

Article

Agent Based Model to Estimate Time to Restoration of Storm-Induced Power Outages

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Supplementary Materials

Table S1. R², MAE and standard deviation of modeled restoration curves from Figure 2.

Storm	Crew Start	Search Strategy	Repair Time Range (hrs)	R ²	MAE (customers per hour)	Standard Deviation
Storm 1	AWC	Most Outages	1 to 7	0.94	1521.33	7101.68
Storm 1	AWC	Nearest	1 to 7	0.93	1656.37	7476.97
Storm 1	AWC	Nearest within Radius	1 to 7	0.94	1666.37	7144.03
Storm 1	AWC	Fastest Repair Time	1 to 7	0.97	962.35	6544.29
Storm 1	AWC	Fastest Repair Time within Radius	1 to 7	0.95	2019.68	7644.88
Storm 1	AWC	Fastest Repair Time and Maximum Customers	1 to 7	0.97	908.9	6347.44
Storm 1	Random	Most Outages	1 to 7	0.9	1999.85	7863.24
Storm 1	Random	Nearest	1 to 7	0.96	1334.49	7202.95
Storm 1	Random	Nearest within Radius	1 to 7	0.95	1392.28	6705.20
Storm 1	Random	Fastest Repair Time Outages	1 to 7	0.95	2255.92	6368.60
Storm 1	Random	Fastest Rrepair Time within Radius	1 to 7	0.96	1150.88	6900.30
Storm 1	Random	Fastest Repair Time and Most Customers	1 to 7	0.93	2243.37	6749.33
Storm 2	AWC	Most Outages	1 to 13	0.94	8843.04	17442.81
Storm 2	AWC	Nearest	1 to 13	0.91	5411.44	19386.00
Storm 2	AWC	Nearest within Radius	1 to 13	0.89	6243.71	20486.54
Storm 2	AWC	Fastest Repair Time	1 to 13	0.97	3704.87	17397.89
Storm 2	AWC	Fastest Repair Time within Radius	1 to 13	0.91	5525.18	17397.89
Storm 2	AWC	Fastest Repair Time and Maximum Customers	1 to 13	0.89	11759.2	17559.86
Storm 2	Random	Most Outages	1 to 13	0.93	6395.96	19996.08
Storm 2	Random	Nearest	1 to 13	0.91	5423.3	18268.16
Storm 2	Random	Nearest within Radius	1 to 13	0.98	7346.1	18937.42
Storm 2	Random	Fastest Repair Time Outages	1 to 13	0.93	6804.23	20918.59
Storm 2	Random	Fastest Rrepair Time within Radius	1 to 13	0.91	5321.12	18313.75
Storm 2	Random	Fastest Repair Time and Most Customers	1 to 13	0.93	4264.41	18501.83
Storm 3	AWC	Most Outages	1 to 9	0.95	754.85	4308.54
Storm 3	AWC	Nearest	1 to 9	0.9	1094.51	4403.35
Storm 3	AWC	Nearest within Radius	1 to 9	0.92	875.38	3928.36
Storm 3	AWC	Fastest Repair Time	1 to 9	0.97	662.23	3941.78

Storm 3	AWC	Fastest Repair Time within Radius	1 to 9	0.95	735.78	4040.33
Storm 3	AWC	Fastest Repair Time and Maximum Customers	1 to 9	0.91	910.71	4140.65
Storm 3	Random	Most Outages	1 to 9	0.9	1050.98	4707.76
Storm 3	Random	Nearest	1 to 9	0.96	993.78	3500.34
Storm 3	Random	Nearest within Radius	1 to 9	0.93	898.77	4481.08
Storm 3	Random	Fastest Repair Time Outages	1 to 9	0.74	1896.63	4683.91
Storm 3	Random	Fastest Rrepair Time within Radius	1 to 9	0.86	1187.06	4220.87
Storm 3	Random	Fastest Repair Time and Most Customers	1 to 9	0.84	1506.83	4194.73
Storm 4	AWC	Most Outages	1 to 13	0.91	9861.29	23484.46
Storm 4	AWC	Nearest	1 to 13	0.98	3895.57	29564.30
Storm 4	AWC	Nearest within Radius	1 to 13	0.98	4061.35	30510.87
Storm 4	AWC	Fastest Repair Time	1 to 13	0.98	2633.03	25023.54
Storm 4	AWC	Fastest Repair Time within Radius	1 to 13	0.99	2233.73	27746.07
Storm 4	AWC	Fastest Repair Time and Maximum Customers	1 to 13	0.92	5758	24257.37
Storm 4	Random	Most Outages	1 to 13	0.86	12609.17	29146.42
Storm 4	Random	Nearest	1 to 13	0.99	2970.47	27930.11
Storm 4	Random	Nearest within Radius	1 to 13	0.87	13248.99	21812.31
Storm 4	Random	Fastest Repair Time Outages	1 to 13	0.97	4561.43	26271.34
Storm 4	Random	Fastest Rrepair Time within Radius	1 to 13	0.98	8744.26	28874.69
Storm 4	Random	Fastest Repair Time and Most Customers	1 to 13	0.97	3468.79	25568.69
Storm 5	AWC	Most Outages	1 to 11	0.94	1783.42	6171.16
Storm 5	AWC	Nearest	1 to 11	0.98	1219.57	5668.15
Storm 5	AWC	Nearest within Radius	1 to 11	0.95	1068.25	5896.76
Storm 5	AWC	Fastest Repair Time	1 to 11	0.98	775.01	4440.09
Storm 5	AWC	Fastest Repair Time within Radius	1 to 11	0.96	1513.02	5652.65
Storm 5	AWC	Fastest Repair Time and Maximum Customers	1 to 11	0.93	1937.21	5649.18
Storm 5	Random	Most Outages	1 to 11	0.93	1544.54	6071.35
Storm 5	Random	Nearest	1 to 11	0.95	1462.11	5777.63
Storm 5	Random	Nearest within Radius	1 to 11	0.94	1557.19	5868.36
Storm 5	Random	Fastest Repair Time Outages	1 to 11	0.95	1646	5614.55
Storm 5	Random	Fastest Rrepair Time within Radius	1 to 11	0.98	545.18	5231.42
Storm 5	Random	Fastest Repair Time and Most Customers	1 to 11	0.94	1818.14	5626.37

Table S2. R², MAE and standard deviation of modeled restoration curves from Figure 4.

Storm	Min. Repair Time (hrs)	Max Repair Time (hrs)	R ²	MAE (customers per hour)	Standard Deviation
Storm 1	1	1	0.63	1003.07	2725.03
Storm 1	1	2	0.73	857.47	3050.95
Storm 1	1	3	0.84	643.95	3530.35
Storm 1	1	4	0.89	561.67	3829.78
Storm 1	1	5	0.93	416.32	3983.13
Storm 1	1	6	0.95	459.68	4421.56
Storm 1	1	7	0.96	411.92	4579.69
Storm 1	1	8	0.96	476.26	4838.46
Storm 1	1	9	0.95	560.89	4955.27
Storm 1	1	10	0.94	714.01	5233.78
Storm 1	1	11	0.92	859.6	5369.46
Storm 1	1	12	0.91	1088.06	5471.15
Storm 1	1	13	0.87	1488.5	5636.25
Storm 1	1	14	0.85	1584.62	5562.23
Storm 1	1	15	0.83	1872.21	5758.82
Storm 2	1	1	0.50	11858.84	10210.04
Storm 2	1	2	0.60	10993.52	11735.52
Storm 2	1	3	0.73	9909.29	12898.46
Storm 2	1	4	0.72	9800.92	13346.71
Storm 2	1	5	0.80	9058.81	13809.08
Storm 2	1	6	0.85	7803.49	15371.46
Storm 2	1	7	0.90	6643.03	16003.26
Storm 2	1	8	0.91	5993.78	16662.68
Storm 2	1	9	0.92	5477.39	16870.57
Storm 2	1	10	0.94	5157.44	16353.06
Storm 2	1	11	0.94	4240.07	17295.84
Storm 2	1	12	0.94	3837.29	18433.79
Storm 2	1	13	0.94	3625.22	18630.13
Storm 2	1	14	0.92	4231.45	19527.39
Storm 2	1	15	0.92	4058.23	18667.35
Storm 3	1	1	0.48	1816.28	2224.29
Storm 3	1	2	0.64	1621.16	2451.39
Storm 3	1	3	0.76	1396	2790.99
Storm 3	1	4	0.83	1254.32	2920.13
Storm 3	1	5	0.93	879.38	3344.76
Storm 3	1	6	0.96	727.13	3385.62
Storm 3	1	7	0.96	740.08	3248.18
Storm 3	1	8	0.98	405.6	3728.86
Storm 3	1	9	0.98	388.3	3702.99
Storm 3	1	10	0.94	575.03	3951.83
Storm 3	1	11	0.91	686.07	3709.24
Storm 3	1	12	0.93	656.29	3886.25
Storm 3	1	13	0.92	742.51	3761.20

Storm 3	1	14	0.91	831.87	3820.70
Storm 3	1	15	0.82	1307.79	3869.17
Storm 4	1	1	0.38	14108.05	13417.94
Storm 4	1	2	0.48	13142.39	15452.91
Storm 4	1	3	0.60	11878.34	17354.63
Storm 4	1	4	0.67	10880.17	19025.76
Storm 4	1	5	0.76	9667.56	20419.09
Storm 4	1	6	0.84	8199.64	22103.93
Storm 4	1	7	0.88	7216.04	23311.13
Storm 4	1	8	0.92	6137.66	23779.68
Storm 4	1	9	0.96	4566.25	24926.08
Storm 4	1	10	0.97	4297.78	25071.42
Storm 4	1	11	0.98	3374.88	26173.87
Storm 4	1	12	0.99	2363.04	27024.72
Storm 4	1	13	0.99	2225.84	27353.72
Storm 4	1	14	0.99	2553.41	27823.18
Storm 4	1	15	0.96	3969.74	28401.46
Storm 5	1	1	0.60	3434.27	3664.16
Storm 5	1	2	0.70	2879.66	4342.96
Storm 5	1	3	0.73	2669.25	4571.00
Storm 5	1	4	0.81	2157.71	4903.62
Storm 5	1	5	0.85	1940.99	5048.70
Storm 5	1	6	0.90	1526.87	5395.96
Storm 5	1	7	0.93	1259.45	5354.69
Storm 5	1	8	0.93	1254.43	5577.81
Storm 5	1	9	0.96	937.36	5699.48
Storm 5	1	10	0.97	913.37	5601.22
Storm 5	1	11	0.98	745.3	5543.55
Storm 5	1	12	0.96	1053.59	5607.45
Storm 5	1	13	0.95	1264.63	5670.01
Storm 5	1	14	0.96	1261.82	5515.71
Storm 5	1	15	0.94	1652.61	5605.91

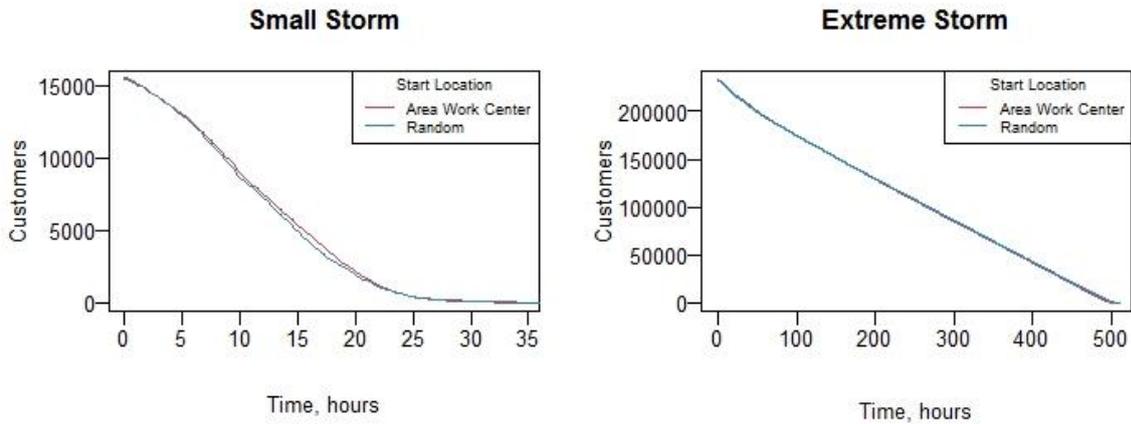


Figure S1. Start location for simulated small storms with 1,000 outages and extreme storms with 15,000 outages. Crew start location varied as indicated. Travel speed set to 25 mph, 272 crews with 85% working during day shift, 99% working during evening shift and 66% working during night shift, 1 to 10 hour repair time range and nearest outage search strategy. ETR curve was insensitive to crew start location.

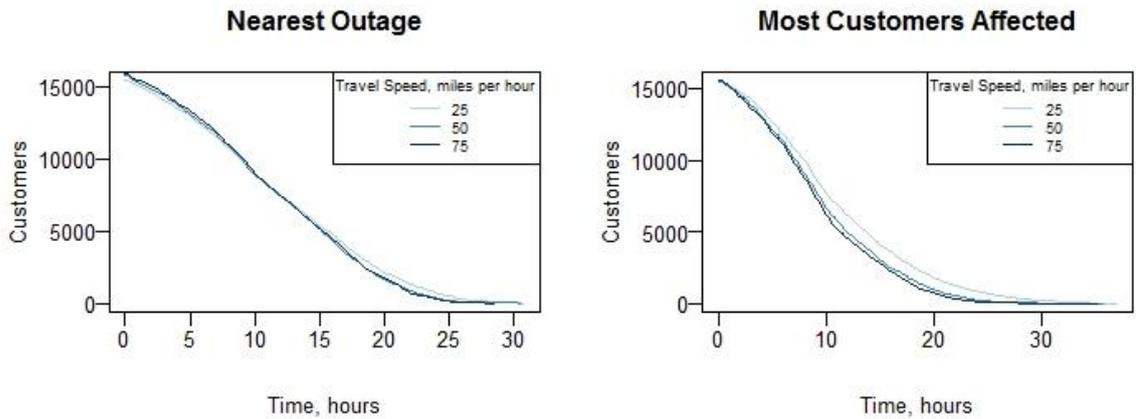


Figure S2. Travel speeds for simulated small storms with 1,000 outages. Crew start location set to area work center and search strategy as indicated in plot title. Travel speed set as indicated in legend. 272 crews with 85% working during day shift, 99% working during evening shift and 66% working during night shift, 1 to 10 hour repair time range. ETR curve was relatively insensitive to travel speed, but some differences are seen in the most customers affected search strategy. Nearest within radius search strategy was omitted for the small storm because it showed no differences to nearest outage search strategy.

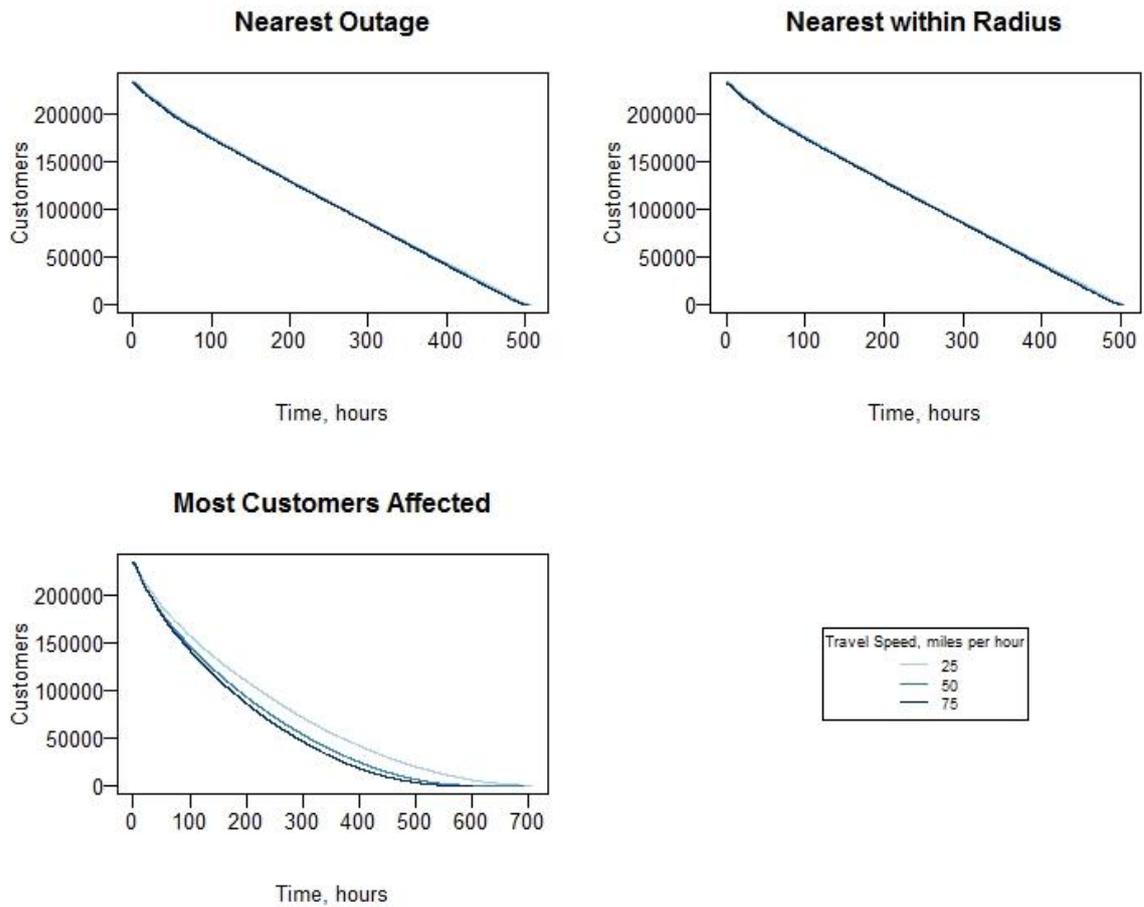


Figure S3. Travel speeds for simulated extreme storms with 15,000 outages. Crew start location set to area work center and search strategy as indicated in plot title. Travel speed set as indicated in legend. 272 crews with 85% working during day shift, 99% working during evening shift and 66% working during night shift, 1 to 10 hour repair time range. ETR curve was relatively insensitive to travel speed, but some differences are seen in the most customers affected search strategy.