

2023-27 Transmission Revenue Reset

Appendix 9A: Fitting probability distributions to Service Component data

Updated for 2020 data

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PUBLIC



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1 Service Component Parameters

This Appendix sets out the information used to calculate AusNet's proposed Service Component caps and floors, as presented in section 8.3.1.2 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 floors 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 ElectraNet, TransGrid and TasNetworks. The distributions and caps and floors have been revised since AusNet's Revenue Proposal to take account of 2020 actual data, which was unavailable at the time. Consistent with the requirements of the STPIS, the caps and floors set out in this document are based on the five most recent years of performance data (2016-20).

In the Draft Decision, the AER disagreed with AusNet's preference to adopt distributions based on the Anderson-Darling (A-D) fit statistics. Instead, the AER relied solely on the Kolmogorov-Smirnov (K-S) method of fitting probability distributions. For this Revised Revenue Proposal, AusNet 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 floors for these sub-parameters.

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

Table 1.1: Summary of probability distributions and percentiles

Parameter	Preferred Distribution	5th percentile	95th percentile
Average circuit outage rate			
Line event rate (fault)	Gamma	0.1243	0.2237
Transformer event rate (fault)	Erlang	0.0649	0.1880
Reactive plant event rate (fault)	Dagum	0.1490	0.3043
Line event rate (forced)	FatigueLife	0.0382	0.2074
Transformer event rate (forced)	Burr12	0.0754	0.1588
Reactive plant event rate (forced)	Burr12	0.1965	0.3466
Loss of supply event frequency			
Number of events >0.05 system minutes	Poisson	0	4
Number of events >0.30 system minutes	Poisson	0	2
Average outage duration			
Average outage duration	Rayleigh	10.6	80.8
Proper operation of equipment			
Failure of protection equipment	Poisson	22	40
Material failure of SCADA system	Geometric	0	3
Incorrect operational isolation of primary or secondary equipment	Poisson	3	11

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

1.1.2 Transformer event rate – fault (continuous)

The @risk software found that the Erlang distribution is the most appropriate fit.

Figure 1-2: Transformer event rate (fault) – distribution fit using K-S

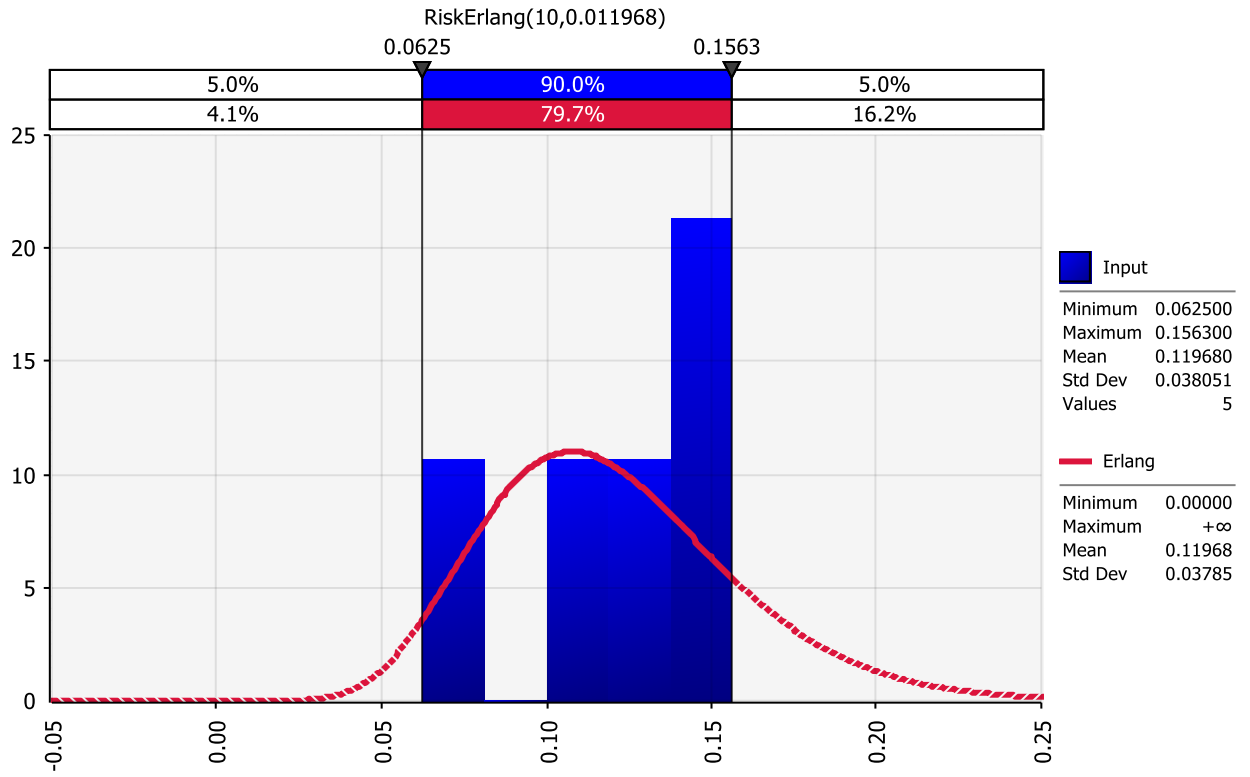


Figure 1.2: Transformer event rate (fault) – statistics table using K-S

Rank By	K-S	Value	Input	Erlang	Gamma	Lognorm2	Lognorm	Burr12	Weibull	BetaGeneral	FatigueLife	Invgauss	Pearson5	Pearson6	Frechet	Rayleigh	Triang	Uniform	Kum
Fit	Erlang	0.2062	Minimum 0.0625	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Gamma	0.2064	Maximum 0.1563	+infinity	-infinity	-infinity	-infinity	-infinity	-infinity	0.1563	-infinity	+infinity	-infinity	-infinity	-infinity	-infinity	-infinity	0.1563	0.1954
	Lognorm2	0.2195	Mean 0.1197	0.1197	0.1204	0.1204	0.1204	0.1203	0.1203	0.1237	0.1197	0.1197	0.121588283	0.1216	0.1337	0.1103	0.1042	0.0977	0.0000
	Lognorm	0.2195	Mode 0.0648 [ref]	0.1077	0.1080	0.1020	0.1020	0.1243	0.1243	0.1563	0.1008	0.1006	0.095884178	0.0999	0.0852	0.0880	0.1563	0.0000	0.0000
	Burr12	0.2202	Median 0.1260	0.1157	0.1156	0.1139	0.1139	0.1214	0.1214	0.1394	0.1133	0.1132	0.111581163	0.1116	0.1086	0.1036	0.1105	0.0977	0.0000
	Weibull	0.2203	Std Deviation 0.0381	0.0378	0.0374	0.0412	0.0412	0.0314	0.0314	0.0274	0.0407	0.0408	0.047836239	0.0478	0.1062	0.0576	0.0568	0.0564	0.0000
	BetaGeneral	0.2210	Skewness -0.8672	0.6325	0.6355	1.0661	1.0661	-1.4195	-1.5509	-1.2561	0.9987	1.0238	1.3619	1.8619	1.8619	0.6311	0.5657	0.0000	0.0000
	FatigueLife	0.2245	Kurtosis 2.9611	3.6000	3.5869	5.0667	5.0667	2.7800	2.7869	3.6523	4.6765	4.7436	10.7108	10.7109	-infinity	3.2451	2.4000	1.8000	0.0000
	Pearson6	0.2334	Percentiles																
	Pearson5	0.2334	5%	0.0625	0.0649	0.0654	0.0659	0.0659	0.0666	0.0648	0.0656	0.0657	0.066006714	0.0660	0.0642	0.0282	0.0349	0.00977	0.0000
	Frechet	0.2572	10%	0.0625	0.0745	0.0749	0.0744	0.0744	0.0786	0.0786	0.0635	0.0738	0.0739	0.07332716	0.0735	0.0404	0.0494	0.0195	0.0000
	Rayleigh	0.3027	15%	0.0625	0.0814	0.0816	0.0807	0.0807	0.0869	0.0869	0.0800	0.0801	0.079280172	0.0793	0.0756	0.0502	0.0605	0.0293	0.0000
	Triang	0.3161	20%	0.0625	0.0872	0.0876	0.0861	0.0861	0.0935	0.0935	0.0934	0.0934	0.0934	0.0934	0.0902	0.0588	0.0699	0.0391	0.0000
	Uniform	0.3323	25%	0.1040	0.0925	0.0928	0.0910	0.0910	0.0991	0.0991	0.1045	0.0903	0.089399999	0.0899	0.0847	0.0667	0.0782	0.0488	0.0000
	Lognormal	0.3915	30%	0.1040	0.0973	0.0976	0.0957	0.0957	0.1042	0.1042	0.1139	0.0950	0.093973788	0.0934	0.0891	0.0743	0.0856	0.0586	0.0000
	Expon	0.4058	35%	0.1040	0.1020	0.1022	0.1002	0.1002	0.1088	0.1088	0.1219	0.0995	0.097808750	0.0994	0.0936	0.0817	0.0925	0.0684	0.0000
	Pareto2	0.4058	40%	0.1040	0.1066	0.1067	0.1047	0.1047	0.1132	0.1131	0.1287	0.1040	0.1039	0.102256375	0.1023	0.0893	0.0889	0.0999	0.0782
	Levy	0.5925	45%	0.1040	0.1111	0.1112	0.1092	0.1092	0.1173	0.1173	0.1345	0.1086	0.1085	0.106803406	0.1086	0.1032	0.0962	0.1040	0.0879
	ChiSq	0.6826	50%	0.1260	0.1157	0.1158	0.1139	0.1139	0.1214	0.1214	0.1394	0.1133	0.1132	0.111581163	0.1116	0.1086	0.1036	0.1105	0.0977
	ChiSq	0.8000	55%	0.1260	0.1304	0.1305	0.1187	0.1187	0.1254	0.1254	0.1435	0.1181	0.1180	0.116626057	0.1166	0.1146	0.1112	0.1159	0.1075
	Logistic	N/A	60%	0.1496	0.1254	0.1254	0.1239	0.1239	0.1294	0.1294	0.1489	0.1233	0.1232	0.122072620	0.1221	0.1213	0.1191	0.1211	0.1172
	Pareto	N/A	65%	0.1496	0.1306	0.1305	0.1294	0.1294	0.1336	0.1336	0.1497	0.1289	0.1288	0.128059382	0.1281	0.1289	0.1275	0.1260	0.1270
	Perf	N/A	70%	0.1496	0.1363	0.1361	0.1356	0.1356	0.1378	0.1378	0.1518	0.1351	0.1350	0.134796289	0.1348	0.1380	0.1365	0.1308	0.1368
			75%	0.1496	0.1426	0.1424	0.1425	0.1425	0.1424	0.1424	0.1535	0.1420	0.1419	0.142601535	0.1426	0.1491	0.1483	0.1354	0.1465
			80%	0.1496	0.1488	0.1485	0.1507	0.1507	0.1474	0.1474	0.1547	0.1502	0.1501	0.150200024	0.1502	0.1634	0.1579	0.1398	0.1563
			85%	0.1563	0.1586	0.1581	0.1607	0.1607	0.1531	0.1531	0.1602	0.1602	0.164031087	0.1640	0.1831	0.1714	0.1441	0.1661	0.0000
			90%	0.1563	0.1700	0.1695	0.1744	0.1744	0.1601	0.1601	0.1560	0.1560	0.1738	0.180988538	0.1810	0.2140	0.1888	0.1483	0.1758
			95%	0.1563	0.1880	0.1872	0.1968	0.1968	0.1701	0.1701	0.1563	0.1563	0.1959	0.210574046	0.2106	0.2773	0.2154	0.1523	0.1856

1.1.4 Lines event rate – forced (continuous)

The @risk software found that the FatigueLife distribution is the most appropriate fit.

Figure 1-5: Lines event rate (forced) – distribution fit using K-S

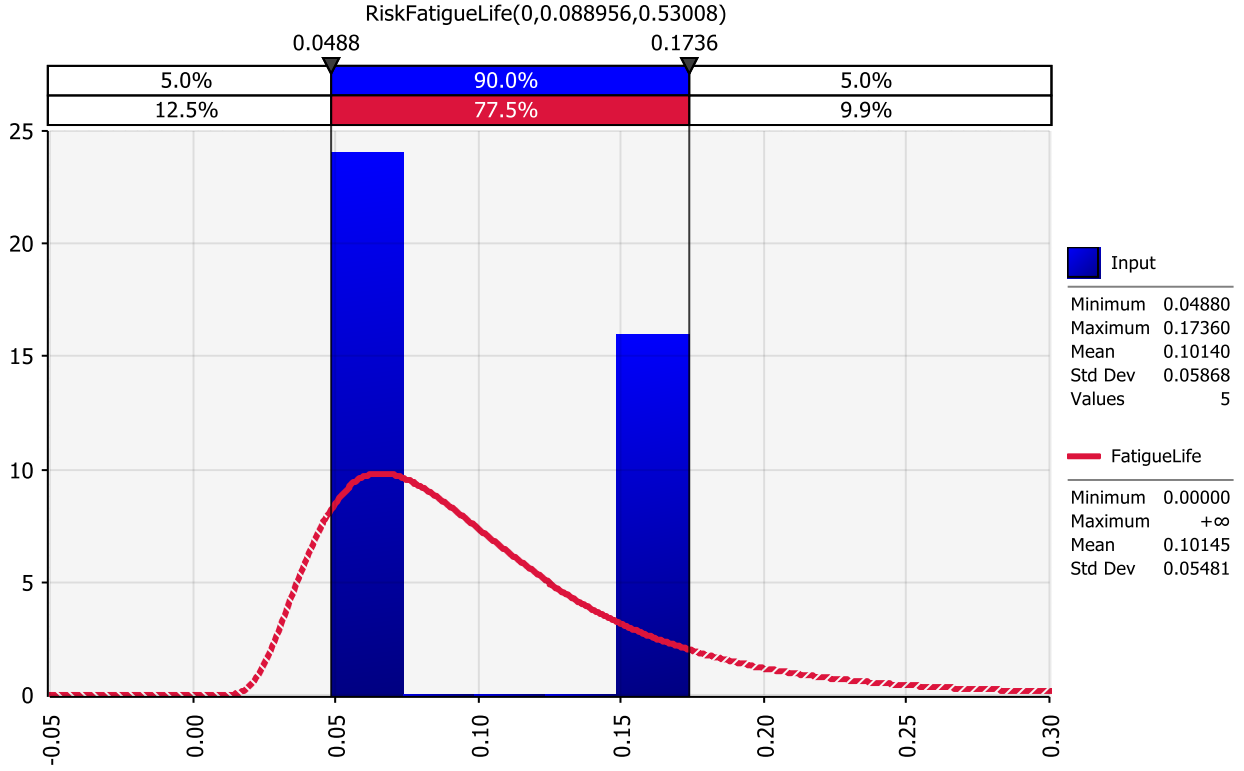


Figure 1-6: Lines event rate (forced) – statistics table using K-S

Rank By	K-S	Value	Input	FatigueLife	Invgauss	Logistic	Lognorm	Lognorm2	Pearson5	Pearson3	Uniform	Dagum	Frechet	Rayleigh	Gamma	Erlang	Weibull	Pert	
FatigueLife	0.2577		0.0488	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Invgauss	0.2583	Maximum	0.1736	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	0.2552
Logistic	0.2591	Mean	0.1014	0.1015	0.1014	0.1033	0.1014	0.1014	0.1028	0.1029	0.1085	0.105061	0.1051	0.1012	0.1014	0.1014	0.1022	0.1020	0.1020
Lognorm	0.2606	Mode	0.0519 [p=0]	0.0661	0.0635	0.0685	0.0673	0.0673	0.062170131	0.0628	0.0000	0.059489	0.0595	0.0807	0.0748	0.0761	0.0648	0.0692	0.0692
Lognorm2	0.2617	Median	0.0720	0.0590	0.0584	0.0558	0.0584	0.0584	0.060464623	0.0647	0.1305	0.080103	0.0601	0.0951	0.0927	0.0931	0.0969	0.0969	0.0969
Pearson5	0.2617	Std. Deviation	0.0587	0.0548	0.0556	0.0519	0.0566	0.0566	0.070481476	0.0705	0.0628	0.123109	0.1231	0.0529	0.0520	0.0507	0.0511	0.0473	0.0473
Pearson3	0.2617	Skewness	0.5721	1.5340	1.6432	97.9763	1.8568	1.8568	5.1664	5.1664	0.0000	N/A	+Infinity	0.6311	1.0249	1.0000	0.5671	0.2710	0.2710
Uniform	0.2662	Kurtosis	0.0811	6.8742	7.5109	+Infinity	9.6965	9.6965	397.2956	397.3145	1.8000	N/A	+Infinity	3.2451	4.5755	4.5000	3.1321	2.4313	2.4313
Dagum	0.2690	Percentiles																	
Frechet	0.2690																		
Rayleigh	0.2719	5%	0.0488	0.0382	0.0384	0.0325	0.0374	0.0374	0.040537007	0.0406	0.0109	0.043354	0.0436	0.0239	0.0334	0.0346	0.0280	0.0297	0.0297
Gamma	0.2738	10%	0.0488	0.0457	0.0458	0.0416	0.0453	0.0453	0.048976385	0.0470	0.0217	0.046597	0.0466	0.0371	0.0451	0.0442	0.0395	0.0412	0.0412
Erlang	0.2800	15%	0.0488	0.0517	0.0517	0.0484	0.0514	0.0514	0.052111637	0.0521	0.0226	0.052877	0.0527	0.0460	0.0566	0.0517	0.0466	0.0500	0.0500
Weibull	0.2896	20%	0.0488	0.0571	0.0571	0.0543	0.0570	0.0570	0.056703044	0.0568	0.0434	0.056410	0.0564	0.0539	0.0572	0.0562	0.0465	0.0583	0.0583
Pert	0.3041	25%	0.0569	0.0623	0.0621	0.0597	0.0622	0.0622	0.061185436	0.0612	0.0543	0.060026	0.0600	0.0612	0.0653	0.0643	0.0637	0.0656	0.0656
Expon	0.3820	30%	0.0569	0.0674	0.0671	0.0649	0.0672	0.0672	0.065372521	0.0656	0.0651	0.063654	0.0637	0.0662	0.0662	0.0701	0.0706	0.0726	0.0726
Pareto2	0.3820	35%	0.0569	0.0725	0.0722	0.0700	0.0723	0.0723	0.070038880	0.0700	0.0760	0.067390	0.0674	0.0749	0.0750	0.0757	0.0793	0.0793	0.0793
Kumarasw.	0.4189	40%	0.0569	0.0778	0.0773	0.0751	0.0773	0.0773	0.074637507	0.0746	0.0888	0.071317	0.0713	0.0816	0.0808	0.0814	0.0808	0.0809	0.0809
Triang	0.4280	45%	0.0720	0.0852	0.0827	0.0805	0.0828	0.0828	0.079490939	0.0795	0.0977	0.075231	0.0755	0.0863	0.0866	0.0872	0.0905	0.0924	0.0924
Lny	0.4972	50%	0.0720	0.0890	0.0884	0.0858	0.0884	0.0884	0.086464623	0.0847	0.1085	0.080103	0.0801	0.0951	0.0927	0.0931	0.0969	0.0969	0.0969
ChiSq	0.6789	55%	0.0720	0.0951	0.0944	0.0917	0.0944	0.0944	0.090339023	0.0903	0.1194	0.085190	0.0852	0.1020	0.0990	0.0993	0.1056	0.1057	0.1057
Burr12	N/A	60%	0.1557	0.1017	0.1010	0.0981	0.1009	0.1009	0.096610236	0.0966	0.1302	0.090955	0.0910	0.1093	0.1057	0.1058	0.1106	0.1126	0.1126
Pert2	N/A	65%	0.1557	0.1091	0.1084	0.1052	0.1081	0.1081	0.103709538	0.1037	0.1411	0.097642	0.0976	0.1170	0.1130	0.1129	0.1180	0.1197	0.1197
		70%	0.1557	0.1174	0.1163	0.1135	0.1163	0.1163	0.111953588	0.1120	0.1519	0.105625	0.1056	0.1253	0.1210	0.1207	0.1260	0.1273	0.1273
		75%	0.1557	0.1270	0.1263	0.1233	0.1258	0.1258	0.121942529	0.1218	0.1628	0.115512	0.1155	0.1344	0.1300	0.1295	0.1348	0.1355	0.1355
		80%	0.1557	0.1385	0.1379	0.1355	0.1373	0.1373	0.134042518	0.1342	0.1736	0.120397	0.1204	0.1448	0.1406	0.1398	0.1447	0.1445	0.1445
		85%	0.1736	0.1531	0.1528	0.1520	0.1520	0.1520	0.15083451	0.1509	0.1945	0.148510	0.1485	0.1573	0.1536	0.1524	0.1565	0.1548	0.1548
		90%	0.1736	0.1733	0.1735	0.1720	0.1727	0.1727	0.175742708	0.1757	0.1953	0.175478	0.1755	0.1733	0.1711	0.1694	0.1716	0.1673	0.1673
		95%	0.1736	0.2074	0.2088	0.2265	0.2088	0.2088	0.22324441	0.2233	0.2062	0.236787	0.2368	0.1976	0.1991	0.1966	0.1945	0.1847	0.1847

1.1.6 Reactive plant event rate – forced (continuous)

The @risk software found that the Burr12 distribution is the most appropriate fit.

Figure 1-9: Reactive plant event rate (forced) – distribution fit using K-S

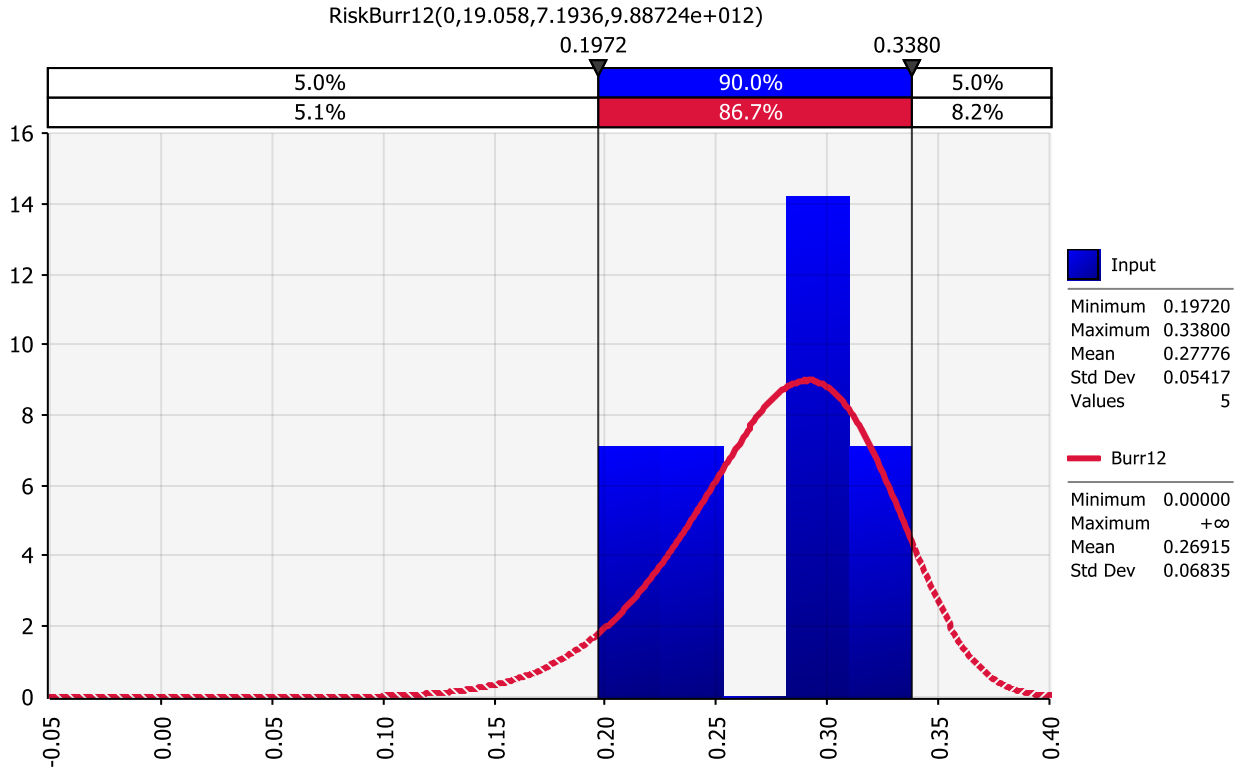


Figure 1-10: Reactive plant event rate (forced) – statistics table using K-S

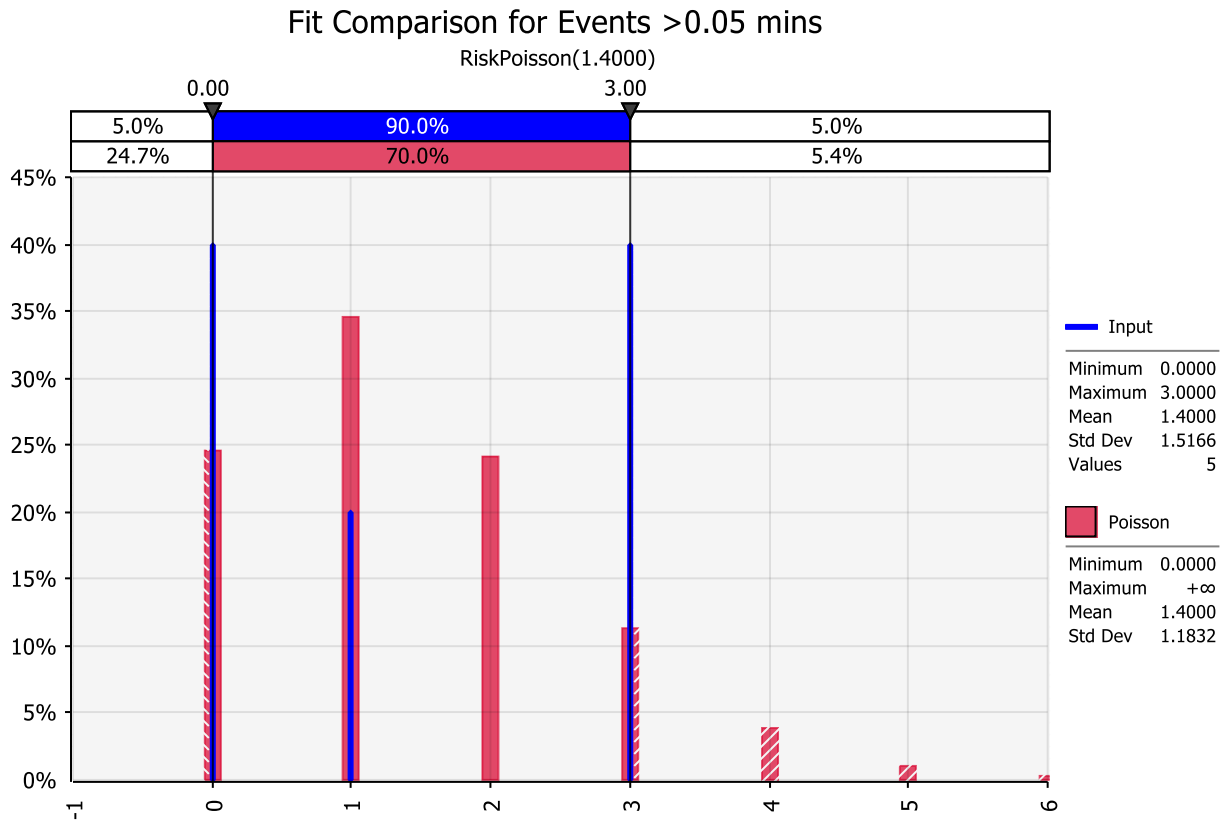
Fit	K-S	Value	Input	Burr12	Weibull	Erlang	Gamma	Lognorm2	Lognorm	FatigueLife	Impgnss	Dagum	Frechet	Pearsons	Pearsons	BetaGeneral	Triang	Rajleigh	
Burr12	0.2160	0.1972	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Weibull	0.2163	0.3380	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	+Infinity	0.3380	0.3380	0.3380	+Infinity
Erlang	0.2587	0.2778	0.2886	0.2788	0.2776	0.2776	0.2776	0.2780	0.2780	0.2778	0.2778	0.2870	0.2870	0.2870	0.2783	0.2839	0.2253	0.2499	0.2499
Gamma	0.2589	0.2556	0.2808	0.2808	0.2748	0.2748	0.2748	0.2732	0.2732	0.2729	0.2729	0.2858	0.2858	0.2858	0.2719	0.2811	0.2163	0.1915	0.1915
Lognorm2	0.2647	0.2647	0.2914	0.2914	0.2855	0.2854	0.2854	0.2838	0.2838	0.2834	0.2833	0.2887	0.2887	0.2887	0.2586	0.2586	0.2586	0.2586	0.2586
Lognorm	0.2647	0.2556	0.2808	0.2808	0.2748	0.2748	0.2748	0.2732	0.2732	0.2729	0.2729	0.2858	0.2858	0.2858	0.2719	0.2811	0.2163	0.1915	0.1915
FatigueLife	0.2658	0.2658	N/A	0.0437	0.05071	0.05071	0.0525	0.0524	0.0524	0.0524	0.0524	0.0682	0.0682	0.0682	0.0550	0.0638	0.0797	0.1206	0.1206
Impgnss	0.2660	0.2660	3.1643	3.1643	3.2000	3.1992	3.1992	3.5886	3.5886	3.5889	3.5889	3.5334	44.3136	44.2983	4.3145	4.3145	4.7860	2.4000	2.4000
Dagum	0.2687	0.2687	0.2552	0.2552	0.2539	0.2539	0.2539	0.2542	0.2542	0.2539	0.2539	0.2539	0.2539	0.2539	0.2539	0.2539	0.2539	0.2539	0.2539
Frechet	0.2687	0.2687	0.2552	0.2552	0.2539	0.2539	0.2539	0.2542	0.2542	0.2539	0.2539	0.2539	0.2539	0.2539	0.2539	0.2539	0.2539	0.2539	0.2539
Pearsons6	0.2706	5%	0.1972	0.1965	0.1969	0.19993	0.20007	0.2008	0.2008	0.2007	0.2007	0.1993	0.1993	0.20128975	0.2013	0.1441	0.0756	0.0639	0.0639
Pearsons5	0.2706	10%	0.1972	0.1972	0.2176	0.21507	0.21519	0.2149	0.2149	0.2147	0.2147	0.2099	0.2099	0.21488604	0.2145	0.1872	0.1069	0.0915	0.0915
BetaGeneral	0.3375	15%	0.1972	0.2011	0.2312	0.23572	0.23582	0.2350	0.2350	0.2348	0.2348	0.2341	0.2341	0.2341	0.2341	0.2341	0.2341	0.2341	0.2341
Triang	0.3659	20%	0.1972	0.2417	0.2416	0.23432	0.2334	0.2334	0.2331	0.2331	0.2331	0.2322	0.2322	0.23227238	0.2321	0.2385	0.1512	0.1332	0.1332
Rayleigh	0.3869	25%	0.2535	0.2502	0.2503	0.24209	0.24216	0.2408	0.2408	0.2405	0.2405	0.2319	0.2319	0.23262665	0.2393	0.2562	0.1690	0.1512	0.1512
Uniform	0.4667	30%	0.2535	0.2577	0.2578	0.24910	0.24916	0.2476	0.2476	0.2474	0.2474	0.2385	0.2385	0.24597238	0.2460	0.2709	0.1851	0.1684	0.1684
Kumarasw.	0.5039	35%	0.2535	0.2647	0.2647	0.25572	0.25571	0.2542	0.2542	0.2539	0.2539	0.2450	0.2450	0.25241859	0.2524	0.2831	0.2000	0.1851	0.1851
Expon	0.5083	40%	0.2535	0.2711	0.2710	0.26211	0.26215	0.2605	0.2605	0.2603	0.2602	0.2516	0.2516	0.25164589	0.2587	0.2935	0.2138	0.2015	0.2015
Chisq	0.5610	45%	0.2558	0.2770	0.2770	0.26840	0.26842	0.2668	0.2668	0.2666	0.2666	0.2585	0.2585	0.25857683	0.2651	0.3063	0.2287	0.2160	0.2160
Ley	0.6270	50%	0.2558	0.2828	0.2828	0.27488	0.27488	0.2732	0.2732	0.2729	0.2729	0.2658	0.2658	0.27149849	0.2715	0.3098	0.2390	0.2247	0.2247
Loglogistic	N/A	55%	0.2658	0.2884	0.2884	0.28106	0.28106	0.2797	0.2797	0.2795	0.2794	0.2737	0.2737	0.27813550	0.2781	0.3161	0.2507	0.2320	0.2320
Pareto1	N/A	60%	0.3043	0.2939	0.2940	0.28764	0.28763	0.2864	0.2864	0.2862	0.2862	0.2823	0.2823	0.28510253	0.2851	0.3215	0.2618	0.2499	0.2499
Pareto2	N/A	65%	0.3043	0.2996	0.2996	0.29455	0.29455	0.2936	0.2936	0.2934	0.2934	0.2919	0.2919	0.29254956	0.2925	0.3259	0.2725	0.2688	0.2688
Perf	N/A	70%	0.3043	0.3053	0.3054	0.30196	0.30191	0.3013	0.3013	0.3012	0.3012	0.3029	0.3029	0.30297989	0.3007	0.3295	0.2828	0.2707	0.2707
		75%	0.3043	0.3114	0.3114	0.31008	0.31002	0.3099	0.3099	0.3098	0.3098	0.3160	0.3160	0.30979362	0.3098	0.3324	0.2927	0.2827	0.2827
		80%	0.3043	0.3179	0.3179	0.31929	0.31921	0.3188	0.3188	0.3186	0.3186	0.3322	0.3322	0.33227687	0.3324	0.3347	0.3023	0.3377	0.3377
		85%	0.3380	0.3253	0.3253	0.33028	0.33016	0.3314	0.3314	0.3315	0.3315	0.3316	0.3316	0.33161213	0.3313	0.3363	0.3116	0.3084	0.3084
		90%	0.3380	0.3342	0.3342	0.34441	0.34427	0.3472	0.3472	0.3470	0.3470	0.3550	0.3550	0.35502318	0.3506	0.3307	0.3207	0.3278	0.3278
		95%	0.3380	0.3466	0.3466	0.36610	0.36591	0.3716	0.3716	0.3712	0.3712	0.3713	0.3713	0.37134954	0.3785	0.3379	0.3294	0.4880	0.4880

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 Geometric distribution is the best fit according to AIC and IntUniform according to BIC, the Poisson distribution has been adopted, consistent with both the loss of supply event frequency (>0.30 system minutes) parameter and the Draft Decision.

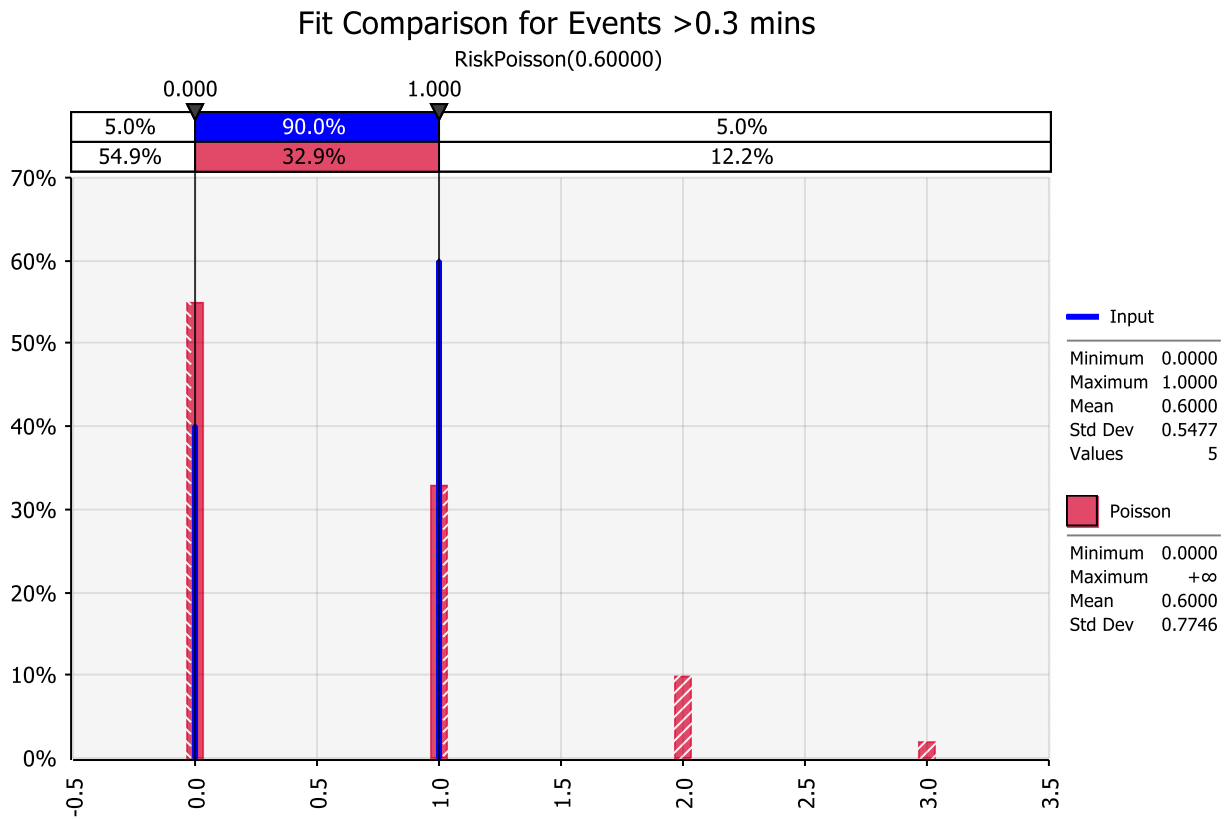
Figure 1-11: Number of events >0.05 system minutes – Poisson distribution



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 and is in accordance with AIC.

Figure 1-14: Number of events >0.30 system minutes – Poisson distribution

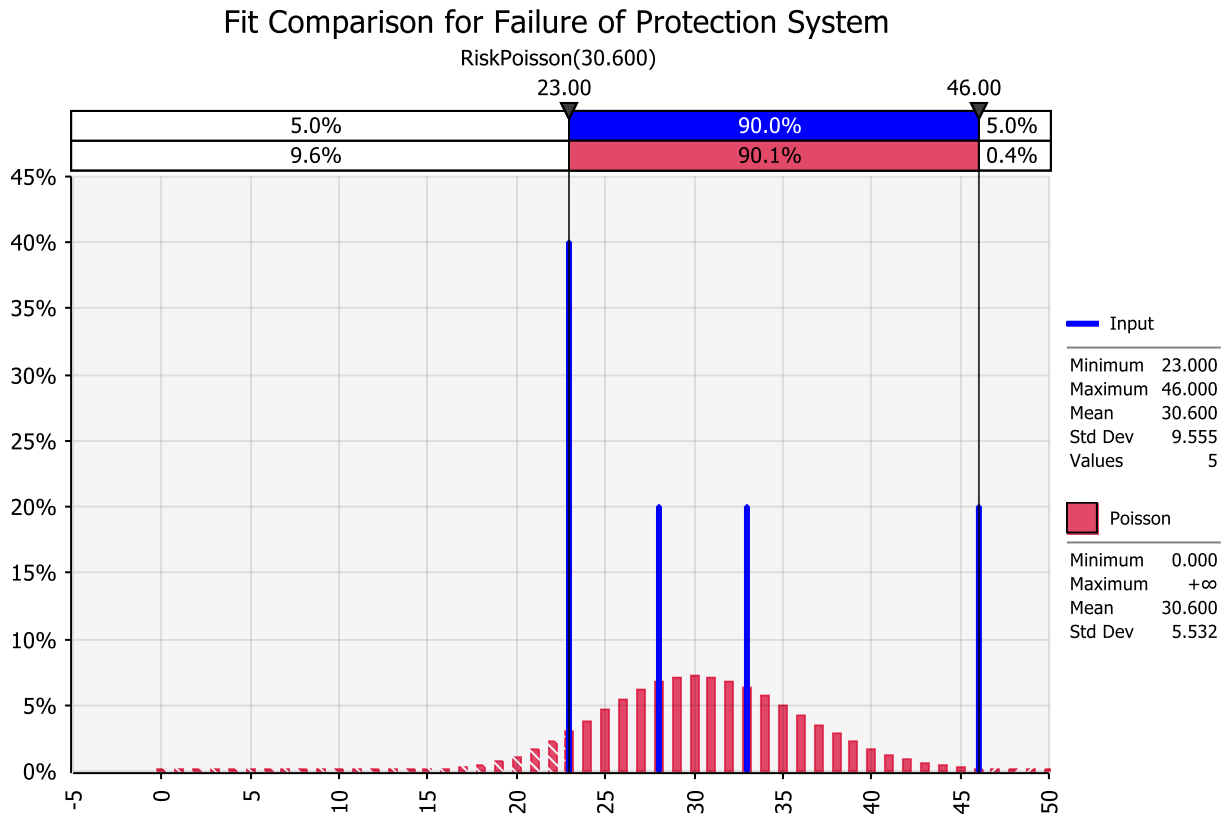


1.4 Service parameter 4 – proper operation of equipment

1.4.1 Failure of protection system (discrete)

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

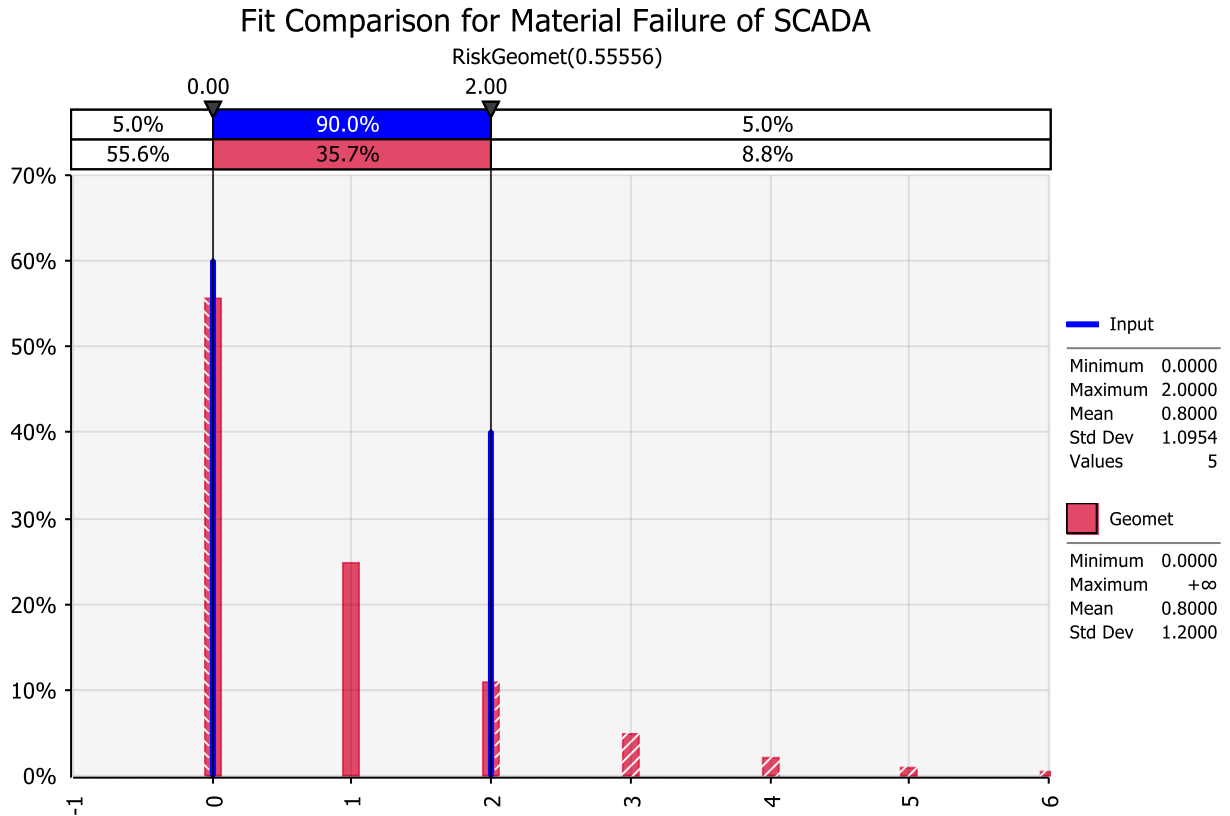
Figure 1-19: Failure of protection system – Poisson distribution



1.4.2 Material failure of SCADA system (discrete)

The @risk software found the Geometric distribution is the most appropriate fit.

Figure 1-22: Material failure of SCADA system – Geometric distribution



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

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

Figure 1-25: Incorrect operational isolation of equipment – Poisson distribution

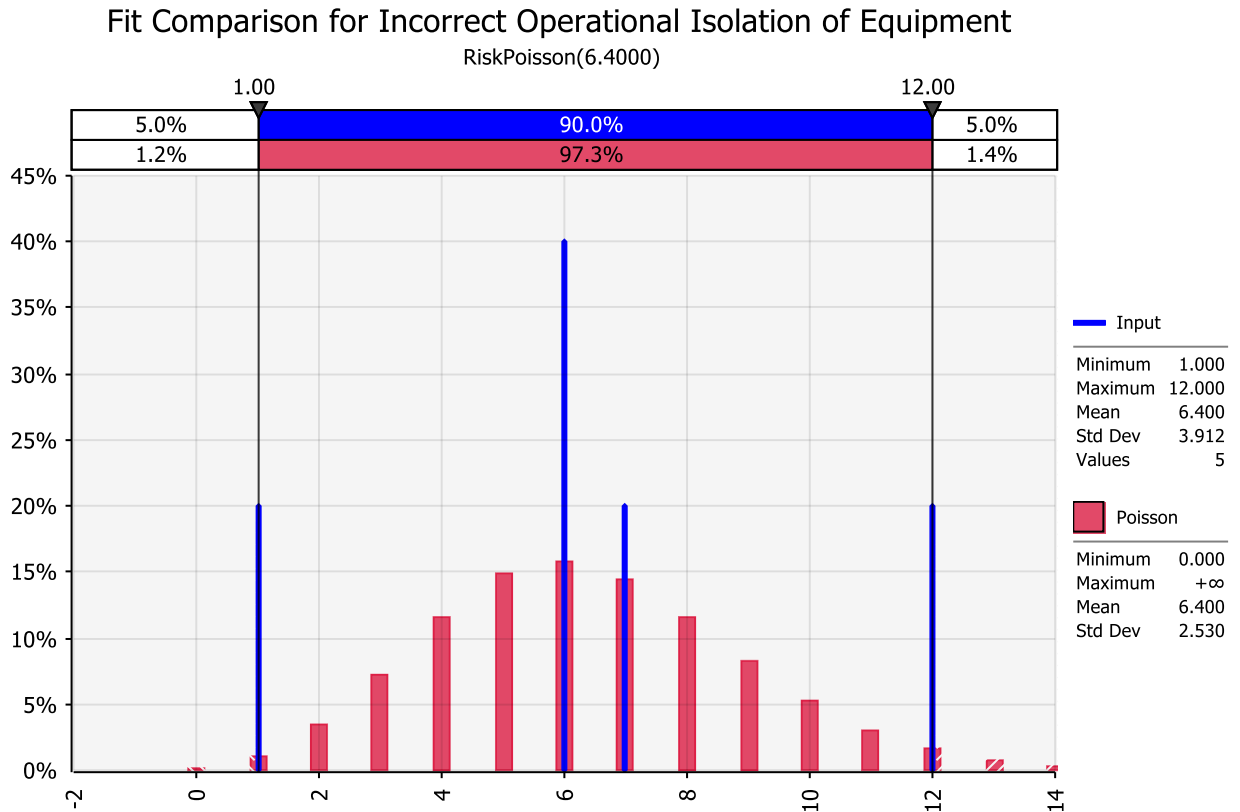


Figure 1-26: Incorrect operational isolation of equipment – AIC distribution

Rank By	AIC	Value					
Fit			95% Lower Limit*				N/A
<input checked="" type="checkbox"/> Poisson	31.8720		95% Upper Limit*				N/A
<input type="checkbox"/> Geomet	32.6398		Conf. Interval Width*				N/A
<input type="checkbox"/> IntUniform	34.8491						
<input type="checkbox"/> NegBin	36.9383						
<input type="checkbox"/> Hypergeo	58.7208						
<input type="checkbox"/> Binomial	N/A						
Distribution Statistics							
Minimum	1.0000		1.0000	0.0000	0.0000	1.0000	0.0000
Maximum	12.0000		12.0000	+Infinity	+Infinity	12.0000	+Infinity
Mean	6.4000		6.4000	6.4000	6.4000	6.5000	6.4000
Mode	6.0000		6.0000	6.0000	6.0000	1.0000	5.0000
Median	6.0000		6.0000	4.0000	6.0000	6.0000	6.0000
Std. Deviation	3.9115		2.5298	6.8819	3.4521	3.8199	2.4791
Skewness	0.1270		0.3953	2.0053	0.0000	0.9319	0.3732
Kurtosis	4.7929		3.1563	9.0211	1.7832	4.2685	3.1278
Percentiles							
5%	1.0000		3.0000	0.0000	1.0000	1.0000	3.0000
10%	1.0000		3.0000	0.0000	2.0000	2.0000	3.0000
15%	1.0000		4.0000	1.0000	2.0000	3.0000	4.0000
20%	1.0000		4.0000	1.0000	3.0000	3.0000	4.0000
25%	6.0000		5.0000	1.0000	3.0000	4.0000	5.0000
30%	6.0000		5.0000	2.0000	4.0000	4.0000	5.0000
35%	6.0000		5.0000	2.0000	5.0000	4.0000	5.0000
40%	6.0000		6.0000	3.0000	5.0000	5.0000	6.0000
45%	6.0000		6.0000	4.0000	6.0000	5.0000	6.0000
50%	6.0000		6.0000	4.0000	6.0000	6.0000	6.0000
55%	6.0000		7.0000	5.0000	7.0000	6.0000	7.0000
60%	6.0000		7.0000	6.0000	8.0000	7.0000	7.0000
65%	7.0000		7.0000	7.0000	8.0000	7.0000	7.0000
70%	7.0000		8.0000	8.0000	9.0000	8.0000	8.0000
75%	7.0000		8.0000	9.0000	9.0000	9.0000	8.0000
80%	7.0000		8.0000	11.0000	10.0000	9.0000	8.0000
85%	12.0000		9.0000	13.0000	11.0000	10.0000	9.0000
90%	12.0000		10.0000	15.0000	11.0000	12.0000	10.0000
95%	12.0000		11.0000	20.0000	12.0000	14.0000	11.0000
Information Criteria							
Akaike (AIC)		31.8720	32.6398	34.8491	36.9383	58.7208	
Bayesian (BIC)		30.1481	30.9159	28.0679	30.1572	33.5491	
Av. LogL		-2.8539	-2.9306	-2.4849	-2.6938	-2.8721	
Chi-Squared Test - (* Values unavailable without running a bootstrap)							
Chi-Sq Statistic		0.0000	0.0000	0.0000	0.0000	0.0000	
P-Value*		N/A	N/A	N/A	N/A	N/A	
Cr. Value @ 0.750*		N/A	N/A	N/A	N/A	N/A	
Cr. Value @ 0.500*		N/A	N/A	N/A	N/A	N/A	
Cr. Value @ 0.250*		N/A	N/A	N/A	N/A	N/A	
Cr. Value @ 0.150*		N/A	N/A	N/A	N/A	N/A	
Cr. Value @ 0.100*		N/A	N/A	N/A	N/A	N/A	
Cr. Value @ 0.050*		N/A	N/A	N/A	N/A	N/A	
Cr. Value @ 0.025*		N/A	N/A	N/A	N/A	N/A	
Cr. Value @ 0.010*		N/A	N/A	N/A	N/A	N/A	
Cr. Value @ 0.005*		N/A	N/A	N/A	N/A	N/A	
Cr. Value @ 0.001*		N/A	N/A	N/A	N/A	N/A	
Chi-Sq Test (Binning Information)							
Bin #1: Minimum		0.0000	0.0000	1.0000	0.0000	0.0000	
Bin #1: Maximum		+Infinity	+Infinity	12.0000	+Infinity	202.0000	
Bin #1: Input		5.0000	5.0000	5.0000	5.0000	5.0000	
Bin #1: Fit		5.0000	5.0000	5.0000	5.0000	5.0000	

Figure 1-27: Incorrect operational isolation of equipment – BIC distribution

Rank By	BIC	Value					
Fit			95% Lower Limit*				N/A
<input checked="" type="checkbox"/> IntUniform	28.0679		95% Upper Limit*				N/A
<input type="checkbox"/> Poisson	30.1481		Conf. Interval Width*				N/A
<input type="checkbox"/> NegBin	30.1572						
<input type="checkbox"/> Geomet	30.9159						
<input type="checkbox"/> Hypergeo	33.5491						
<input type="checkbox"/> Binomial	N/A						
Distribution Statistics							
Minimum	1.0000		1.0000	0.0000	0.0000	0.0000	0.0000
Maximum	12.0000		12.0000	+Infinity	+Infinity	12.0000	+Infinity
Mean	6.4000		6.5000	6.4000	6.4000	6.4000	6.3861
Mode	6.0000		1.0000	6.0000	5.0000	0.0000	6.0000
Median	6.0000		6.0000	6.0000	6.0000	4.0000	6.0000
Std. Deviation	3.9115		3.4521	2.5298	3.8199	6.8819	2.4791
Skewness	0.1270		0.0000	0.3953	0.9319	2.0053	0.3732
Kurtosis	4.7929		1.7832	3.1563	4.2685	9.0211	3.1278
Percentiles							
5%	1.0000		1.0000	3.0000	1.0000	0.0000	3.0000
10%	1.0000		2.0000	3.0000	2.0000	0.0000	3.0000
15%	1.0000		2.0000	4.0000	3.0000	1.0000	4.0000
20%	1.0000		3.0000	4.0000	3.0000	1.0000	4.0000
25%	6.0000		3.0000	5.0000	4.0000	1.0000	5.0000
30%	6.0000		4.0000	5.0000	4.0000	2.0000	5.0000
35%	6.0000		5.0000	5.0000	4.0000	2.0000	5.0000
40%	6.0000		5.0000	6.0000	5.0000	3.0000	6.0000
45%	6.0000		6.0000	6.0000	5.0000	4.0000	6.0000
50%	6.0000		6.0000	6.0000	6.0000	4.0000	6.0000
55%	6.0000		7.0000	7.0000	6.0000	5.0000	7.0000
60%	6.0000		8.0000	7.0000	7.0000	6.0000	7.0000
65%	7.0000		8.0000	7.0000	7.0000	7.0000	7.0000
70%	7.0000		9.0000	8.0000	8.0000	8.0000	8.0000
75%	7.0000		9.0000	8.0000	9.0000	9.0000	8.0000
80%	7.0000		10.0000	8.0000	9.0000	11.0000	8.0000
85%	12.0000		11.0000	9.0000	10.0000	13.0000	9.0000
90%	12.0000		11.0000	10.0000	12.0000	15.0000	10.0000
95%	12.0000		12.0000	11.0000	14.0000	20.0000	11.0000
Information Criteria							
Akaike (AIC)			34.8491	31.8720	36.9383	32.6398	58.7208
Bayesian (BIC)			28.0679	30.1481	30.1572	30.9159	33.5491
Av. LogL			-2.4849	-2.8539	-2.6938	-2.9306	-2.8721
Chi-Squared Test - (* Values unavailable without running a bootstrap)							
Chi-Sq Statistic			0.0000	0.0000	0.0000	0.0000	0.0000
P-Value*			N/A	N/A	N/A	N/A	N/A
Cr. Value @ 0.750*			N/A	N/A	N/A	N/A	N/A
Cr. Value @ 0.500*			N/A	N/A	N/A	N/A	N/A
Cr. Value @ 0.250*			N/A	N/A	N/A	N/A	N/A
Cr. Value @ 0.150*			N/A	N/A	N/A	N/A	N/A
Cr. Value @ 0.100*			N/A	N/A	N/A	N/A	N/A
Cr. Value @ 0.050*			N/A	N/A	N/A	N/A	N/A
Cr. Value @ 0.025*			N/A	N/A	N/A	N/A	N/A
Cr. Value @ 0.010*			N/A	N/A	N/A	N/A	N/A
Cr. Value @ 0.005*			N/A	N/A	N/A	N/A	N/A
Cr. Value @ 0.001*			N/A	N/A	N/A	N/A	N/A
Chi-Sq Test (Binning Information)							
Bin #1: Minimum			1.0000	0.0000	0.0000	0.0000	0.0000
Bin #1: Maximum			12.0000	+Infinity	+Infinity	+Infinity	202.0000
Bin #1: Input			5.0000	5.0000	5.0000	5.0000	5.0000
Bin #1: Fit			5.0000	5.0000	5.0000	5.0000	5.0000