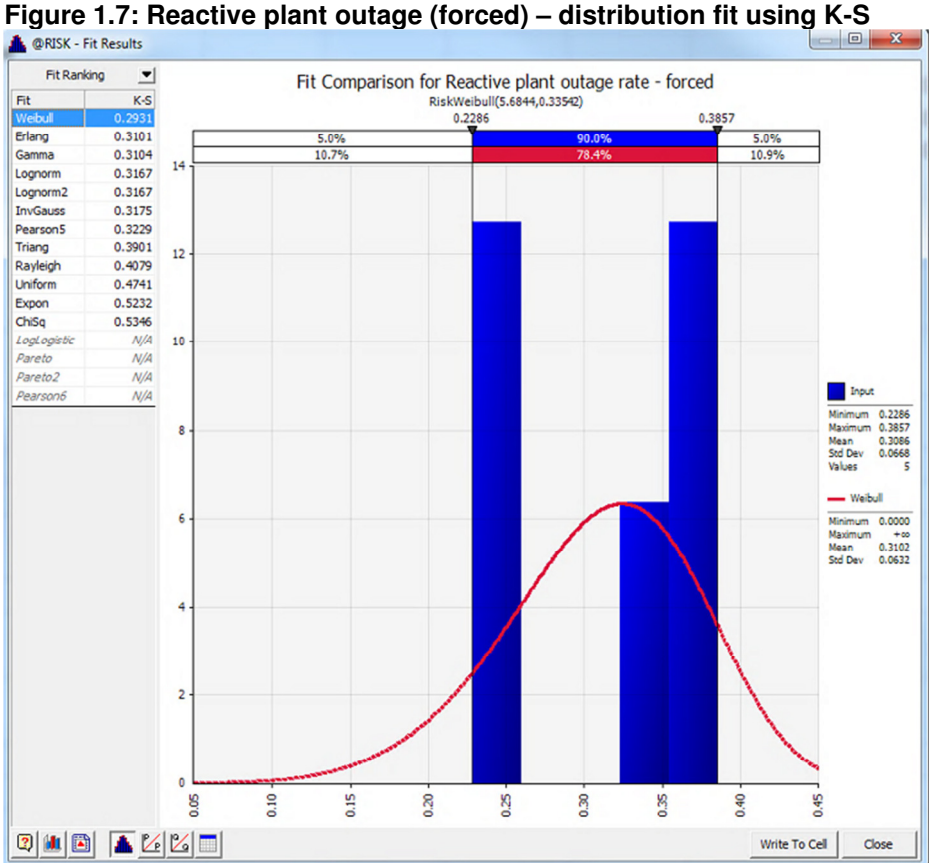
Figure 1.6: Reactive plant outage (fault) – statistics table using K-S



1.1.4 Reactive plant outage – forced (continuous)

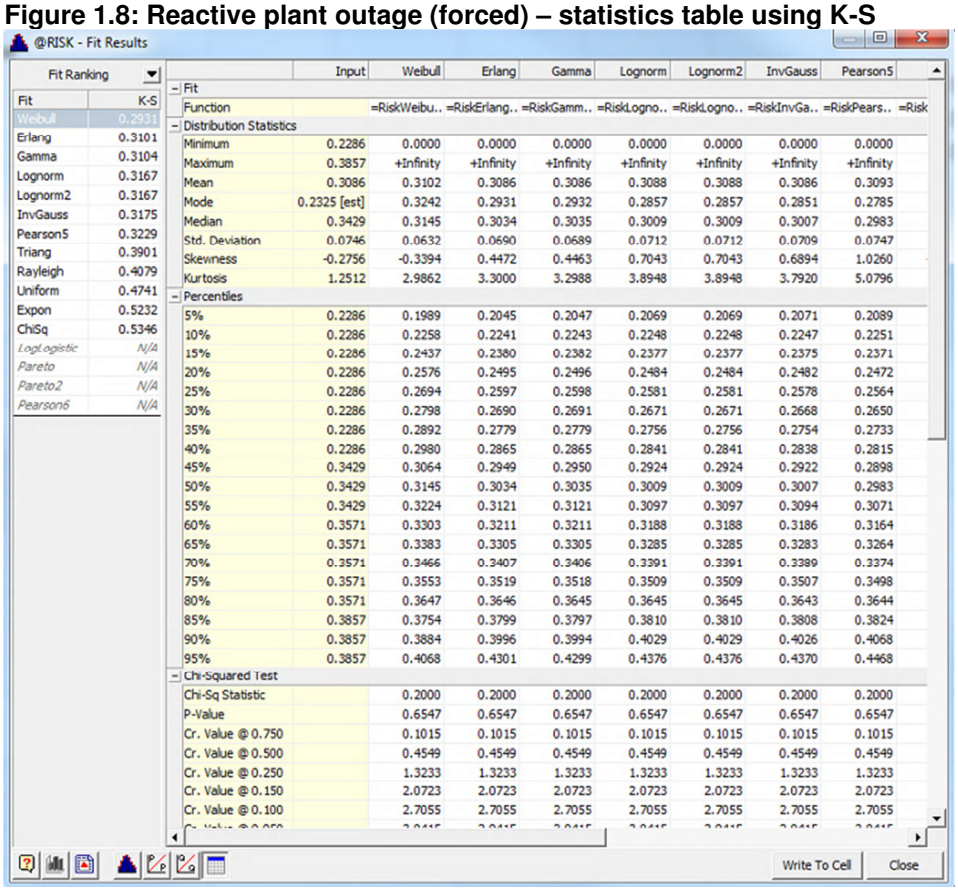
The @RISK software found that the Weibull distribution is the most appropriate fit.

Figure 1.7: Reactive plant outage (forced) – distribution fit using K-S



Fit	K-S
Weibull	0.2931
Erlang	0.3101
Gamma	0.3104
Lognorm	0.3167
Lognorm2	0.3167
InvGauss	0.3175
Pearson5	0.3229
Triang	0.3901
Rayleigh	0.4079
Uniform	0.4741
Expon	0.5232
ChiSq	0.5346
LogLogistic	N/A
Pareto	N/A
Pareto2	N/A
Pearson6	N/A

Figure 1.8: Reactive plant outage (forced) – statistics table using K-S

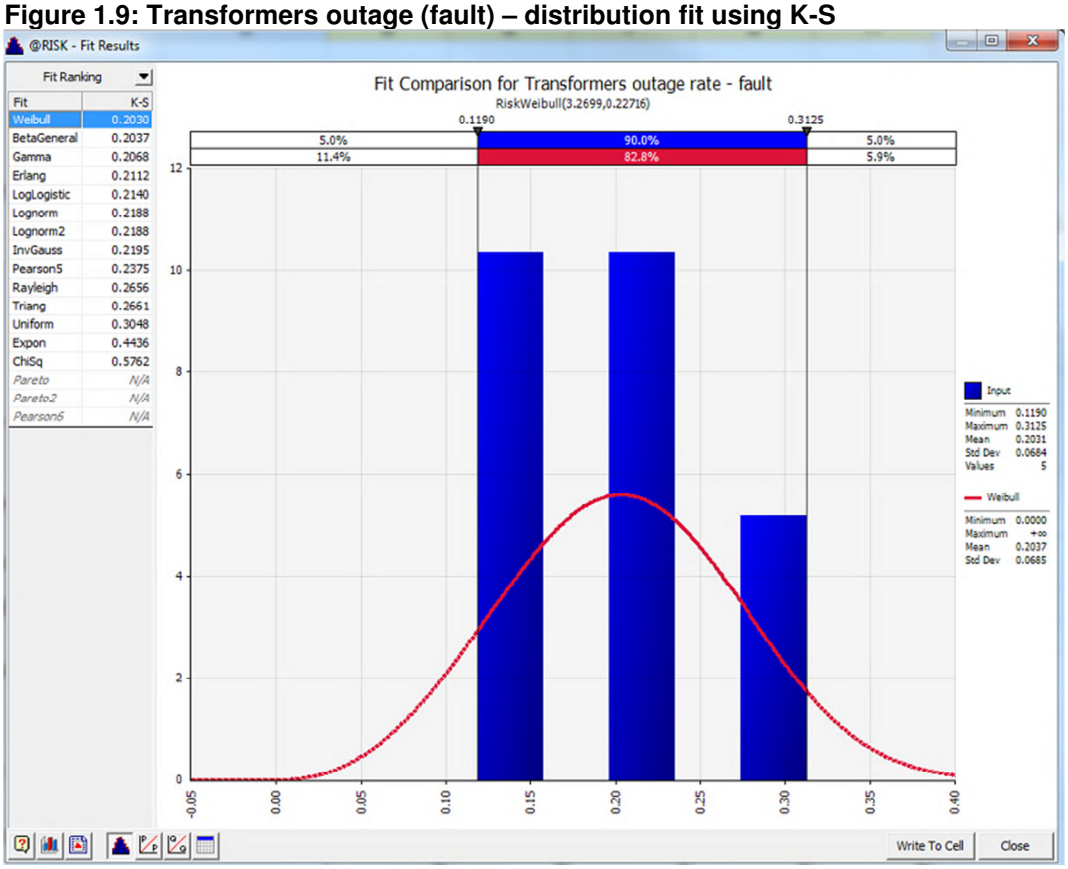


	Input	Weibull	Erlang	Gamma	Lognorm	Lognorm2	InvGauss	Pearson5
Fit								
Function		=RiskWeibu..	=RiskErlang..	=RiskGamm..	=RiskLogno..	=RiskLogno..	=RiskInvGa..	=RiskPears..
Distribution Statistics								
Minimum	0.2286	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.3857	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.3086	0.3102	0.3086	0.3086	0.3088	0.3088	0.3086	0.3093
Mode	0.2325 [est]	0.3242	0.2931	0.2932	0.2857	0.2857	0.2851	0.2785
Median	0.3429	0.3145	0.3034	0.3035	0.3009	0.3009	0.3007	0.2983
Std. Deviation	0.0746	0.0632	0.0690	0.0689	0.0712	0.0712	0.0709	0.0747
Skewness	-0.2756	-0.3394	0.4472	0.4463	0.7043	0.7043	0.6894	1.0260
Kurtosis	1.2512	2.9862	3.3000	3.2988	3.8948	3.8948	3.7920	5.0796
Percentiles								
5%	0.2286	0.1989	0.2045	0.2047	0.2069	0.2069	0.2071	0.2089
10%	0.2286	0.2258	0.2241	0.2243	0.2248	0.2248	0.2247	0.2251
15%	0.2286	0.2437	0.2380	0.2382	0.2377	0.2377	0.2375	0.2371
20%	0.2286	0.2576	0.2495	0.2496	0.2484	0.2484	0.2482	0.2472
25%	0.2286	0.2694	0.2597	0.2598	0.2581	0.2581	0.2578	0.2564
30%	0.2286	0.2798	0.2690	0.2691	0.2671	0.2671	0.2668	0.2650
35%	0.2286	0.2892	0.2779	0.2779	0.2756	0.2756	0.2754	0.2733
40%	0.2286	0.2980	0.2865	0.2865	0.2841	0.2841	0.2838	0.2815
45%	0.3429	0.3064	0.2949	0.2950	0.2924	0.2924	0.2922	0.2898
50%	0.3429	0.3145	0.3034	0.3035	0.3009	0.3009	0.3007	0.2983
55%	0.3429	0.3224	0.3121	0.3121	0.3097	0.3097	0.3094	0.3071
60%	0.3571	0.3303	0.3211	0.3211	0.3188	0.3188	0.3186	0.3164
65%	0.3571	0.3383	0.3305	0.3305	0.3285	0.3285	0.3283	0.3264
70%	0.3571	0.3466	0.3407	0.3406	0.3391	0.3391	0.3389	0.3374
75%	0.3571	0.3553	0.3519	0.3518	0.3509	0.3509	0.3507	0.3498
80%	0.3571	0.3647	0.3646	0.3645	0.3645	0.3645	0.3643	0.3644
85%	0.3857	0.3754	0.3799	0.3797	0.3810	0.3810	0.3808	0.3824
90%	0.3857	0.3884	0.3996	0.3994	0.4029	0.4029	0.4026	0.4068
95%	0.3857	0.4068	0.4301	0.4299	0.4376	0.4376	0.4370	0.4468
Chi-Squared Test								
Chi-Sq Statistic		0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
P-Value		0.6547	0.6547	0.6547	0.6547	0.6547	0.6547	0.6547
Cr. Value @ 0.750		0.1015	0.1015	0.1015	0.1015	0.1015	0.1015	0.1015
Cr. Value @ 0.500		0.4549	0.4549	0.4549	0.4549	0.4549	0.4549	0.4549
Cr. Value @ 0.250		1.3233	1.3233	1.3233	1.3233	1.3233	1.3233	1.3233
Cr. Value @ 0.150		2.0723	2.0723	2.0723	2.0723	2.0723	2.0723	2.0723
Cr. Value @ 0.100		2.7055	2.7055	2.7055	2.7055	2.7055	2.7055	2.7055

1.1.5 Transformers outage – fault (continuous)

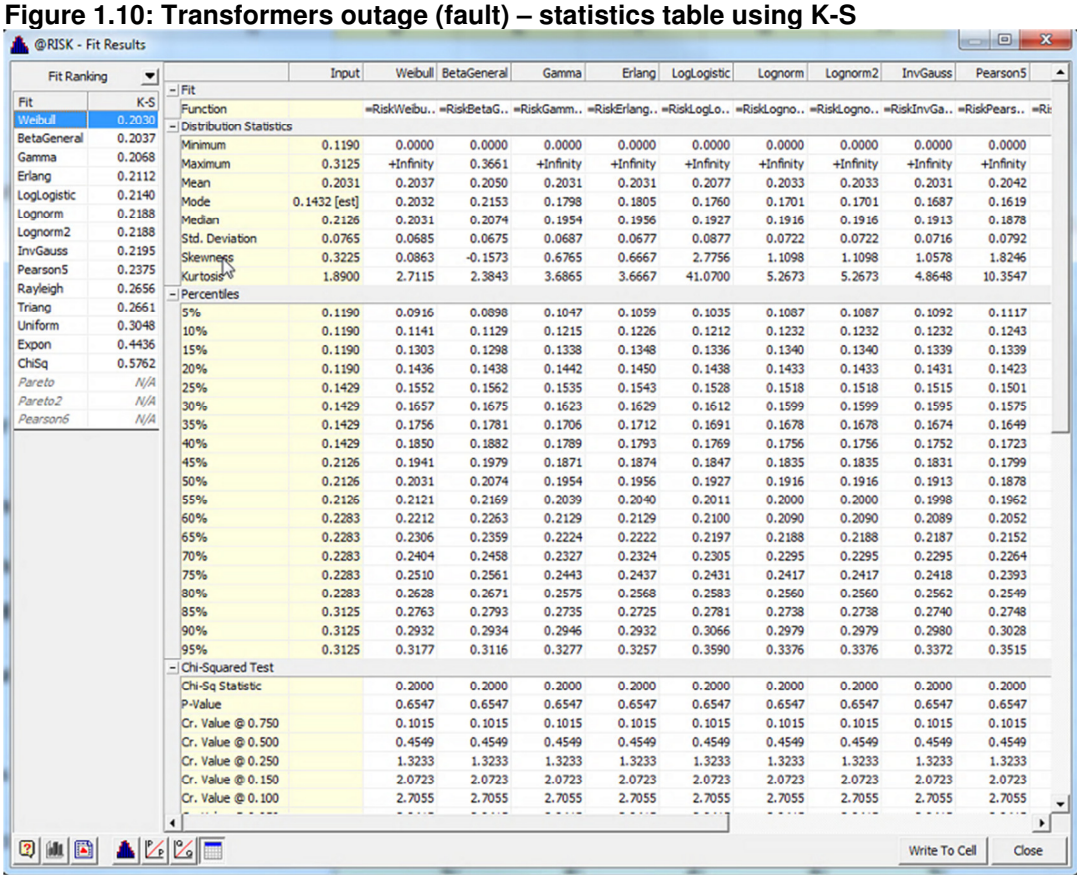
The @RISK software found that the Weibull distribution is the most appropriate fit.

Figure 1.9: Transformers outage (fault) – distribution fit using K-S



Fit	K-S
Weibull	0.2030
BetaGeneral	0.2037
Gamma	0.2068
Erlang	0.2112
LogLogistic	0.2140
Lognorm	0.2188
Lognorm2	0.2188
InvGauss	0.2195
Pearson5	0.2375
Rayleigh	0.2656
Triang	0.2661
Uniform	0.3048
Expon	0.4436
ChiSq	0.5762
Pareto	*N/A*
Pareto2	*N/A*
Pearson6	*N/A*

Figure 1.10: Transformers outage (fault) – statistics table using K-S



Fit	K-S
Weibull	0.2030
BetaGeneral	0.2037
Gamma	0.2068
Erlang	0.2112
LogLogistic	0.2140
Lognorm	0.2188
Lognorm2	0.2188
InvGauss	0.2195
Pearson5	0.2375
Rayleigh	0.2656
Triang	0.2661
Uniform	0.3048
Expon	0.4436
ChiSq	0.5762
Pareto	*N/A*
Pareto2	*N/A*
Pearson6	*N/A*

Fit	Input	Weibull	BetaGeneral	Gamma	Erlang	LogLogistic	Lognorm	Lognorm2	InvGauss	Pearson5
Function		=RiskWeibu..	=RiskBetaG..	=RiskGamm..	=RiskErlang..	=RiskLogLo..	=RiskLogno..	=RiskLogno..	=RiskInvGa..	=RiskPears..
Distribution Statistics										
Minimum	0.1190	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.3125	+Infinity	0.3661	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity
Mean	0.2031	0.2037	0.2050	0.2031	0.2031	0.2077	0.2033	0.2033	0.2031	0.2042
Mode	0.1432 [est]	0.2032	0.2153	0.1798	0.1805	0.1760	0.1701	0.1701	0.1687	0.1619
Median	0.2126	0.2031	0.2074	0.1954	0.1956	0.1927	0.1916	0.1916	0.1913	0.1878
Std. Deviation	0.0765	0.0685	0.0675	0.0687	0.0677	0.0877	0.0722	0.0722	0.0716	0.0792
Skewness	0.3225	0.0863	-0.1573	0.6765	0.6667	2.7756	1.1098	1.1098	1.0578	1.8246
Kurtosis	1.8900	2.7115	2.3843	3.6865	3.6667	41.0700	5.2673	5.2673	4.8648	10.3547
Percentiles										
5%	0.1190	0.0916	0.0898	0.1047	0.1059	0.1035	0.1087	0.1087	0.1092	0.1117
10%	0.1190	0.1141	0.1129	0.1215	0.1226	0.1212	0.1232	0.1232	0.1232	0.1243
15%	0.1190	0.1303	0.1298	0.1338	0.1348	0.1336	0.1340	0.1340	0.1339	0.1339
20%	0.1190	0.1436	0.1438	0.1442	0.1450	0.1438	0.1433	0.1433	0.1431	0.1423
25%	0.1429	0.1552	0.1562	0.1535	0.1543	0.1528	0.1518	0.1518	0.1515	0.1501
30%	0.1429	0.1657	0.1675	0.1623	0.1629	0.1612	0.1599	0.1599	0.1595	0.1575
35%	0.1429	0.1756	0.1781	0.1706	0.1712	0.1691	0.1678	0.1678	0.1674	0.1649
40%	0.1429	0.1850	0.1882	0.1789	0.1793	0.1769	0.1756	0.1756	0.1752	0.1723
45%	0.2126	0.1941	0.1979	0.1871	0.1874	0.1847	0.1835	0.1835	0.1831	0.1799
50%	0.2126	0.2031	0.2074	0.1954	0.1956	0.1927	0.1916	0.1916	0.1913	0.1878
55%	0.2126	0.2121	0.2169	0.2039	0.2040	0.2011	0.2000	0.2000	0.1998	0.1962
60%	0.2283	0.2212	0.2263	0.2129	0.2129	0.2100	0.2090	0.2090	0.2089	0.2052
65%	0.2283	0.2306	0.2359	0.2224	0.2222	0.2197	0.2188	0.2188	0.2187	0.2152
70%	0.2283	0.2404	0.2458	0.2327	0.2324	0.2305	0.2295	0.2295	0.2295	0.2264
75%	0.2283	0.2510	0.2561	0.2443	0.2437	0.2431	0.2417	0.2417	0.2418	0.2393
80%	0.2283	0.2628	0.2671	0.2575	0.2568	0.2583	0.2560	0.2560	0.2562	0.2549
85%	0.3125	0.2763	0.2793	0.2735	0.2725	0.2781	0.2738	0.2738	0.2740	0.2748
90%	0.3125	0.2932	0.2934	0.2946	0.2932	0.3066	0.2979	0.2979	0.2980	0.3028
95%	0.3125	0.3177	0.3116	0.3277	0.3257	0.3590	0.3376	0.3376	0.3372	0.3515
Chi-Squared Test										
Chi-Sq Statistic		0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
P-Value		0.6547	0.6547	0.6547	0.6547	0.6547	0.6547	0.6547	0.6547	0.6547
Cr. Value @ 0.750		0.1015	0.1015	0.1015	0.1015	0.1015	0.1015	0.1015	0.1015	0.1015
Cr. Value @ 0.500		0.4549	0.4549	0.4549	0.4549	0.4549	0.4549	0.4549	0.4549	0.4549
Cr. Value @ 0.250		1.3233	1.3233	1.3233	1.3233	1.3233	1.3233	1.3233	1.3233	1.3233
Cr. Value @ 0.150		2.0723	2.0723	2.0723	2.0723	2.0723	2.0723	2.0723	2.0723	2.0723
Cr. Value @ 0.100		2.7055	2.7055	2.7055	2.7055	2.7055	2.7055	2.7055	2.7055	2.7055

1.1.6 Transformers outage – forced (continuous)

The @RISK software found that the Weibull distribution is the most appropriate fit.

Figure 1.11: Transformers outage (forced) – distribution fit using K-S

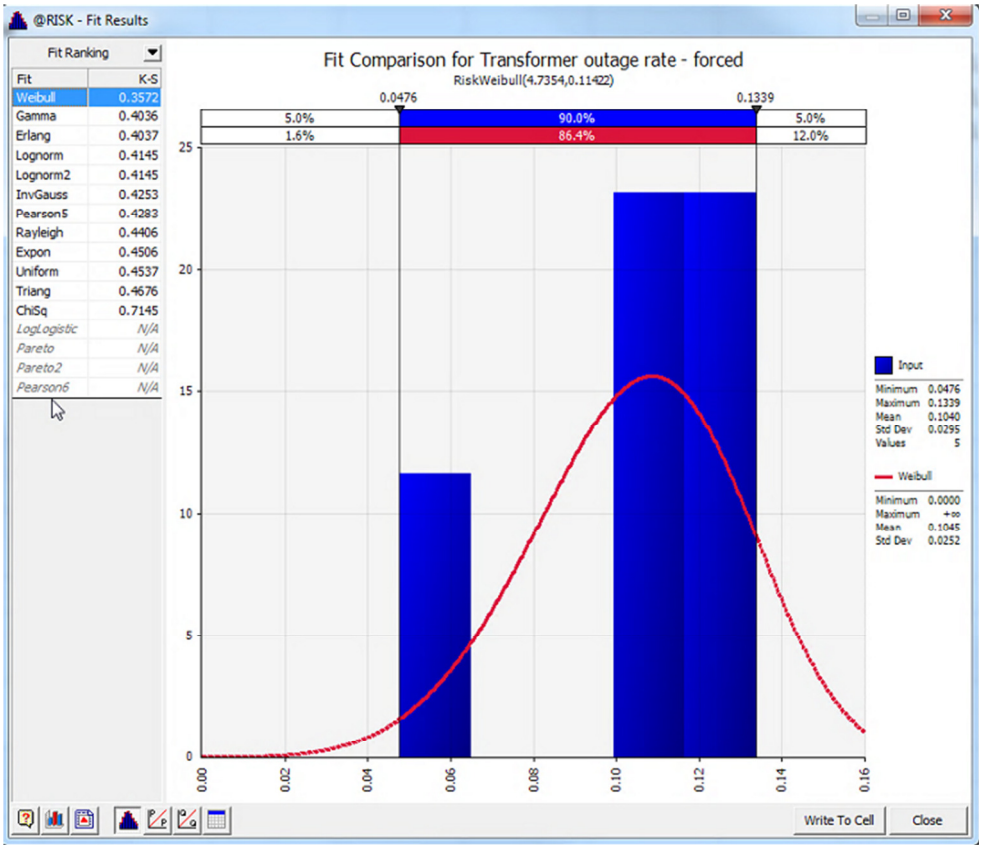
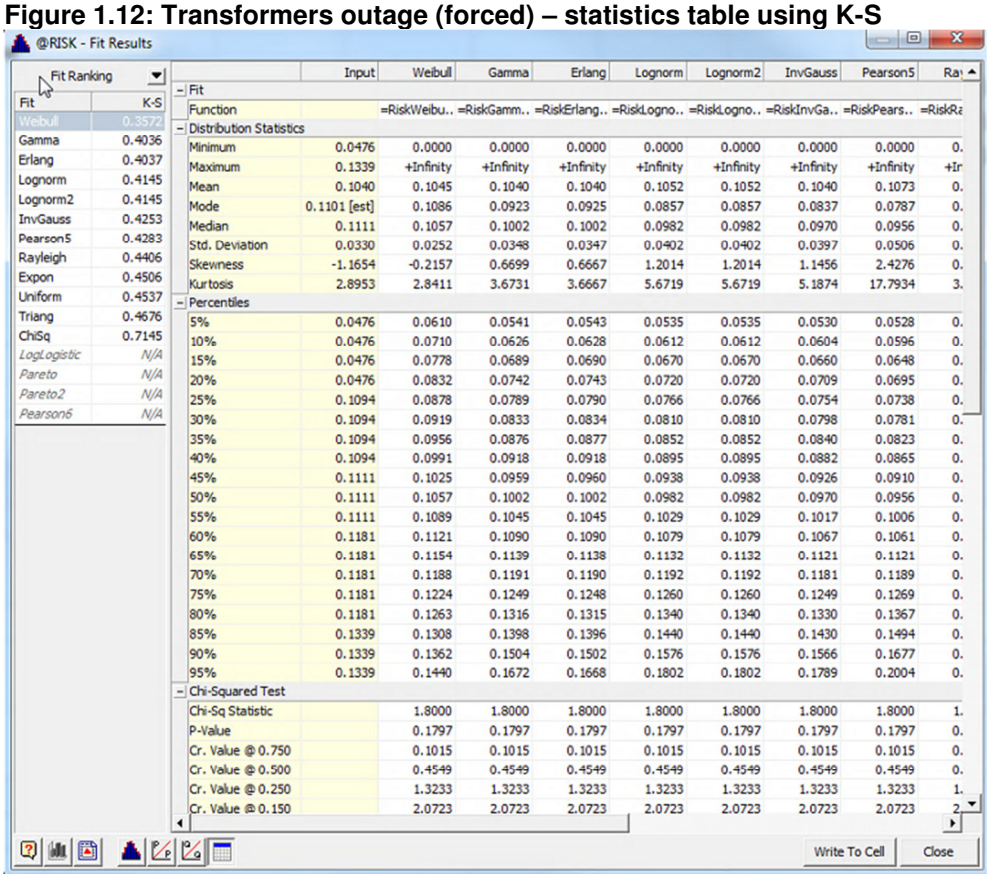


Figure 1.12: Transformers outage (forced) – statistics table using K-S



Fit	K-S
Weibull	0.3572
Gamma	0.4036
Erlang	0.4037
Lognorm	0.4145
Lognorm2	0.4145
InvGauss	0.4253
Pearson5	0.4283
Rayleigh	0.4406
Expon	0.4506
Uniform	0.4537
Triang	0.4676
ChiSq	0.7145
LogLogistic	N/A
Pareto	N/A
Pareto2	N/A
Pearson6	N/A

	Input	Weibull	Gamma	Erlang	Lognorm	Lognorm2	InvGauss	Pearson5	Ray
Fit									
Function		=RiskWeibu..	=RiskGamm..	=RiskErlang..	=RiskLogno..	=RiskLogno..	=RiskInvGa..	=RiskPears..	=RiskRa
Distribution Statistics									
Minimum	0.0476	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.
Maximum	0.1339	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Ir
Mean	0.1040	0.1045	0.1040	0.1040	0.1052	0.1052	0.1040	0.1073	0.
Mode	0.1101 [est]	0.1086	0.0923	0.0925	0.0857	0.0857	0.0837	0.0787	0.
Median	0.1111	0.1057	0.1002	0.1002	0.0982	0.0982	0.0970	0.0956	0.
Std. Deviation	0.0330	0.0252	0.0348	0.0347	0.0402	0.0402	0.0397	0.0506	0.
Skewness	-1.1654	-0.2157	0.6699	0.6667	1.2014	1.2014	1.1456	2.4276	0.
Kurtosis	2.8953	2.8411	3.6731	3.6667	5.6719	5.6719	5.1874	17.7934	3.
Percentiles									
5%	0.0476	0.0610	0.0541	0.0543	0.0535	0.0535	0.0530	0.0528	0.
10%	0.0476	0.0710	0.0626	0.0628	0.0612	0.0612	0.0604	0.0596	0.
15%	0.0476	0.0778	0.0689	0.0690	0.0670	0.0670	0.0660	0.0648	0.
20%	0.0476	0.0832	0.0742	0.0743	0.0720	0.0720	0.0709	0.0695	0.
25%	0.1094	0.0878	0.0789	0.0790	0.0766	0.0766	0.0754	0.0738	0.
30%	0.1094	0.0919	0.0833	0.0834	0.0810	0.0810	0.0798	0.0781	0.
35%	0.1094	0.0956	0.0876	0.0877	0.0852	0.0852	0.0840	0.0823	0.
40%	0.1094	0.0991	0.0918	0.0918	0.0895	0.0895	0.0882	0.0865	0.
45%	0.1111	0.1025	0.0959	0.0960	0.0938	0.0938	0.0926	0.0910	0.
50%	0.1111	0.1057	0.1002	0.1002	0.0982	0.0982	0.0970	0.0956	0.
55%	0.1111	0.1089	0.1045	0.1045	0.1029	0.1029	0.1017	0.1006	0.
60%	0.1181	0.1121	0.1090	0.1090	0.1079	0.1079	0.1067	0.1061	0.
65%	0.1181	0.1154	0.1139	0.1138	0.1132	0.1132	0.1121	0.1121	0.
70%	0.1181	0.1188	0.1191	0.1190	0.1192	0.1192	0.1181	0.1189	0.
75%	0.1181	0.1224	0.1249	0.1248	0.1260	0.1260	0.1249	0.1269	0.
80%	0.1181	0.1263	0.1316	0.1315	0.1340	0.1340	0.1330	0.1367	0.
85%	0.1339	0.1308	0.1398	0.1396	0.1440	0.1440	0.1430	0.1494	0.
90%	0.1339	0.1362	0.1504	0.1502	0.1576	0.1576	0.1566	0.1677	0.
95%	0.1339	0.1440	0.1672	0.1668	0.1802	0.1802	0.1789	0.2004	0.
Chi-Squared Test									
Chi-Sq Statistic		1.8000	1.8000	1.8000	1.8000	1.8000	1.8000	1.8000	1.
P-Value		0.1797	0.1797	0.1797	0.1797	0.1797	0.1797	0.1797	0.
Cr. Value @ 0.750		0.1015	0.1015	0.1015	0.1015	0.1015	0.1015	0.1015	0.
Cr. Value @ 0.500		0.4549	0.4549	0.4549	0.4549	0.4549	0.4549	0.4549	0.
Cr. Value @ 0.250		1.3233	1.3233	1.3233	1.3233	1.3233	1.3233	1.3233	1.
Cr. Value @ 0.150		2.0723	2.0723	2.0723	2.0723	2.0723	2.0723	2.0723	2.

1.2 Service parameter 2 – Loss of supply event frequency

1.2.1 Number of events >0.05 system minutes (discrete)

Whilst @RISK found that the HyperGeometric distribution is the best fit, the Poisson distribution has been adopted, consistent with both the loss of supply event frequency (>0.30 system minutes) parameter and the Draft Decision. The HyperGeometric and Poisson distributions are almost identical.

Figure 1.13: Number of events >0.05 system minutes – Poisson distribution

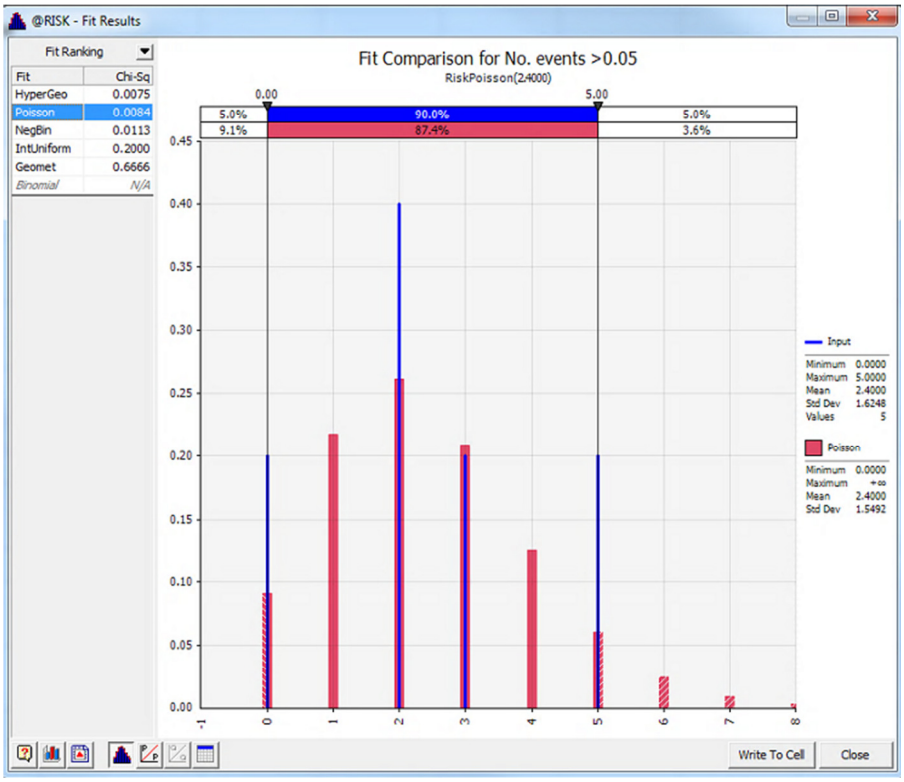
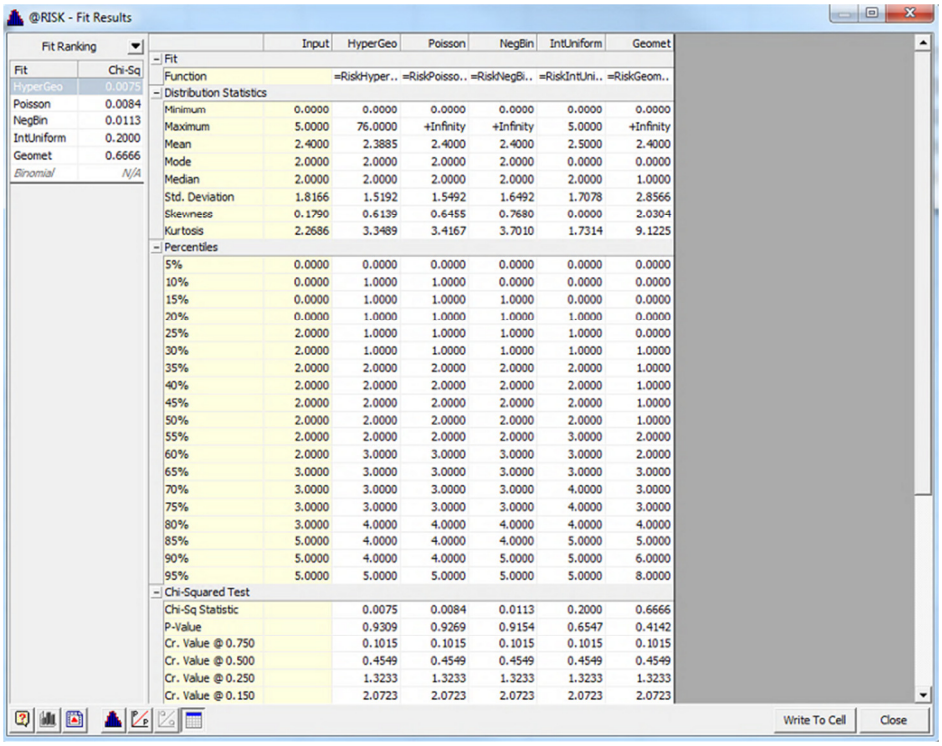


Figure 1.14: Number of events >0.05 system minutes – statistics table



1.2.2 Number of events >0.30 system minutes (discrete)

The data does not lend itself easily to statistical analysis, as it is comprised of either zero or one events. To retain consistency with the 0.05 minutes parameter and the Draft Decision, the Poisson distribution has been adopted.

Figure 1.15: Number of events >0.30 system minutes – Poisson distribution

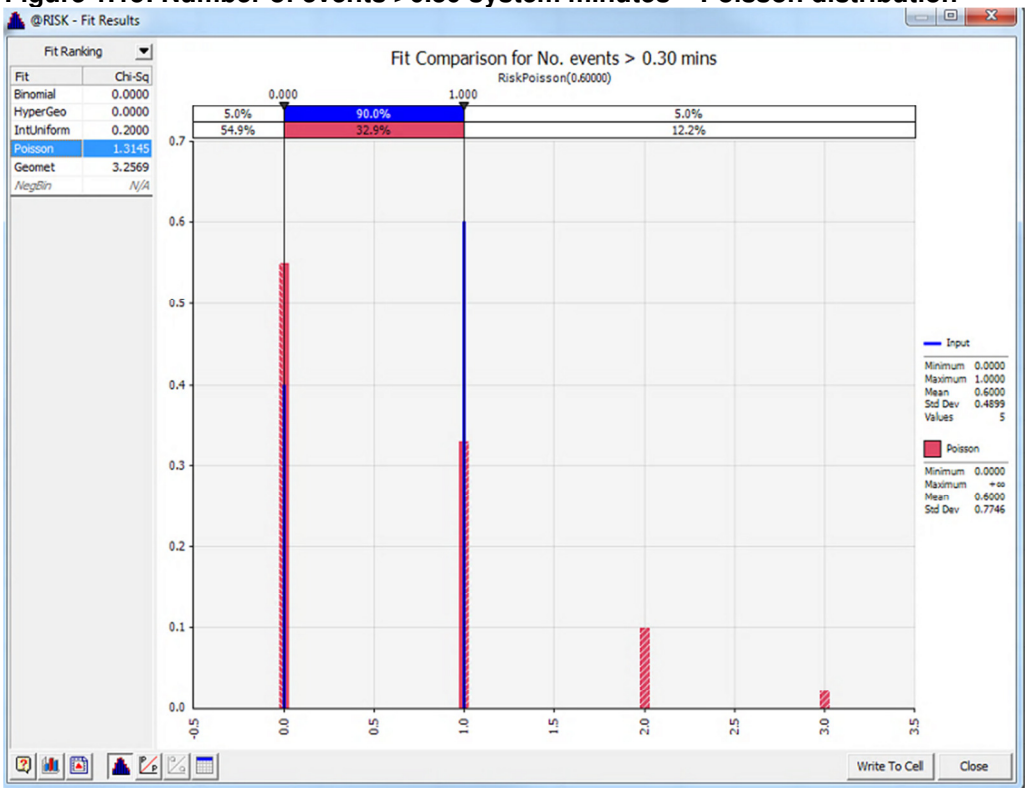
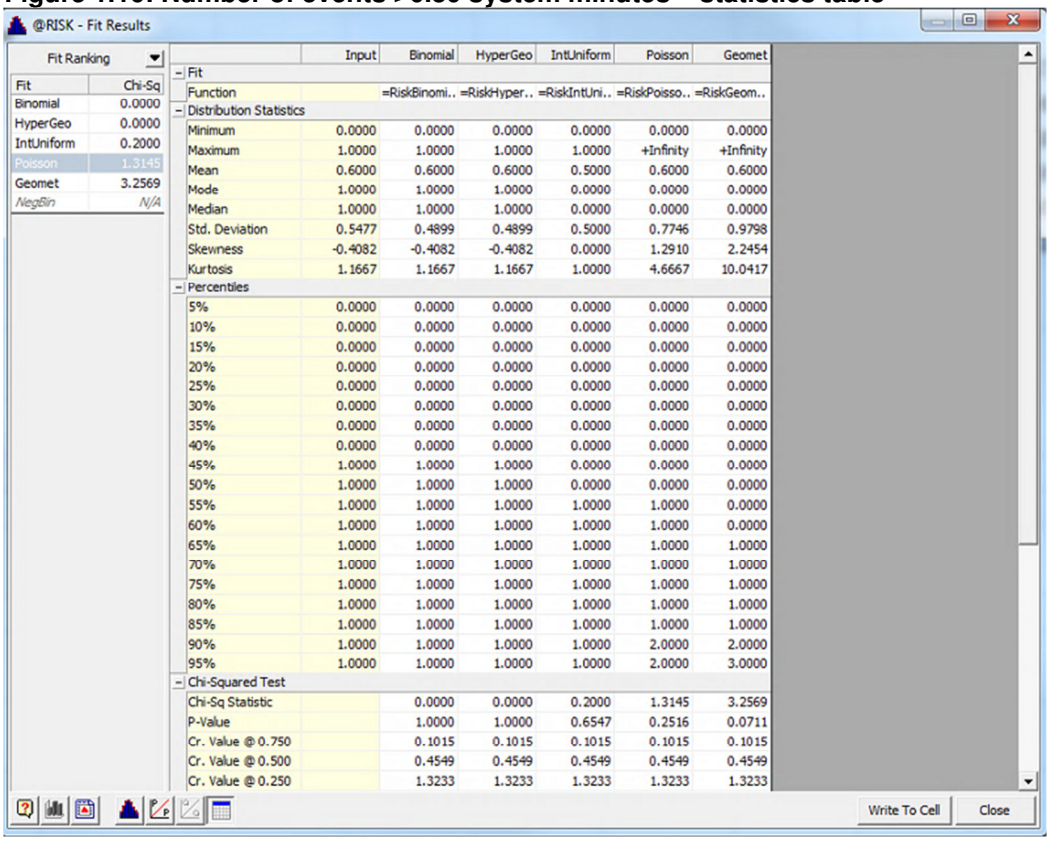


Figure 1.16: Number of events >0.30 system minutes – statistics table



	Input	Binomial	HyperGeo	IntUniform	Poisson	Geomet
Fit						
Function		=RiskBinomi..	=RiskHyper..	=RiskIntUni..	=RiskPoisso..	=RiskGeom..
Distribution Statistics						
Minimum	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	1.0000	1.0000	1.0000	1.0000	+Infinity	+Infinity
Mean	0.6000	0.6000	0.6000	0.5000	0.6000	0.6000
Mode	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000
Median	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000
Std. Deviation	0.5477	0.4899	0.4899	0.5000	0.7746	0.9798
Skewness	-0.4082	-0.4082	-0.4082	0.0000	1.2910	2.2454
Kurtosis	1.1667	1.1667	1.1667	1.0000	4.6667	10.0417
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	0.0000	0.0000
20%	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
30%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
35%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
40%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
45%	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000
50%	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000
55%	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000
60%	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000
65%	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
70%	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
75%	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
80%	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
85%	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
90%	1.0000	1.0000	1.0000	1.0000	2.0000	2.0000
95%	1.0000	1.0000	1.0000	1.0000	2.0000	3.0000
Chi-Squared Test						
Chi-Sq Statistic		0.0000	0.0000	0.2000	1.3145	3.2569
P-Value		1.0000	1.0000	0.6547	0.2516	0.0711
Cr. Value @ 0.750		0.1015	0.1015	0.1015	0.1015	0.1015
Cr. Value @ 0.500		0.4549	0.4549	0.4549	0.4549	0.4549
Cr. Value @ 0.250		1.3233	1.3233	1.3233	1.3233	1.3233

1.3 Service parameter 3 – Average outage duration

1.3.1 Average outage duration (continuous)

The @RISK software found the Lognormal distribution is the most appropriate fit.

Figure 1.17: Average outage duration – distribution fit using K-S

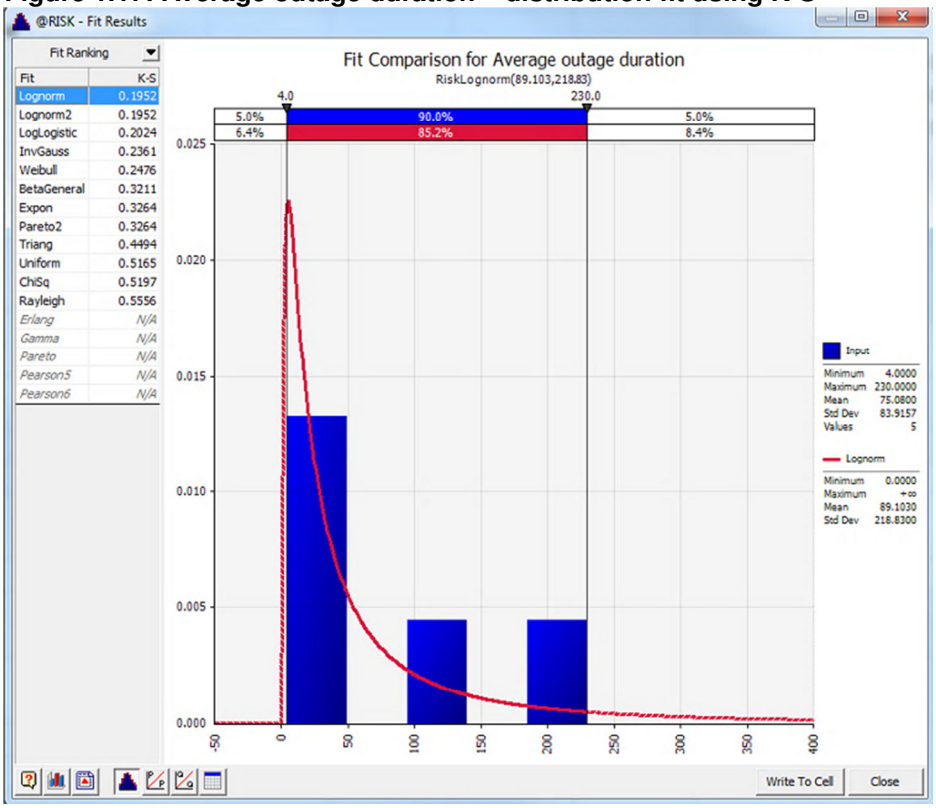
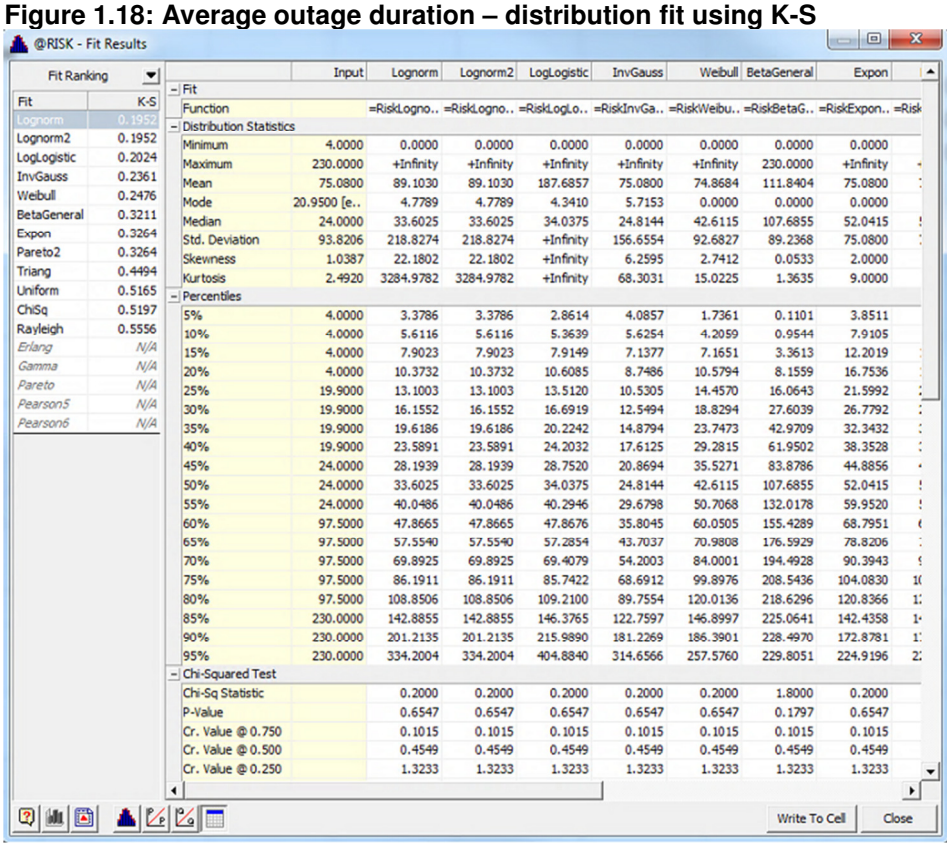


Figure 1.18: Average outage duration – distribution fit using K-S



Fit	K-S
Lognorm	0.1952
Lognorm2	0.1952
LogLogistic	0.2024
InvGauss	0.2361
Weibull	0.2476
BetaGeneral	0.3211
Expon	0.3264
Pareto2	0.3264
Triang	0.4494
Uniform	0.5165
ChiSq	0.5197
Rayleigh	0.5556
Erlang	*N/A*
Gamma	*N/A*
Pareto	*N/A*
Pearson5	*N/A*
Pearson6	*N/A*

	Input	Lognorm	Lognorm2	LogLogistic	InvGauss	Weibull	BetaGeneral	Expon
Fit								
Function		=RiskLogno..	=RiskLogno..	=RiskLogLo..	=RiskInvGa..	=RiskWeibu..	=RiskBetaG..	=RiskExpon..
Distribution Statistics								
Minimum	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	230.0000	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	230.0000	+Infinity
Mean	75.0800	89.1030	89.1030	187.6857	75.0800	74.8684	111.8404	75.0800
Mode	20.9500 [e..	4.7789	4.7789	4.3410	5.7153	0.0000	0.0000	0.0000
Median	24.0000	33.6025	33.6025	34.0375	24.8144	42.6115	107.6855	52.0415
Std. Deviation	93.8206	218.8274	218.8274	+Infinity	156.6554	92.6827	89.2368	75.0800
Skewness	1.0387	22.1802	22.1802	+Infinity	6.2595	2.7412	0.0533	2.0000
Kurtosis	2.4920	3284.9782	3284.9782	+Infinity	68.3031	15.0225	1.3635	9.0000
Percentiles								
5%	4.0000	3.3786	3.3786	2.8614	4.0857	1.7361	0.1101	3.8511
10%	4.0000	5.6116	5.6116	5.3639	5.6254	4.2059	0.9544	7.9105
15%	4.0000	7.9023	7.9023	7.9149	7.1377	7.1651	3.3613	12.2019
20%	4.0000	10.3732	10.3732	10.6085	8.7486	10.5794	8.1559	16.7536
25%	19.9000	13.1003	13.1003	13.5120	10.5305	14.4570	16.0643	21.5992
30%	19.9000	16.1552	16.1552	16.6919	12.5494	18.8294	27.6039	26.7792
35%	19.9000	19.6186	19.6186	20.2242	14.8794	23.7473	42.9709	32.3432
40%	19.9000	23.5891	23.5891	24.2032	17.6125	29.2815	61.9502	38.3528
45%	24.0000	28.1939	28.1939	28.7520	20.8694	35.5271	83.8786	44.8856
50%	24.0000	33.6025	33.6025	34.0375	24.8144	42.6115	107.6855	52.0415
55%	24.0000	40.0486	40.0486	40.2946	29.6798	50.7068	132.0178	59.9520
60%	97.5000	47.8665	47.8665	47.8676	35.8045	60.0505	155.4289	68.7951
65%	97.5000	57.5540	57.5540	57.2854	43.7037	70.9808	176.5929	78.8206
70%	97.5000	69.8925	69.8925	69.4079	54.2003	84.0001	194.4928	90.3943
75%	97.5000	86.1911	86.1911	85.7422	68.6912	99.8976	208.5436	104.0830
80%	97.5000	108.8506	108.8506	109.2100	89.7554	120.0136	218.6296	120.8366
85%	230.0000	142.8855	142.8855	146.3765	122.7597	146.8997	225.0641	142.4358
90%	230.0000	201.2135	201.2135	215.9890	181.2269	186.3901	228.4970	172.8781
95%	230.0000	334.2004	334.2004	404.8840	314.6566	257.5760	229.8051	224.9196
Chi-Squared Test								
Chi-Sq Statistic		0.2000	0.2000	0.2000	0.2000	0.2000	1.8000	0.2000
P-Value		0.6547	0.6547	0.6547	0.6547	0.6547	0.1797	0.6547
Cr. Value @ 0.750		0.1015	0.1015	0.1015	0.1015	0.1015	0.1015	0.1015
Cr. Value @ 0.500		0.4549	0.4549	0.4549	0.4549	0.4549	0.4549	0.4549
Cr. Value @ 0.250		1.3233	1.3233	1.3233	1.3233	1.3233	1.3233	1.3233

1.4 Service parameter 4 – Proper operation of equipment

1.4.1 Failure of protection system (discrete)

Whilst @RISK found that the IntUniform distribution is the best fit, the Poisson distribution has been adopted, consistent with distribution used for the other sub-parameters with discrete distributions (loss of supply event frequency).

Figure 1.19: Failure of protection system – Poisson distribution

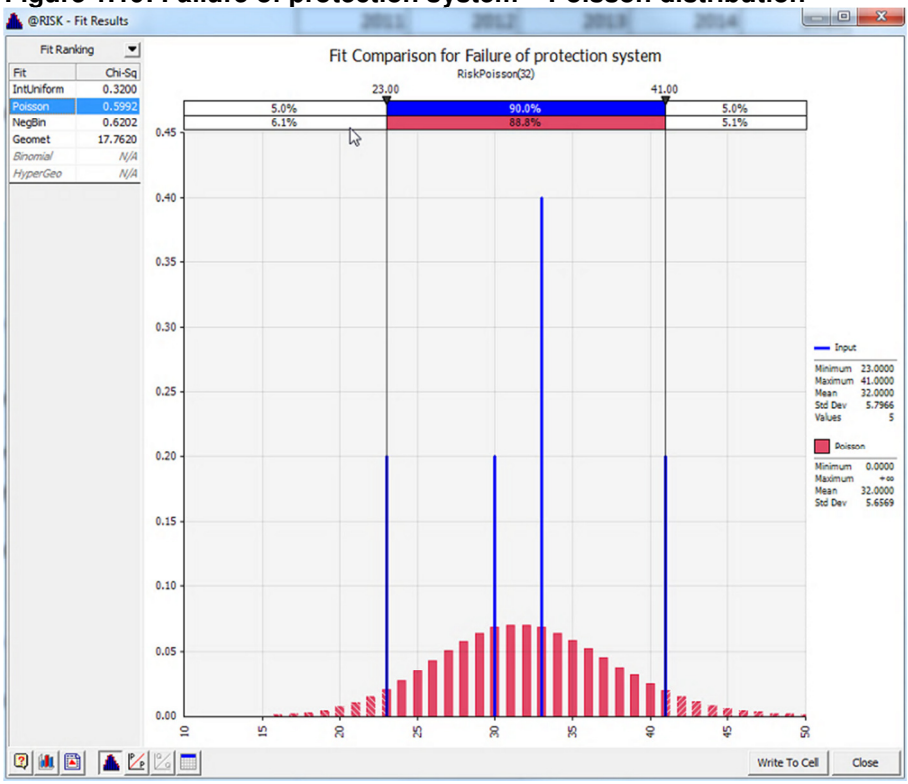
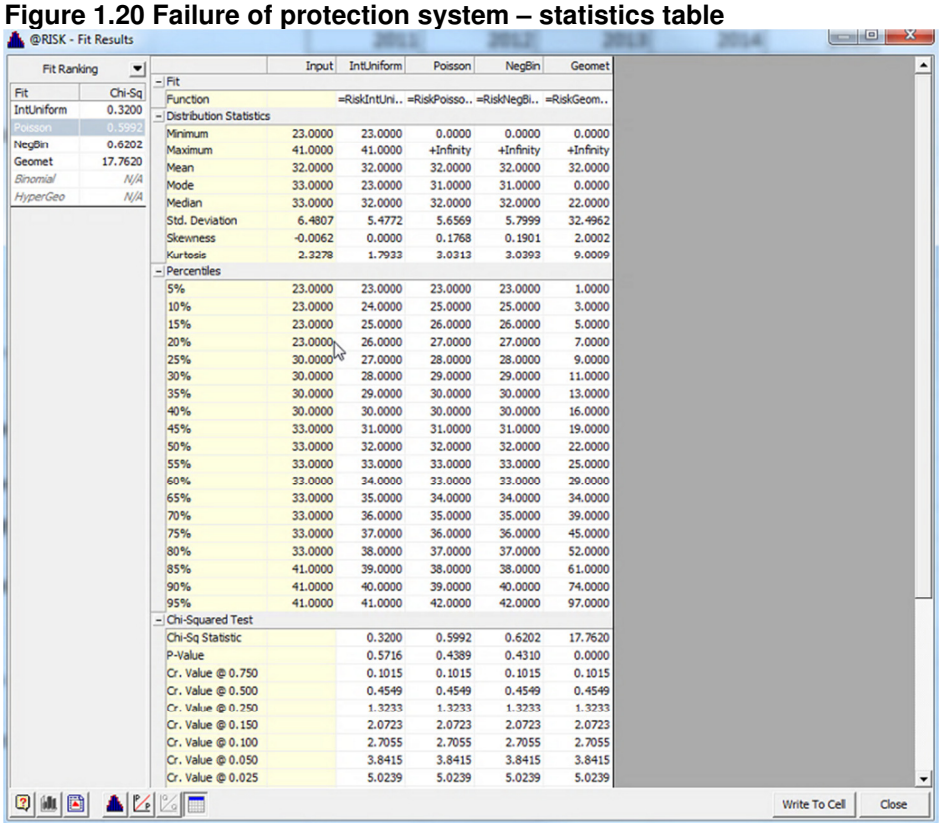


Figure 1.20 Failure of protection system – statistics table



	Input	IntUniform	Poisson	NegBin	Geomet
Fit					
Function		=RiskIntUni..	=RiskPoisso..	=RiskNegBi..	=RiskGeom..
Distribution Statistics					
Minimum	23.0000	23.0000	0.0000	0.0000	0.0000
Maximum	41.0000	41.0000	+Infinity	+Infinity	+Infinity
Mean	32.0000	32.0000	32.0000	32.0000	32.0000
Mode	33.0000	23.0000	31.0000	31.0000	0.0000
Median	33.0000	32.0000	32.0000	32.0000	22.0000
Std. Deviation	6.4807	5.4772	5.6569	5.7999	32.4962
Skewness	-0.0062	0.0000	0.1768	0.1901	2.0002
Kurtosis	2.3278	1.7933	3.0313	3.0393	9.0009
Percentiles					
5%	23.0000	23.0000	23.0000	23.0000	1.0000
10%	23.0000	24.0000	25.0000	25.0000	3.0000
15%	23.0000	25.0000	26.0000	26.0000	5.0000
20%	23.0000	26.0000	27.0000	27.0000	7.0000
25%	30.0000	27.0000	28.0000	28.0000	9.0000
30%	30.0000	28.0000	29.0000	29.0000	11.0000
35%	30.0000	29.0000	30.0000	30.0000	13.0000
40%	30.0000	30.0000	30.0000	30.0000	16.0000
45%	33.0000	31.0000	31.0000	31.0000	19.0000
50%	33.0000	32.0000	32.0000	32.0000	22.0000
55%	33.0000	33.0000	33.0000	33.0000	25.0000
60%	33.0000	34.0000	33.0000	33.0000	29.0000
65%	33.0000	35.0000	34.0000	34.0000	34.0000
70%	33.0000	36.0000	35.0000	35.0000	39.0000
75%	33.0000	37.0000	36.0000	36.0000	45.0000
80%	33.0000	38.0000	37.0000	37.0000	52.0000
85%	41.0000	39.0000	38.0000	38.0000	61.0000
90%	41.0000	40.0000	39.0000	40.0000	74.0000
95%	41.0000	41.0000	42.0000	42.0000	97.0000
Chi-Squared Test					
Chi-Sq Statistic		0.3200	0.5992	0.6202	17.7620
P-Value		0.5716	0.4389	0.4310	0.0000
Cr. Value @ 0.750		0.1015	0.1015	0.1015	0.1015
Cr. Value @ 0.500		0.4549	0.4549	0.4549	0.4549
Cr. Value @ 0.250		1.3233	1.3233	1.3233	1.3233
Cr. Value @ 0.150		2.0723	2.0723	2.0723	2.0723
Cr. Value @ 0.100		2.7055	2.7055	2.7055	2.7055
Cr. Value @ 0.050		3.8415	3.8415	3.8415	3.8415
Cr. Value @ 0.025		5.0239	5.0239	5.0239	5.0239

1.4.2 Material failure of SCADA system (discrete)

Whilst @RISK found that the Geometric distribution is the best fit, the Poisson distribution has been adopted, consistent with distribution used for the other sub-parameters with discrete distributions (loss of supply event frequency).

Figure 1.21: Material failure of SCADA system – Poisson distribution

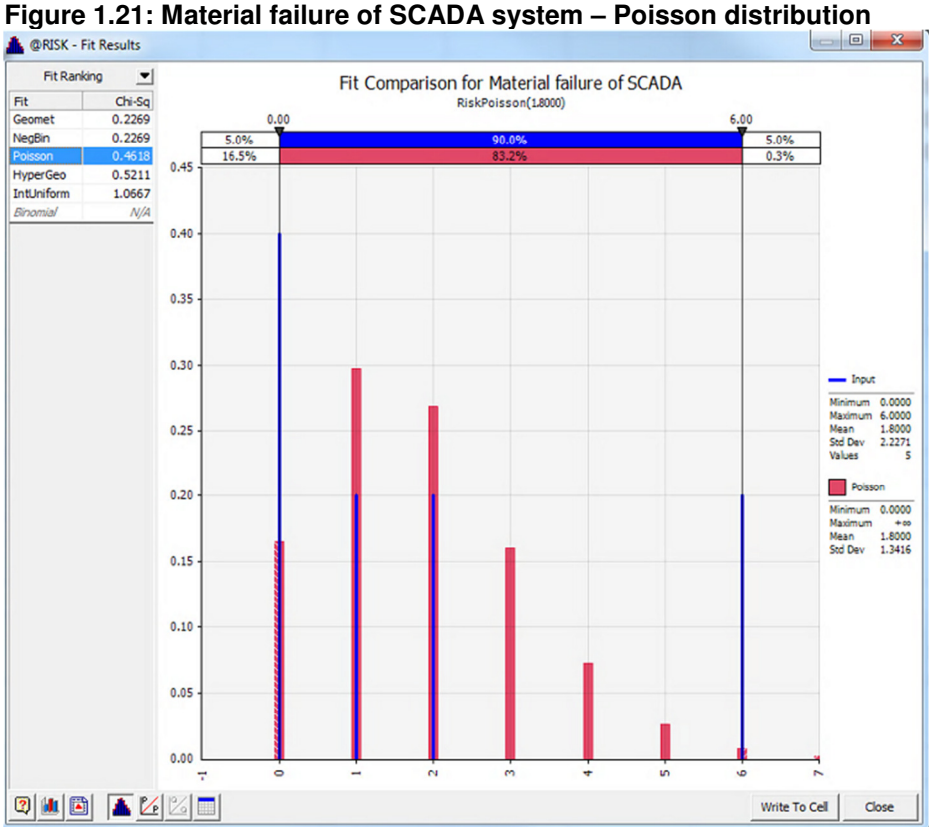
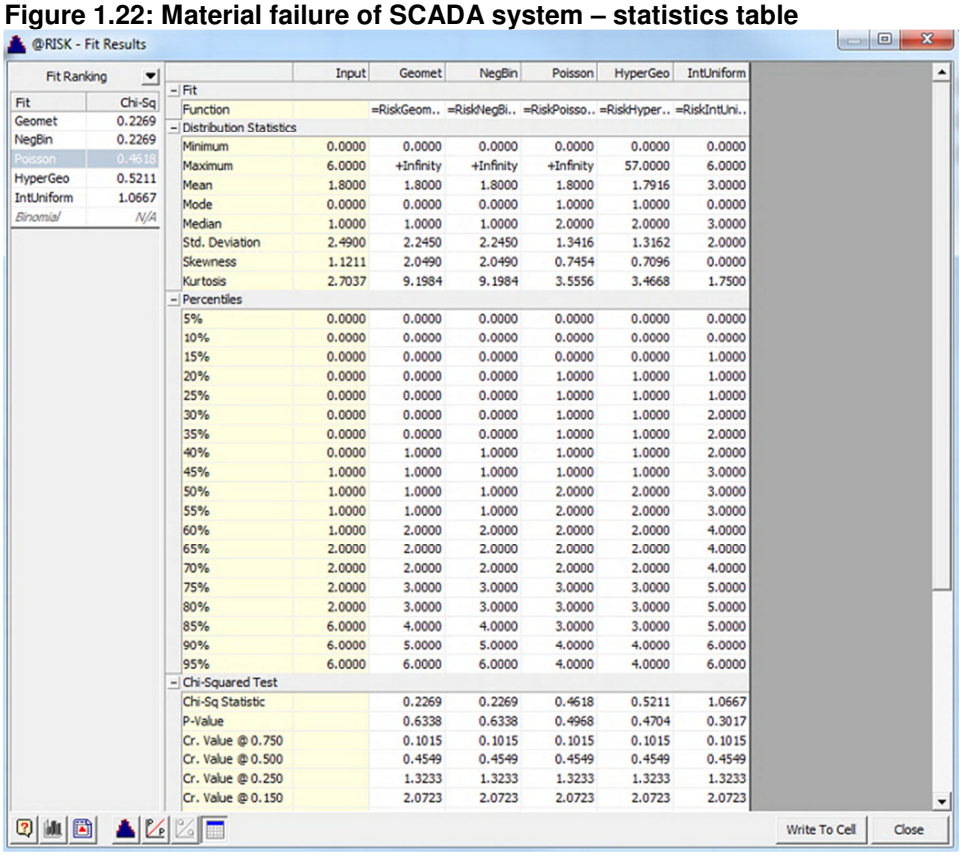


Figure 1.22: Material failure of SCADA system – statistics table



	Input	Geomet	NegBin	Poisson	HyperGeo	IntUniform
Fit						
Function		=RiskGeom..	=RiskNegBi..	=RiskPoisso..	=RiskHyper..	=RiskIntUni..
Distribution Statistics						
Minimum	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	6.0000	+Infinity	+Infinity	+Infinity	57.0000	6.0000
Mean	1.8000	1.8000	1.8000	1.8000	1.7916	3.0000
Mode	0.0000	0.0000	0.0000	1.0000	1.0000	0.0000
Median	1.0000	1.0000	1.0000	2.0000	2.0000	3.0000
Std. Deviation	2.4900	2.2450	2.2450	1.3416	1.3162	2.0000
Skewness	1.1211	2.0490	2.0490	0.7454	0.7096	0.0000
Kurtosis	2.7037	9.1984	9.1984	3.5556	3.4668	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	0.0000	1.0000
20%	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000
25%	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000
30%	0.0000	0.0000	0.0000	1.0000	1.0000	2.0000
35%	0.0000	0.0000	0.0000	1.0000	1.0000	2.0000
40%	0.0000	1.0000	1.0000	1.0000	1.0000	2.0000
45%	1.0000	1.0000	1.0000	1.0000	1.0000	3.0000
50%	1.0000	1.0000	1.0000	2.0000	2.0000	3.0000
55%	1.0000	1.0000	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	2.0000	2.0000	2.0000	2.0000	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	6.0000	4.0000	4.0000	6.0000
Chi-Squared Test						
Chi-Sq Statistic		0.2269	0.2269	0.4618	0.5211	1.0667
P-Value		0.6338	0.6338	0.4968	0.4704	0.3017
Cr. Value @ 0.750		0.1015	0.1015	0.1015	0.1015	0.1015
Cr. Value @ 0.500		0.4549	0.4549	0.4549	0.4549	0.4549
Cr. Value @ 0.250		1.3233	1.3233	1.3233	1.3233	1.3233
Cr. Value @ 0.150		2.0723	2.0723	2.0723	2.0723	2.0723

1.4.3 Incorrect operational isolation of primary or secondary equipment (discrete)

Whilst @RISK found that the HyperGeometric distribution is the best fit, the Poisson distribution has been adopted, consistent with distribution used for the other sub-parameters with discrete distributions (loss of supply event frequency).

Figure 1.23: Incorrect operational isolation of equipment – Poisson distribution

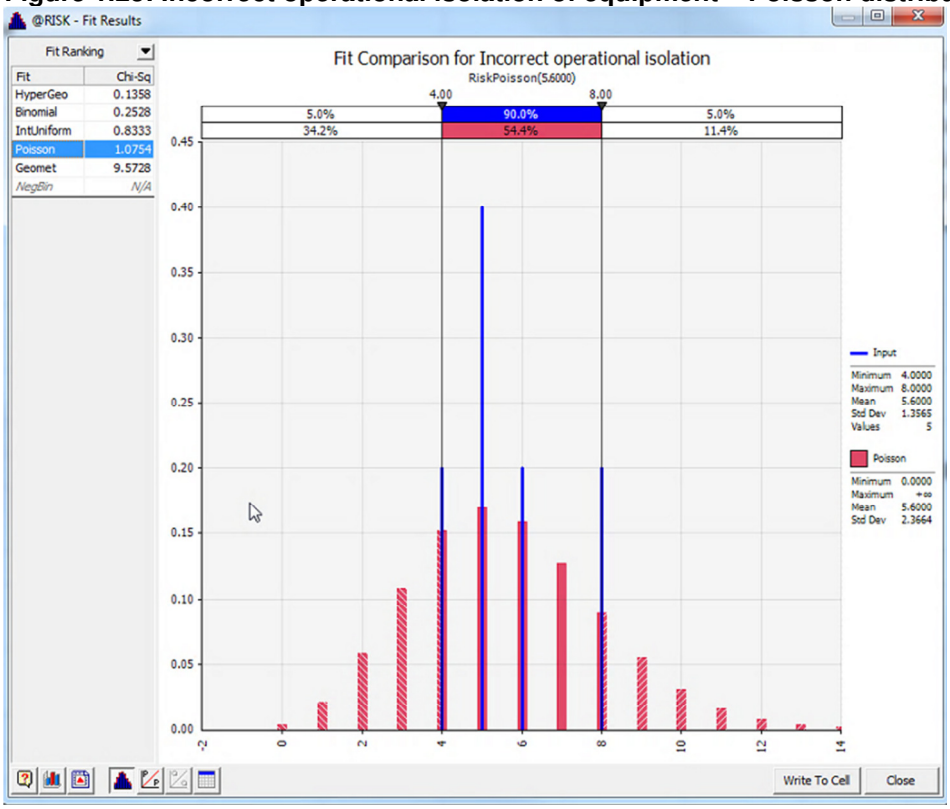
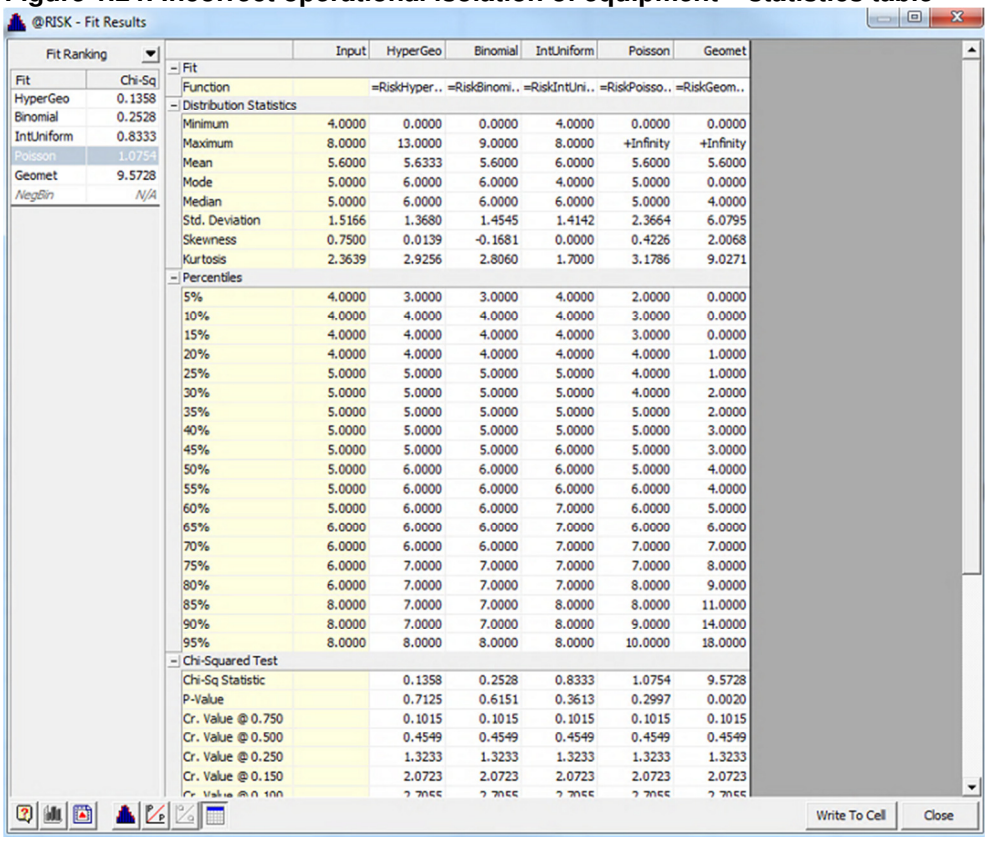


Figure 1.24: Incorrect operational isolation of equipment – statistics table



	Input	HyperGeo	Binomial	IntUniform	Poisson	Geomet
Fit						
Function		=RiskHyper..	=RiskBinomi..	=RiskIntUni..	=RiskPoisso..	=RiskGeom..
Distribution Statistics						
Minimum	4.0000	0.0000	0.0000	4.0000	0.0000	0.0000
Maximum	8.0000	13.0000	9.0000	8.0000	+Infinity	+Infinity
Mean	5.6000	5.6333	5.6000	6.0000	5.6000	5.6000
Mode	5.0000	6.0000	6.0000	4.0000	5.0000	0.0000
Median	5.0000	6.0000	6.0000	6.0000	5.0000	4.0000
Std. Deviation	1.5166	1.3680	1.4545	1.4142	2.3664	6.0795
Skewness	0.7500	0.0139	-0.1681	0.0000	0.4226	2.0068
Kurtosis	2.3639	2.9256	2.8060	1.7000	3.1786	9.0271
Percentiles						
5%	4.0000	3.0000	3.0000	4.0000	2.0000	0.0000
10%	4.0000	4.0000	4.0000	4.0000	3.0000	0.0000
15%	4.0000	4.0000	4.0000	4.0000	3.0000	0.0000
20%	4.0000	4.0000	4.0000	4.0000	4.0000	1.0000
25%	5.0000	5.0000	5.0000	5.0000	4.0000	1.0000
30%	5.0000	5.0000	5.0000	5.0000	4.0000	2.0000
35%	5.0000	5.0000	5.0000	5.0000	5.0000	2.0000
40%	5.0000	5.0000	5.0000	5.0000	5.0000	3.0000
45%	5.0000	5.0000	5.0000	6.0000	5.0000	3.0000
50%	5.0000	6.0000	6.0000	6.0000	5.0000	4.0000
55%	5.0000	6.0000	6.0000	6.0000	6.0000	4.0000
60%	5.0000	6.0000	6.0000	7.0000	6.0000	5.0000
65%	6.0000	6.0000	6.0000	7.0000	6.0000	6.0000
70%	6.0000	6.0000	6.0000	7.0000	7.0000	7.0000
75%	6.0000	7.0000	7.0000	7.0000	7.0000	8.0000
80%	6.0000	7.0000	7.0000	7.0000	8.0000	9.0000
85%	8.0000	7.0000	7.0000	8.0000	8.0000	11.0000
90%	8.0000	7.0000	7.0000	8.0000	9.0000	14.0000
95%	8.0000	8.0000	8.0000	8.0000	10.0000	18.0000
Chi-Squared Test						
Chi-Sq Statistic		0.1358	0.2528	0.8333	1.0754	9.5728
P-Value		0.7125	0.6151	0.3613	0.2997	0.0020
Cr. Value @ 0.750		0.1015	0.1015	0.1015	0.1015	0.1015
Cr. Value @ 0.500		0.4549	0.4549	0.4549	0.4549	0.4549
Cr. Value @ 0.250		1.3233	1.3233	1.3233	1.3233	1.3233
Cr. Value @ 0.150		2.0723	2.0723	2.0723	2.0723	2.0723