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Calculation of Buildings Damage Estimation and Retrofit cost

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Building restoration function

(Koliou and van de Lindt, 2019)

$$Q_{ijk}^{t} = \frac{\frac{Q_{ijk}^{0}}{e^{-r_{ijk}t}}}{\frac{Q_{ijk}^{0}}{e^{-r_{ijk}t}} + (1 - Q_{ijk}^{0})}$$

 Q_{ijk}^{t} : Building functionality Q_{ijk}^{0} : Starting level of building functionality right after disaster r_{ijk} : based on Q_{ijk}^{0} and repair time to reach 100% of building functionality t: recovery time after disaster impact

Damage state	Damage factor range (%)
1–None	0
2–Slight	0–1
3–Light	1–10
4–Moderate	10–30
5–Heavy	30–60
6–Major	60–100
7–Destroyed	100

Table 2. ATC-13 Damage States and Corresponding Damage FactorRanges [Adapted from Applied Technology Council (ATC 1985)]

(Bai et al,2009)

There is no study done about the damage states and damage factor for tornado disaster. Therefore, I used the available information from earthquake studies to proposed a table for Joplin project. There is no study done about the damage states and damage factor for tornado disaster. Therefore, we proposed the following table for Joplin project to calculated the loss estimation and initial values of buildings functionality.

Damage State	Damage Factor(%)
None(N)	0
Insignificant(I)	5
Moderate(M)	30
Heavy(H)	68
Complete(C)	100

Tornado Building Fragility Curve Parameters

We use this information to create fragility curve on building type 1 and 5

	Considered Retrofit	Strategies Based on I	Different Types of 2	Roof Covering, Roo	f Sheathing Nailin	g Patterns, and Roof-	to-Wall Connectio	ns			
Retro	ofit strategies #	Roof covering Roof sheathing nailing pattern Roof-to-wall connection type				n type					
Keut	fin strategies #	Asphalt shingles	Clay tiles	8d C6/12	8d C6/6	Two 16d toe nails	H2.5 clip	Two H2.5 clips			
	1	Х	-	Х	-	Х	-	-			
	2	Х	-	-	Х	-	-	X			
	3	-	Х	-	Х	-	-	X			
Note: this table	is referenced from the pap	er written by Masoom	ni et al. (2017)								
			Buildin	g-level Tornado Fra	gility Curves for R	esidential Buildings (A	Archetype 1 - Arcl	hetype 5)			
Damage state	Construction product	Archet	ype 1	Arche	etype 2	Archetype 3 Arche		type 4 Archetype 5			
Damage state	combination #	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ
DS1	1	3.47 (4.28)	0.14 (0.14)	3.44 (4.25)	0.14 (0.13)	3.43 (4.24)	0.14 (0.14)	3.57 (4.37)	0.13 (0.13)	3.41 (4.21)	0.13 (0.13)
	2	3.86 (4.67)	0.14 (0.14)	3.82 (4.62)	0.14 (0.14)	3.82 (4.63)	0.14 (0.14)	3.83 (4.64)	0.14 (0.14)	3.79 (4.59)	0.14 (0.14)
	3	3.87 (4.68)	0.15 (0.15)	3.84 (4.64)	0.14 (0.14)	3.83 (4.64)	0.14 (0.14)	3.96 (4.77)	0.14 (0.14)	3.80 (4.60)	0.14 (0.14)
DS2	1	3.55 (4.35)	0.13 (0.13)	3.51 (4.32)	0.12 (0.12)	3.50 (4.31)	0.12 (0.12)	3.63 (4.44)	0.12 (0.12)	3.47 (4.28)	0.12 (0.12)
	2	3.93 (4.74)	0.13 (0.13)	3.88 (4.68)	0.13 (0.13)	3.89 (4.70)	0.13 (0.13)	3.89 (4.70)	0.12 (0.12)	3.86 (4.66)	0.12 (0.12)
	3	3.95 (4.76)	0.13 (0.13)	3.91 (4.72)	0.12 (0.12)	3.91 (4.71)	0.13 (0.13)	4.04 (4.84)	0.12 (0.12)	3.87 (4.68)	0.12 (0.12)
DS3	1	3.62 (4.42)	0.12 (0.12)	3.57 (4.38)	0.12 (0.12)	3.57 (4.38)	0.12 (0.12)	3.70 (4.50)	0.12 (0.12)	3.53 (4.34)	0.12 (0.12)
	2	4.01 (4.82)	0.12 (0.12)	3.95 (4.75)	0.11 (0.12)	3.97 (4.78)	0.11 (0.11)	4.04 (4.85)	0.11 (0.11)	3.94 (4.74)	0.12 (0.12)
	3	4.03 (4.84)	0.12 (0.12)	3.98 (4.79)	0.12 (0.12)	3.98 (4.79)	0.12 (0.12)	4.10 (4.90)	0.12 (0.12)	3.94 (4.75)	0.12 (0.12)
DS4	1	3.64 (4.45)	0.14 (0.15)	3.57 (4.37)	0.15 (0.14)	3.61 (4.42)	0.14 (0.15)	3.61 (4.41)	0.14 (0.15)	3.50 (4.31)	0.15 (0.15)
	2	4.05 (4.86)	0.12 (0.12)	3.97 (4.77)	0.12 (0.12)	4.03 (4.83)	0.12 (0.12)	4.04 (4.84)	0.11 (0.11)	3.98 (4.78)	0.11 (0.11)
	3	4.24 (5.04)	0.12 (0.12)	4.14 (4.94)	0.12 (0.12)	4.21 (5.02)	0.12 (0.12)	4.18 (4.98)	0.13 (0.13)	4.03 (4.84)	0.14 (0.14)

Note: μ refers to logarithmic mean of curves and σ refers to logarithmic standard deviation of curves, and the unit is m/s (mph).

(Masoomi et al ,2018)

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Actual data of Fragility curve for Joplin

			DS1			DS2			DS3			DS4	
	Mind Crood	Strategy1	Strategy2	Strategy3	Strategy1	Strategy2	Strategy3	Strategy1	Strategy2	Strategy3	Strategy1	Strategy2	Strategy3
	wind speed	3.47	3.86	3.87	3.55	3.93	3.95	3.62	4.01	4.03	3.64	4.05	4.24
		0.14	0.14	0.15	0.13	0.13	0.13	0.12	0.12	0.12	0.14	0.12	0.12
	20	0.0003525	3.34309E-10	2.7972E-09	1.0058E-05	3.31941E-13	1.06382E-13	9.84551E-08	1.4289E-17	3.3801E-18	2.09315E-06	7.7791E-19	1.71732E-25
	24	0.01851969	5.5505E-07	1.9847E-06	0.00211071	3.64288E-09	1.44218E-09	0.000115305	2.0617E-12	6.2581E-13	0.000484087	1.8485E-13	4.39359E-19
	28	0.16249544	8.16343E-05	0.00016834	0.0469328	2.12847E-06	1.00571E-06	0.00823578	8.1023E-09	3.0324E-09	0.013955352	1.1046E-09	1.93988E-14
	32	0.48785096	0.002429981	0.00351844	0.25843253	0.000177632	9.76156E-05	0.099302847	2.8729E-06	1.2869E-06	0.106613016	5.612E-07	5.51187E-11
	36	0.79127397	0.024141751	0.02807474	0.60173403	0.003846682	0.002408037	0.380560576	0.0001897	9.9345E-05	0.343313697	5.0674E-05	2.24162E-08
	40	0.94102363	0.110799063	0.11362554	0.85730818	0.031814294	0.022288746	0.71701456	0.00372528	0.00223686	0.636507505	0.00130909	2.18804E-06
	44	0.98759061	0.294080598	0.28363758	0.9641847	0.131012405	0.101072467	0.914382605	0.02993478	0.02025945	0.848477618	0.01337707	7.28108E-05
	48	0.9979197	0.531884243	0.50319419	0.99325901	0.325526468	0.27220888	0.981840671	0.12370601	0.09286368	0.950675189	0.06811323	0.001058439
Archtype 1	52	0.9997064	0.742715816	0.70596149	0.99898733	0.564903453	0.503816649	0.997113153	0.31219586	0.2558148	0.986897811	0.20526281	0.008057461
	56	0.99996358	0.881215224	0.84982379	0.99987218	0.768365476	0.718917378	0.999634833	0.55089811	0.48455047	0.997043002	0.4186288	0.036828678
	60	0.99999589	0.952923864	0.932625	0.99998588	0.89691889	0.866574329	0.999961391	0.75893204	0.70409145	0.999413403	0.64413663	0.112412948
	64	0.99999957	0.983614559	0.97294077	0.99999859	0.960850247	0.945950102	0.99999645	0.89264029	0.85859442	0.999894849	0.81789152	0.249528479
	68	0.99999996	0.994884346	0.99009828	0.99999987	0.987025773	0.980920197	0.999999707	0.95958562	0.94285844	0.999982585	0.92110805	0.432202654
	72	1	0.998540714	0.99664706	0.99999999	0.996169571	0.994011416	0.999999978	0.9868657	0.98008709	0.999997287	0.97054633	0.62002673
	76	1	0.999613633	0.99893527	1	0.998973873	0.998298185	0.999999998	0.9962387	0.99389664	0.999999597	0.99034378	0.775208727
	80	1	0.999903788	0.99967934	1	0.999746592	0.999555175	1	0.99903312	0.99832448	0.999999942	0.9971703	0.881705426
	84	1	0.999977216	0.99990754	1	0.999941526	0.9998916	1	0.99977324	0.99958132	0.999999992	0.99924687	0.944098373
	88	1	0.999994821	0.99997427	1	0.999987247	0.999975087	1	0.99995079	0.99990342	0.999999999	0.99981538	0.976024746
	92	1	0.999998861	0.99999304	1	0.999997346	0.999994547	1	0.99999	0.99997918	1	0.9999578	0.990568771
	96	1	0.999999756	0.99999816	1	0.999999468	0.999998854	1	0.99999808	0.99999576	1	0.99999091	0.996563145
	100	1	0.999999949	0.99999952	1	0.999999897	0.999999767	1	0.99999965	0.99999918	1	0.99999814	0 998829169
			0.0000000	0.0000000	-			_		0.0000010	-	0.0000001	0.550025105
			DS1		-	DS2			DS3		-	DS4	0.550025105
	Wind Speed	Strategy1	DS1 Strategy2	Strategy3	Strategy1	DS2 Strategy2	Strategy3	Strategy1	DS3 Strategy2	Strategy3	Strategy1	DS4 Strategy2	Strategy3
	Wind Speed	Strategy1 3.41	DS1 Strategy2 3.79	Strategy3 3.8	Strategy1 3.47	DS2 Strategy2 3.86	Strategy3 3.87	Strategy1 3.53	DS3 Strategy2 3.94	Strategy3 3.94	Strategy1 3.5	DS4 Strategy2 3.98	Strategy3 4.03
	Wind Speed	Strategy1 3.41 0.13	DS1 Strategy2 3.79 0.14	Strategy3 3.8 0.14	Strategy1 3.47 0.12	DS2 Strategy2 3.86 0.12	Strategy3 3.87 0.12	Strategy1 3.53 0.12	DS3 Strategy2 3.94 0.12	Strategy3 3.94 0.12	Strategy1 3.5 0.15	DS4 Strategy2 3.98 0.11	Strategy3 4.03 0.14
	Wind Speed	Strategy1 3.41 0.13 0.00071959	DS1 Strategy2 3.79 0.14 7.00196E-09	Strategy3 3.8 0.14 4.6023E-09	Strategy1 3.47 0.12 3.8713E-05	DS2 Strategy2 3.86 0.12 2.96176E-13	Strategy3 3.87 0.12 1.60163E-13	Strategy1 3.53 0.12 4.24913E-06	DS3 Strategy2 3.94 0.12 1.7889E-15	Strategy3 3.94 0.12 1.7889E-15	Strategy1 3.5 0.15 0.000387202	DS4 Strategy2 3.98 0.11 1.8117E-19	Strategy3 4.03 0.14 7.47364E-14
	Wind Speed 20 24	Strategy1 3.41 0.13 0.00071959 0.03719548	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06	Strategy1 3.47 0.12 3.8713E-05 0.00748953	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09	Strategy1 3.53 0.12 4.24913E-06 0.001679143	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10	Strategy1 3.5 0.15 0.000387202 0.015924215	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10
	Wind Speed 20 24 28	Strategy1 3.41 0.13 0.00071959 0.03719548 0.27477758	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07	Strategy1 3.5 0.15 0.000387202 0.015924215 0.131647602	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07
	Wind Speed 20 24 28 32	Strategy1 3.41 0.13 0.00071959 0.03719548 0.27477758 0.66594294	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.48582691	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000377389	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05	Strategy1 3.5 0.15 0.000387202 0.015924215 0.131647602 0.409657028	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05
	Wind Speed 20 24 28 32 36	Strategy1 3.41 0.13 0.00071959 0.03719548 0.27477758 0.66594294 0.90902272	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124458	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938 0.06101688	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.48582691 0.82792345	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000377389 0.008485344	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277 0.672198182	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573	Strategy1 3.5 0.15 0.000387202 0.015924215 0.131647602 0.409657028 0.71116554	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.00015645	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458
	Wind Speed 20 24 28 32 36 40	Strategy1 3.41 0.13 0.00071959 0.03719548 0.27477758 0.66594294 0.90902272 0.98403263	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124458 0.235058219	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938 0.06101688 0.21367976	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.48582691 0.82792345 0.96592362	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.076933514	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000377389 0.008485344 0.065606229	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.49645998 0.296140277 0.672198182 0.907247722	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.01818926	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.01818926	Strategy1 3.5 0.15 0.000387202 0.015924215 0.131647602 0.409657028 0.71116554 0.896020292	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.00015645 0.00015645	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.00741354
	Wind Speed 20 24 28 32 36 40 44	Strategy1 3.41 0.13 0.00071959 0.03719548 0.62594294 0.90902272 0.98403263 0.99800139	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124458 0.235058219 0.483447604	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938 0.06101688 0.21367976 0.45504256	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.48582691 0.82792345 0.96592362 0.99558086	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.076933514 0.263774128	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000377389 0.008485344 0.065606229 0.237277833	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277 0.672198182 0.907247722 0.82922921	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.01818926 0.09707157	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.01818926 0.09707157	Strategy1 3.5 0.15 0.000387202 0.31547602 0.31647602 0.409657028 0.71116554 0.896020292 0.970927131	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.00015645 0.00406587 0.03753027	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.00741354 0.039562279
	Wind Speed 20 24 32 36 40 44 44	Strategy1 3.41 0.13 0.0071959 0.03719548 0.27477758 0.66554294 0.90902272 0.98403263 0.99800139 0.99980569	DS1 Strategy2 3.79 0.14 7.001966-09 6.18269E-06 0.000537799 0.010274436 0.070124458 0.235058219 0.483447604 0.719045126	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938 0.06101688 0.21367976 0.45504256 0.6944762	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.48582691 0.82792345 0.96592362 0.99558086 0.99958026	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.0010611074 0.076933514 0.263774128 0.53718397	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000377389 0.008485344 0.065606229 0.237277833 0.503992717	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277 0.672198182 0.907247722 0.9927267841 0.992767841	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 0.8718E-05 0.00148573 0.01818926 0.09707157 0.28321236	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.01818926 0.09707157 0.28321236	Strategy1 3.5 0.15 0.000387202 0.015924215 0.409657028 0.409657028 0.71116554 0.896020292 0.970927131 0.99332097	DS4 Strategy2 3.98 0.11 1.8117E-19 1.9421E-09 1.4689E-06 0.00015645 0.00406587 0.3753027 0.1631158	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.00741354 0.039562279 0.128338874
Archtype 5	Wind Speed 20 24 28 32 36 40 44 44 48 52	Strategy1 3.41 0.13 0.00071959 0.03719548 0.27477758 0.66594294 0.99403263 0.99800139 0.99980569 0.99988432	DS1 Strategy2 3.79 0.14 7.00196E-09 0.000537799 0.010274436 0.070124438 0.235058219 0.483447604 0.719045126 0.875286209	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938 0.06101688 0.21367976 0.45504256 0.6944762 0.85999843	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.48582691 0.82792345 0.96592362 0.99558086 0.99958086 0.99958082	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.00508946 0.010611074 0.076933514 0.263774128 0.53718397 0.776481578	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.008485344 0.065606229 0.237277833 0.503992717 0.7508066853	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277 0.672198182 0.907247722 0.907247722 0.992767841 0.999776253	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.01818926 0.01818926 0.09707157 0.28321236 0.53732533	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.0148573 0.01818926 0.0387157 0.28321236 0.53732533	Strategy1 3.5 0.15 0.000387202 0.015524215 0.131647602 0.409657028 0.7116554 0.896020292 0.970927131 0.993332097 0.998866395	D54 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.0015645 0.0040587 0.03753027 0.16131158 0.39688403	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.00741354 0.039562279 0.128338874 0.286872422
Archtype 5	Wind Speed 20 24 28 32 36 40 44 44 48 52 56	Strategy1 3.41 0.13 0.00071959 0.03719548 0.27477758 0.66594294 0.99002272 0.98403263 0.99800139 0.99980139 0.99998432 0.99998432	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124458 0.235058219 0.483447604 0.719045126 0.875286209 0.935626652 0.955626652	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938 0.0101688 0.21367976 0.45504256 0.6944762 0.85999843 0.9462634	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.48582691 0.82792345 0.96592362 0.99558086 0.99958086 0.99958612 0.99998612	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.000508946 0.0010611074 0.076933514 0.076933514 0.3774128 0.53718397 0.776481578 0.915887666	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000377889 0.008485344 0.065606229 0.237277833 0.503992717 0.750806853 0.902270429	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.296140277 0.672198182 0.907247722 0.982222921 0.9997767841 0.9997767841	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.00148573 0.09707157 0.28321236 0.53732533 0.7615397	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.0148573 0.0148573 0.01818926 0.09707157 0.28321236 0.53732533 0.7615397	Strategy1 3.5 0.15 0.000387202 0.015924215 0.409657028 0.409657028 0.71116554 0.896020292 0.970927131 0.99332097 0.998866395 0.999769409	D54 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.00015645 0.00406587 0.03753027 0.16131158 0.39688403 0.65993586	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.00741354 0.039562279 0.128338874 0.286872422 0.486756668
Archtype 5	Wind Speed 20 24 28 32 36 40 40 44 48 52 56 60 0	Strategy1 3.41 0.13 0.00071959 0.03719548 0.27477758 0.69594294 0.9990272 0.98403263 0.99980139 0.99980569 0.99998432 0.9999993 0.99999993	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124458 0.235058219 0.483447604 0.719045126 0.875286209 0.855326652	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938 0.06101688 0.21367976 0.45504256 0.6944762 0.85998843 0.9462634 0.9462634	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.48582691 0.82792345 0.96592362 0.99558086 0.99958612 0.99996969 0.99999815 0.999999815	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.010611074 0.076933514 0.263774128 0.53778397 0.53718397 0.53718397 0.915887666 0.974582579	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000477389 0.008485344 0.065606229 0.237277833 0.503992717 0.750806853 0.902270429 0.9092276	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.49645998 0.296140277 0.672198182 0.907247722 0.982922921 0.997767841 0.999776253 0.999981698 0.999998177	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.001818926 0.09707157 0.28321236 0.53732533 0.7615397 0.90081418	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.01818926 0.09707157 0.28321236 0.537322533 0.7615397 0.90081418	Strategy1 3.5 0.15 0.000387202 0.015924215 0.31547602 0.409657028 0.71116554 0.896020292 0.970927131 0.99332097 0.999868395 0.999962884 0.999962884	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.00015645 0.00406587 0.034568403 0.39688403 0.39688403 0.39688403	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.00741354 0.039562279 0.128338874 0.286872422 0.486756668 0.677099762
Archtype 5	Wind Speed 20 24 32 36 40 44 44 48 52 56 60 60 64	Strategy1 3.41 0.13 0.00071959 0.63719548 0.27477758 0.66594294 0.99002272 0.98403263 0.99980569 0.99998432 0.99998432 0.9999893 0.99999893 1	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124438 0.235058219 0.483447604 0.719045126 0.875286209 0.953626652 0.985143291 0.995791638	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.06101688 0.21367976 0.45504256 0.6944762 0.85999843 0.9462634 0.94824355	Strategy1 3.47 0.12 3.8713E-05 0.0748953 0.12542325 0.48582691 0.82792345 0.96592362 0.99558086 0.9958612 0.99958612 0.99999815 0.9999991 1	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.076933514 0.263774128 0.53718397 0.776481578 0.915887666 0.914582579 0.93625277	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 0.00377E-06 0.00377839 0.008485344 0.065606229 0.237277833 0.503992717 0.750806853 0.902270429 0.902270429 0.902270429	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277 0.672198182 0.907247722 0.9222921 0.997767841 0.999776253 0.999976253 0.999998109	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.01818926 0.09707157 0.28321236 0.39732533 0.7615397 0.760592591	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.00148573 0.001818926 0.09707157 0.28321236 0.53732533 0.7615397 0.90081418 0.96592591	Strategy1 3.5 0.15 0.000387202 0.015524215 0.131647602 0.409657028 0.71116554 0.896020292 0.970927131 0.99332097 0.998866395 0.999769409 0.999962884 0.99994339	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.00015645 0.00015645 0.00046587 0.03753027 0.16131158 0.39688403 0.65993586 0.65993586 0.85071295 0.94804749 0.4007295	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.00071354 0.0039562279 0.128338874 0.286872422 0.4286756668 0.486756668 0.486756668
Archtype 5	Wind Speed 20 24 32 36 40 44 48 52 56 60 00 64 64 68 87 72	Strategy1 3.41 0.13 0.00071959 0.03719548 0.27477758 0.66594294 0.90902272 0.98403263 0.99900139 0.999908432 0.99999893 0.99999893 1 1	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124438 0.235058219 0.483447604 0.719045126 0.875286209 0.953526652 0.985542321 0.98591638 0.9989222 0.9989222	Strategy3 3.8 0.14 4.6023E-09 4.4455E-06 0.00041679 0.00847938 0.06101688 0.01610688 0.21367976 0.45504256 0.6594762 0.85599843 0.9642634 0.994281813 0.99481813	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.48582631 0.82792345 0.94558086 0.9995802362 0.99998023 0.99999815 0.99999815 0.9999991 1 1	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.263774128 0.53718397 0.776481578 0.93482579 0.993625277 0.998631808	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000377389 0.008485344 0.065606229 0.237277833 0.902270429 0.950806853 0.902270429 0.991965818 0.992266	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277 0.672198182 0.907247722 0.98222921 0.9997767841 0.9997767841 0.999981698 0.999981698	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.0148573 0.09707157 0.28321236 0.99081418 0.90081418 0.96592591 0.9007658	Strategy3 3,94 0,12 1,7889E-15 1,0797E-10 2,0424E-07 3,8718E-05 0,00148573 0,00148573 0,009701757 0,28321260 0,09707157 0,28321260 0,09704157 0,90081418 0,90582591 0,9007658	Strategy1 3.5 0.15 0.000387202 0.015524215 0.131647602 0.409657028 0.71116554 0.896020292 0.970927131 0.99886395 0.999769409 0.999962884 0.9999963499 0.999999194	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.00015645 0.00406587 0.03753027 0.03753027 0.16131158 0.39688403 0.65993586 0.65907255 0.94804749 0.98507125	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.00741354 0.039562279 0.128338874 0.286872422 0.486756668 0.677099762 0.821368639 0.91207221
Archtype 5	Wind Speed 20 24 32 36 40 40 44 48 52 56 6 6 60 64 68 72 77	Strategy1 3.41 0.13 0.0071959 0.03719548 0.03719548 0.03719548 0.0370272 0.99800139 0.99800139 0.99980569 0.9999832 0.9999893 1 1 1 1	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124436 0.235058219 0.483447604 0.719045126 0.875286209 0.953626652 0.985143291 0.995791638 0.9985143291	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938 0.06101688 0.21367976 0.45504256 0.6944762 0.9462634 0.9462634 0.9462634 0.9462634 0.948648131 0.99866489	Strategy1 3.477 0.12 3.8713F-05 0.48582691 0.12542325 0.48582691 0.96592362 0.99558086 0.99958612 0.99998615 0.99999815 0.99999999 1.1 1.1	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.263774128 0.53718397 0.776481578 0.915887666 0.974582579 0.998631808 0.999741911 0.998631808	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 0.0003778-06 0.00037789 0.0655066229 0.237277833 0.503992717 0.750806853 0.902270429 0.999226 0.9992526 0.999165818 0.998207628	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277 0.672198182 0.907247722 0.982922921 0.997767841 0.999976253 0.9999981698 0.999999817 0.999999851 0.999999995 1.000000000000000000000000000000000000	DS3 Strategy2 3.94 0.12 1.7898-15 1.0797E-10 2.0424E-07 3.8718E-05 0.01818926 0.09107157 0.28321236 0.01818926 0.09707157 0.28321236 0.53732533 0.7615397 0.90681418 0.96592591 0.990076589 0.990748847 0.9002157	Strategy3 3,94 0,12 1,7889E-15 1,0797E-10 2,0424E-07 3,8718E-05 0,00148573 0,01818926 0,09707157 0,28321236 0,01818926 0,9307658 0,99007658 0,99007658	Strategy1 3.5 0.00387202 0.0015924215 0.311647602 0.409657028 0.71116554 0.896020292 0.970927131 0.99386395 0.999962884 0.999962884 0.9999962884 0.999999194	DS4 Strategy2 3.98 0.011 1.8117F-19 1.545E-13 1.9421E-09 1.4689E-06 0.0015645 0.00406587 0.00406587 0.03753027 0.16131158 0.39688403 0.65993586 0.39688403 0.39588472 0.94804749 0.9852725 0.9850127 0.9850127	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000714358 0.00741354 0.039562279 0.128338874 0.286872422 0.486756668 0.6271636639 0.92107221 0.960956975
Archtype 5	Wind Speed 20 24 28 32 36 40 44 48 52 56 60 60 64 68 72 2 76	Strategy1 3.41 0.13 0.00071959 0.03719548 0.66594294 0.9090272 0.98403263 0.98403263 0.99800139 0.99998432 0.99998432 0.9999993 1 1 1 1 1	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124458 0.0235058219 0.483447604 0.719045126 0.875286209 0.953626652 0.985143291 0.995791638 0.9989222 0.999745701 0.999943856	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938 0.06101688 0.21367976 0.45504256 0.6544762 0.8599843 0.9462643 0.948224455 0.94824445 0.9986344 0.99866849 0.999866849	Strategyl 3.47 0.12 3.8713E-05 0.48582691 0.12542325 0.48582691 0.82792345 0.9558068 0.99958612 0.99958612 0.999598612 0.9999999 1 1 1 1 1	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.076933514 0.263774128 0.53718397 0.776481578 0.915887666 0.915887666 0.9974582579 0.998631808 0.999861808 0.9999562337 0.9998528277 0.998631808 0.999741911 0.999956233	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000377389 0.008485344 0.065666229 0.037277833 0.503992717 0.750806853 0.902270429 0.969226 0.991965818 0.998207628 0.999820762	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277 0.672198182 0.907247722 0.9077247722 0.9927767841 0.9997767841 0.9999767841 0.9999981698 0.9999981698 0.99999992 0.99999992 1 1 1 1	D53 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.01818926 0.030707157 0.23321236 0.53732533 0.7615397 0.90081418 0.99070454 0.99074847 0.990748525 0.99748525	Strategy3 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.00148573 0.001818926 0.03707157 0.28321236 0.53732533 0.5615397 0.90081418 0.96027658 0.99007684 0.99004525	Strategy1 3.5 0.15 0.000387202 0.015924215 0.131647602 0.409657028 0.71116554 0.896020292 0.970927131 0.99332097 0.998686395 0.999962884 0.999994389 0.999999134 0.999999388 0.999999388	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.00015645 0.00406587 0.00375027 0.16131158 0.39688403 0.65993586 0.85071295 0.94804749 0.985071295 0.98650127 0.9992849 0.9992849 0.9902849	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.007741354 0.039562279 0.128338874 0.286872422 0.486756668 0.677099762 0.486756668 0.677099762 0.921368639 0.91207221 0.960956975 0.984146907
Archtype 5	Wind Speed 20 24 28 32 36 40 44 48 52 56 60 0 60 60 64 68 72 2 76 80 80	Strategy1 3.41 0.13 0.00071959 0.03719548 0.27477758 0.66594294 0.9900272 0.98403263 0.9998032 0.9998032 0.9998032 1 1 1 1 1 1 1	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124458 0.235058219 0.483447604 0.719045126 0.875286209 0.953626652 0.98542321 0.995791638 0.9989222 0.999745701 0.99943856	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041793 0.00847938 0.06101688 0.01367976 0.45504256 0.6944762 0.85999843 0.9462634 0.9462634 0.99966889 0.99996188 0.9999639	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.4858263 0.9458266 0.9995806 0.9995806 0.99959806 0.9999815 0.99999815 0.99999815 1 1 1 1 1 1 1	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.263774128 0.53718397 0.776481578 0.93625277 0.998631808 0.999956233 0.99995233 0.9999912	Strategy3 3.87 0.12 1.60163F-13 4.05351E-09 0.00377E-06 0.0037789 0.008485344 0.065606229 0.337277833 0.30392717 0.750806853 0.392270429 0.969226 0.991965818 0.99963814 0.99938344	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.926140277 0.672198182 0.907247722 0.997767841 0.999776253 0.9999981698 0.999998107 0.99999992 0.99999995 1 1 1	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.0148573 0.03070157 0.28321236 0.53732533 0.90081448 0.90081454 0.9008147 0.9907658 0.99948525 0.90084525 0.90084525	Strategy3 3,94 0,12 1,7889E-15 1,0797E-10 2,0424E-07 3,8718E-05 0,00148573 0,01818926 0,03701557 0,28321236 0,5372533 0,90081418 0,90081418 0,90081418 0,99048847 0,990484525 0,99948525	Strategy1 3.5 0.15 0.000387202 0.015524215 0.131647602 0.71116554 0.896020292 0.970927131 0.99332097 0.998868395 0.99995439 0.99995439 0.999994388 0.999999318 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999988 0.999999988 0.999999988 0.999999988 0.999999988 0.999999988 0.999999988 0.999999988 0.999999988 0.9999999888 0.9999999888 0.999999988 0.999999988 0.999999988 0.999999988 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.999999888 0.99999888 0.99999888 0.99999888 0.99999888 0.99999888 0.99999988 0.999999888 0.999999888 0.99999888 0.9999888 0.9999888 0.99999888 0.99999888 0.9999888 0.9999888 0.9999888 0.999988 0.9999888 0.999988 0.9999888 0.9999888 0.999988 0.9999888 0.999988 0.9999888 0.9999888 0.999988 0.9999888 0.9999888 0.999988 0.9999888 0.999988 0.9999888 0.9999888 0.9999888 0.999988 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.99999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.9999888 0.999988 0.9999888 0.9999888 0.9999888 0.9999888 0.999888 0.9999888 0.9998888 0.9998888 0.999888 0.999888 0.999888	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.0015645 0.0406587 0.03758027 0.03758027 0.3658403 0.65993586 0.98507127 0.99850127 0.99950127 0.99958713 0.99928713	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.00741354 0.039562279 0.128338874 0.286872422 0.382652279 0.128338874 0.286872422 0.3950556975 0.984146907 0.9903556975 0.984146907
Archtype 5	Wind Speed 20 24 28 32 36 40 44 48 52 56 60 64 48 76 60 64 68 72 766 80 84 49	Strategy1 3.41 0.13 0.00071959 0.03719548 0.27477758 0.66594294 0.90902272 0.98403263 0.999080139 0.9999983 0.9999983 1 1 1 1 1 1 1 1 1	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124438 0.235058219 0.483447604 0.719045126 0.875286209 0.953526652 0.985143291 0.9989222 0.998791638 0.9989222 0.999745701 0.999943856 0.999943856	Strategy3 3.8 0.14 4.6023E-09 4.4455E-06 0.00041679 0.00847938 0.06101688 0.016101688 0.05494762 0.85599843 0.9642634 0.99481813 0.99481813 0.99486344 0.99998649 0.99999669 0.99999669	Strategy1 3.47 0.12 3.8713E-05 0.00748953 0.12542325 0.48582631 0.82792345 0.94558086 0.9995802 0.9999802 0.99999999 1 1 1 1 1 1 1 1 1 1 1 1	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.263774128 0.53718397 0.776481578 0.939625277 0.998631808 0.999425277 0.998631808 0.999956233 0.99999321 0.999999017	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000377389 0.008485344 0.065606229 0.237277833 0.902270429 0.969226 0.991965818 0.999207628 0.999965818 0.9999649112 0.999988344 0.99990889 0.999990819	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277 0.672198182 0.9077247722 0.982722921 0.9997767841 0.9999767841 0.999981698 0.999981698 0.999999995 1 1 1 1 1 1	DS3 Strategy2 3.94 0.12 1.7889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.0148573 0.09707157 0.9821226 0.99041553 0.9007058 0.9907458 0.99943525 0.99948847 0.9994855 0.999885 0.99098744	Strategy3 3,94 0,12 1,7889E-15 1,0797E-10 2,0424E-07 3,8718E-05 0,00148573 0,00148573 0,0970157 0,2832126 0,0970157 0,9090145 0,90592591 0,9001658 0,9974847 0,9994855 0,999485 0,999885	Strategy1 3.5 0.000387202 0.015924215 0.131647602 0.409657028 0.71116554 0.896020292 0.970927131 0.998686395 0.999769409 0.9999962884 0.9999994399 0.999999439 0.9999999194 0.999999985 0.999999988 1 1	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.00015645 0.03753027 0.16131158 0.85071295 0.94804749 0.94804749 0.9925249 0.9995812 0.9999713 0.9999719	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 0.78342E-05 0.000713458 0.039562279 0.128338874 0.286872422 0.486756668 0.627099762 0.4821368639 0.91207221 0.960956975 0.984146907 0.984146907 0.994039529 0.997901596
Archtype 5	Wind Speed 20 24 28 32 36 400 44 48 52 56 60 60 64 68 72 76 800 84 88 872 76	Strategy1 3.41 0.13 0.00071959 0.03719548 0.03719548 0.03719548 0.0390272 0.99403263 0.99403263 0.99908059 0.99998432 0.99998432 0.9999993 1 1 1 1 1 1 1 1 1 1 1 1 1	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124458 0.035058219 0.483447604 0.719045126 0.945326652 0.985143291 0.995791638 0.9989222 0.999745701 0.999943856 0.999994354 0.999999545	Strategy3 3.8 0.14 4.6023E-09 4.4465E-06 0.00041679 0.00847938 0.0101688 0.21367976 0.45504256 0.6944762 0.85999843 0.9462634 0.94826444 0.99866444 0.9996689 0.999992496 0.99999549	Strategyl 3.47 0.12 3.8713F-05 0.00748953 0.012542325 0.48582691 0.82792345 0.99558086 0.99558086 0.99598612 0.99998692 0.99999699 1 1 1 1 1 1 1 1 1 1	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.263774128 0.53718397 0.776481578 0.9915837666 0.974582579 0.993625277 0.998631808 0.999956233 0.999956231 0.999956231 0.999956237 0.998625279 0.998625279 0.998625279 0.998625279 0.998625279 0.998625279 0.99852318 0.999956231 0.99956231 0.9956231 0.9956231 0.9956231 0.9956231 0.9956231 0.9956231 0.9956231 0.99562577 0.99562577 0.99562577 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.9956757 0.99567577 0.99567577 0.99567577 0.99567577 0.99567577 0.995675777 0.9956777777 0.995677777 0.995677777 0.995677777 0.9	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 0.000377389 0.008485344 0.065566229 0.237277833 0.503992717 0.750806853 0.902270429 0.992926 0.9992581 0.999207628 0.99938344 0.99990899 0.99999089	Strategy1 3.53 0.12 4.24913E-06 0.049645998 0.296140277 0.672198182 0.907247722 0.982922921 0.997767841 0.9997767841 0.9999767841 0.9999981698 0.9999981698 0.9999981698 0.999999995 1 1 1 1 1 1 1 1	D53 Strategy2 3.94 0.12 7.7898-15 1.0797E-10 2.0424E-07 2.0424E-07 3.8718E-05 0.012182926 0.09707157 0.28321236 0.053732533 0.7615397 0.90081418 0.9907658 0.9907484847 0.99074585 0.999784847 0.99997844 0.999997844 0.999997844 0.99999623	Strategy3 3.94 0.12 1.7898F-15 1.0797F-10 2.0424E-07 3.8718E-05 0.00148573 0.01818926 0.01818926 0.01818926 0.053732533 0.90081418 0.96052591 0.99007658 0.99074847 0.99974847 0.99997844 0.99997844	Strategy1 3.5 0.00387202 0.015924215 0.313647602 0.409657028 0.71116554 0.896020292 0.970927131 0.993332097 0.998686395 0.999962884 0.999992888 0.999999194 0.999999194 0.999999194 0.999999194 0.999999194 0.999999114 0.99999114 0.99999114 0.99999114 0.999114 0.9999114 0.9999114 0.999114	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.4689E-06 0.0015545 0.0406587 0.04753027 0.1513158 0.39688403 0.65993586 0.98627255 0.99650127 0.98527255 0.999651127 0.9992849 0.99987113 0.99999719 0.99999719	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.007741354 0.039562279 0.128338874 0.286872422 0.486756668 0.677099762 0.486756668 0.677099762 0.921368639 0.91207221 0.960956975 0.984146907 0.994039529 0.997901596 0.999301835
Archtype 5	Wind Speed 20 24 28 32 36 40 44 48 52 566 60 64 64 68 72 76 80 84 48 88 92 92 92	Strategy1 3.41 0.13 0.00071959 0.03719548 0.66594294 0.909403263 0.99800139 0.999803569 0.999803569 0.9999832 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	DS1 Strategy2 3.79 0.14 7.00196E-09 6.18269E-06 0.000537799 0.010274436 0.070124458 0.235058219 0.483447604 0.719045126 0.875286209 0.953626652 0.985143291 0.995791638 0.9989222 0.999745701 0.999943856 0.999943856 0.999945701	Strategy3 3.8 0.14 4.6023E-09 4.4455E-06 0.00041679 0.00041679 0.00041679 0.45504256 0.6944762 0.45504256 0.6944762 0.94526436 0.9462644 0.9462644 0.9996830 0.999992496 0.999992496 0.9999934	Strategyl 3.47 0.12 3.8713E-05 0.48582691 0.12542325 0.48582691 0.82792345 0.99558066 0.99958060 0.99958612 0.999598612 0.999998619 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	DS2 Strategy2 3.86 0.12 2.96176E-13 6.62208E-09 5.45521E-06 0.000508946 0.010611074 0.076933514 0.263774128 0.53718397 0.7764815786 0.997482579 0.993625277 0.998631808 0.9999341911 0.99999362 0.999999017 0.999999017 0.9999999017 0.999999866 0.99999866 0.99999866 0.99999866 0.999999866 0.999999866 0.999999866 0.999999866 0.99999886 0.99999886 0.99999886 0.99999886 0.99999886 0.99999886 0.99999886 0.99999886 0.99999886 0.9999886 0.9999886 0.99999886 0.9999886 0.9999886 0.99999886 0.9999886 0.9999886 0.9999886 0.99999886 0.9999886 0.9999886 0.9999886 0.999988 0.9999886 0.99999886 0.99999886 0.99999886 0.9999886 0.999988 0.998888 0.998888 0.99888 0.998888 0.998888 0.9988888 0.998888888 0.998888888 0.99888888888888 0.9988888888888888888888888888888888888	Strategy3 3.87 0.12 1.60163E-13 4.05351E-09 3.70377E-06 0.000377389 0.008485344 0.065606229 0.037277833 0.503992717 0.750806853 0.902270429 0.99226 0.991965818 0.999649112 0.999938314 0.9999908519 0.999999792	Strategy1 3.53 0.12 4.24913E-06 0.001679143 0.049645998 0.296140277 0.672198182 0.907767841 0.999776253 0.999776253 0.99999992 0.999999992 1 1 1 1 1 1 1 1 1	DS3 Strategy2 3.94 0.12 7.7889E-15 1.77889E-15 1.0797E-10 2.0424E-07 3.8718E-05 0.01818926 0.00476175 0.09707157 0.28321236 0.7615397 0.90081418 0.99007658 0.99748847 0.99943525 0.9999885 0.99999384 0.99999384	Strategy3 3,94 0,12 1,7889E-15 1,0797E-10 2,0424E-07 3,8718E-05 0,0148573 0,01818926 0,0970157 0,28321236 0,5973253 0,90081418 0,99625591 0,99948525 0,9999885 0,9999844 0,9999938	Strategy1 3.5 0.15 0.000387202 0.0155924215 0.311647602 0.409657028 0.71116554 0.896020292 0.970927131 0.99332097 0.998686395 0.999962884 0.999994399 0.999994399 0.999999194 0.9999999194 0.999999988 0.999999988 0.999999988 1 1 1	DS4 Strategy2 3.98 0.11 1.8117E-19 1.545E-13 1.9421E-09 1.9421E-09 1.4689E-06 0.0015645 0.00406587 0.03753027 0.16131158 0.365804709 0.94820725 0.94820725 0.94501277 0.99958123 0.99997913 0.99995813 0.99999918 0.99999918	Strategy3 4.03 0.14 7.47364E-14 5.81259E-10 3.11007E-07 2.78342E-05 0.000713458 0.00741354 0.039562279 0.128338874 0.286872422 0.486756668 0.677099762 0.821368639 0.91207221 0.960956975 0.984146907 0.994039529 0.997901596 0.999301483 0.999778274

Tornado Building Fragility Curve

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Damage		Dai	mage indicators	
state	Roof covering failure	Window/door failure	Roof sheathing failure	Roof-to-wall connection failur
1	$>2\%$ and $\le 15\%^{a}$	1^a	No	No
2	$>15\%$ and $\leq 50\%^{a}$	2 or 3 ^a	$1 - 3^{a}$	No
3	>50% ^a	>3 ^a	>3 and $\leq 35\%^{a}$	No
4	Typically $> 50\%$	Typically > 3	>35% ^a	Yes ^a



Structure associated with the fragility curve Wood frame residential building (Multi-family building)

Building Economic Loss Estimation

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Calculate the estimation of loss of building at zone i = 1 of archetype j = 5 at level k = 1 (M_{15} : appraised value of buildings for building in block 1 of archetype 5)

 $l_{151} = (P_{N|WS} \times 0 + P_{I|WS} \times 0.05 + P_{M|WS} \times 0.3 + P_{H|WS} \times 0.68 + P_{C|WS} \times 1) \times M_{15}$

Calculate Q_{ijk}^0

Damage State	Damage Factor(%)					
None(N)	0					
Insignificant(I)	5					
Moderate(M)	30					
Heavy(H)	68					
Complete(C)	100					
$Q_{ijk}^0(WS)$						
= 1 - E[percentage loss of building]						

 $Q_{151}^{0}(WS = 135mph)$ = 1 - (P_{N|WS}× 0 + P_{I|WS}× 0.05 + P_{M|WS}× 0.3 + P_{H|WS}× 0.68 + P_{C|WS}× 1)

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Damage state	Description
Insignificant (I)	Damage requires no more than cosmetic repair. No structural repairs are necessary. For nonstructural elements, repairs could include spackling, partition cracks, picking up spilled contents, putting back fallen ceiling tiles, and righting equipment.
Moderate (M)	Repairable SD has occurred. The existing elements can be repaired essentially in place, without substantial demolition or replacement of elements. For nonstructural elements, repairs would include minor replacement of damaged partitions, ceilings, contents, and equipment or their anchorages.
Heavy (H)	While the damage is significant, the structure is still standing. SD would require major repairs, including substantial demolition or replacement of elements. For nonstructural elements, repairs would include major replacement of damaged partitions, ceilings, contents, equipment or their anchorages.
Complete (C)	Damage is so extensive that repair of most structural elements is not feasible. Structure is destroyed or most of the structural members have reached their ultimate capacities.
	(Bai et al.2009)

Strategy Cost Calculation – Building type

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Image: Construction of the second state of the second s



Retrofit Strategies



Retrofit	Roof covering		Roof sheat pat	hing nailing tern	Roof-to-wall connection type		
strategies	Asphalt shingles	Clay tiles	8d C6/12	8d C6/6	Two 16d toe nails	H2.5 clip	Two H2.5 clips
1	х	-	х	-	Х	-	-
2	х	-	-	Х	-	-	Х
3	-	х	-	Х	-	-	Х

Retrofit Strategy	Archetype	Retrofit cost percentage (
Stratogy 1	1	0.1141
Strategy 1	5	0.0826
Ctrate av 2	1	0.1733
Strategy 2	5	0.1434
Churche and D	1	0.3533
Strategy 3	5	0.2574

The final retrofit cost =

Appraisal Value of the building * Retrofit cost percentage