FEMA Manpower Model

Christopher Teixeira
OR719
May 7, 2010

Abstract

FEMA is charged with supporting the United States public with food, water, shelter, and other supplies during and after hazards. This paper will discuss a Bayesian Network approach to determining the amount of people to be employed by FEMA for disaster recovery support. The model built to accompany this paper will use information on eight hazard categories to determine the amount of personnel required compared to the amount of personnel available. Netica is used to build the model and display the prioritized options for personnel decisions.

Table of Contents

Introduction

The Federal Emergency Management Agency (FEMA) has the mission to support the United States citizens and first responders in times of emergency. These emergencies are defined as acts of terrorism, tornadoes, earthquakes, hurricanes, blizzards, floods, fires, or other natural disasters. FEMA provides multiple services and supplies during these times including personnel, water, food, shelter and other miscellaneous needs of the area.

FEMA has several pieces of information on each of these events. This information includes required resources for each event given the size, place, and timing of the event. There are storage areas for supplies allowing for additional stock during periods of likely events. However, the number of trained personnel available is more constant. This implies that trained personnel can be very limited during events, especially if there is more then one event at a time.

This project will look at the several factors that FEMA considers when a emergency occurs. The main focus will be on personnel required per event. Given the uncertainty of events, their size, and the actual amount of people required for each event it is very hard to plan how many people should be trained and ready for deployment at anyone time. FEMA currently employs approximately 3,700 full time employees and 4,000 standby employees. This project will concentrate on the 4,000 standby employees and try to determine how many of them are necessary.

Background

FEMA has many historical records on the different natural and man-made disasters that have occurred in the United States over the past decade. Through the collection of data, they have partitioned each event into one of eight categories. These categories include Hurricane, Earthquake, Fire, Flood/Storms, Snow/Ice, Tornado, Typhoon, and other natural disasters. Each event is classified as either a minor, moderate, or severe event. Each record contains info on an event size, time and the resources required for the event. However, the data can be inconsistent and incomplete. This provides a great deal of uncertainty into the requirements and frequency of each hazard type.

Several models have been built using this data to help determine the amount of necessary people each year. These models include simple EXCEL based workbooks that take the probabilities and consequences for each hazard and look at each one individually. Other model types include integer programming or generalized linear programming models but have proven to be time consuming and inaccurate. The problem with either approach is that it ignores the joint probabilities of events. In other terms, what the requirements would be if two events were to occur at the same time or within close proximity.

The information collected in the reports is still useful. Through some data mining and organization, joint probabilities can be determined for this group of events. Excel has its limitations for efficient calculations and data manipulation. In addition, Excel has trouble representing probabilities and creating user-friendly interfaces.

Model

A number of factors need to be considered when evaluating the number of people required to handle an emergency event. The uncertainty around each of the factors drives the problem's complication. This problem's uncertainty and relationships between variables implies that a Bayesian Network (BN) will provide insight problem.

A high level look at the model shows that given some inputs, a break down of how many personnel are required is produced. With the current number of personnel introduced in another node, the utility for the situation is produced. The utility of the situation is a relative value that defines the "happiness" FEMA will have given the situation. For example, the hazards required more people than currently available would produce a negative utility to reflect the lack of personnel.

There are several data requirements for this model including: types of hazards, regions of the United States, severity of each hazard, and timing of each hazard. This model breaks down the relationship of each hazard based on the region, timing, and severity. The US is broken down into thirteen regions based on the occurrence of natural hazards and their frequency. A detailed breakout of the regions can be found in the Appendix. The timing of each event is broken down by month within the year. The severity of each event is categorized as three different intensities. Each of the severity categories is dependent on the hazard for how it is defined.

Available data for each of the hazards allowed for these relationships to be developed easily. Each hazard will be broken down in detail due to the uniqueness of each one. Conditional probability tables for each node and partition can be found in the Appendix.

Hazard Nodes

Hurricane

Hurricanes commonly occur on the Atlantic coast or in the Gulf of Mexico. Therefore, only regions bordering those two bodies of water have a probability of a Hurricane. This allows for a partition on the Region node to separate the regions into states that are susceptible to hurricanes and a state for regions that will not be affected by hurricanes.

Hurricanes are typically categorized by wind speed by the National Oceanic and Atmospheric Administration (NOAA). Using these categories, the three severity categories for hurricanes are defined as groups of categories. The table below defines the relationship between the severity states and the hurricane categories.

Severity	NOAA Category
Major	CAT 4, CAT 5
Moderate	CAT 2, CAT 3
Minor	Tropical Storm, CAT 1

Hurricanes are unique to the timing during the year. Hurricanes are known to occur during certain months in a year often referred to as the "hurricane season." The hurricane season is defined as starting in June and lasting through December. It is very rare to see one between January and May, therefore a partition was created to help decrease the distributions involved.

The data for the likelihood of a hurricane is based upon those three categories. Each of the partitions helps decrease the amount of data that needed to be collected and entered into the model. The data for hurricane occurrences, strength, and locations came from a combination of data sources including NOAA's website and a program provided by FEMA called HAZUS-MH.

Earthquake

Earthquakes differ from Hurricanes in that any region in the US is susceptible to an earthquake. Therefore, there is no partition that can be used to limit the number of distributions entered into the model by region. In addition, there is no particular time of year that are more common for earthquakes. This allows for the distributions of an earthquake occurrence to be based upon severity and region only. The severity of an earthquake is determined by the United States Geological Society. They use the Richter Scale that measures the magnitude of each earthquake in a logarithmic scale. The table below displays the relationship between the model's severity node and the corresponding measurements on the Richter Scale. The data for earthquake occurrences can be found through either the USGS or HAZUS-MH.

Severity	Richter Scale Magnitude
Major	7 - 10+
Moderate	4 - 7
Minor	1 - 3

Wild Fire and Flood

Wild fires and floods have some shared properties to them regardless of the differences in the actual hazard. Both of these hazards have similar areas of occurrences. Neither hazard is known for occurring within the continental US. Both Alaska and Hawaii are not known for having floods or wild fires. There is no generalization that can be made on timing of either event. Both events are possible to occur throughout the year. Therefore, there needs to be a unique distribution for each month of the year for each hazard. The severity of each of the hazards is based upon the square mileage of area affected by the hazard. Data for both hazards is collected by NOAA, however HAZUS-MH has information on frequency on floods across the US. Distributions for the likelihood of each hazard is calculated based upon this data.

Winter Storm

Like the hurricane hazard, winter storms are only possible where the weather can get cold enough to sustain the storm long enough to accumulate snow and ice. The partition used for winter storms groups the regions into places with winter events and places that do not have them. Some of these locations are known to have the possibility of having winter events throughout the year. Therefore a partition on the months would not be useful. The data for these events can be found through NOAA's website.

Tornado

Tornadoes are possible in every region in the United States even though they might be very unlikely. Therefore a partition on the region variable is unnecessary. The same can be said about the timing of tornadoes. This results in the likelihood for a tornado to be based upon all twelve months, thirteen regions, and three severities. The data for the tornado occurrences can be found through NOAA's website.

Typhoon

Typhoons are a unique hazard due to the conditions required for the hazard to happen. There is only one region in the United States that has the potential for a typhoon. Given that fact, a partition was used to separate the regions into the twelve regions that are not susceptible to typhoons and Hawaii. Unfortunately for Hawaii, typhoons have a possibility of happening every month during the year. The data to create the probability table for typhoon occurrence came from NOAA's website.

Other

There are several other hazards that are important to FEMA including chemical disasters, terrorist attacks, volcano eruptions, hazardous material situations, landslides and others. Most of these events are very unlikely. For the purpose of this project, what data can be found on these were grouped together into a single node. The data for these hazards came mostly from NOAA.

Personnel Nodes

Personnel Required

Given the information in the hazard nodes, a single node is created on the frequency of each hazard. This is helpful since the data provided by FEMA is aggregated by hazard type. The data ignores the parent information of what time of year the event took place or the severity of the event. Although the data seems limited, a distribution can be made on how many people are required for each type of event. However, the data provided by FEMA is sensitive. For this project, a sanitized dataset is used to illustrate the behavior of the model.

Personnel Available

Similar to the personnel required, information on the data for personnel available is limited. FEMA provided only the personnel counts at the beginning of each month. This data can then be transformed into a distribution of personnel available given the month. Due to the sensitive nature of this information, a representative set of distributions is used.

FEMA's Utility

The goal of this project is ultimately to identify if the correct number of people is employed by FEMA to handle the current situation. One way of determining this is to use a utility node. The utility node determines the current number of personnel available minus the amount required. If this amount of personnel is negative, meaning that FEMA is lacking personnel, the utility will be negative. The complement of this situation is also possible. If the amount of personnel determined in the utility node is positive, then the utility value will be positive. However, there is one consideration that is made. FEMA is concerned with employing too many personnel compared to the amount that is actually required. Therefore there is a penalty associated with having too many personnel available compared to the amount of personnel required. Ideally the function to determine the change in utility would be elicited from management. Due to availability and timing of this project, a simple function was used to imitate the thinking of a typical FEMA manager.

FEMA's Personnel Decision

Using the information from the Utility node, it is expected that FEMA could make a decision on whether to let go of some personnel or hire some more. Netica allows for the decision node to be populated with the utility values for each of the situations. In every case, the proposed best decision on how many people to hire (or fire if that is the case) will be the highest utility value.

Analysis

After several iterations of building nodes and connections, data was entered into the model. The best way to evaluate the efficiency and validity of the sample data was to enter in some test situations. Through these cases, the model should produce some expected solutions. There were two main cases that were evaluated to test the model.

The first case involved testing an extreme case in the model. This case involved having five hazards take place with a minimal amount of people available for support. The expected result is that FEMA would require to hire as many people as possible. In fact, the state of the decision node with the highest utility was not to hire as many people as possible. Given that there were a number of hazards and minimal amount of people available, it was still not that beneficial to hire that many people. It was still beneficial to hire people but not quite as many as was expected.

The second case involved testing the extreme of being during the summer without a hazard taking place. The expected result of the model would be that we would lay off as many people as possible. The results from entering this knowledge is exactly this situation.

Given the results from the two test evaluations, the model seems to be reasonable accurate. However, the model could benefit from some real world data and perhaps some structure learning from the addition of new hazards. The results from the test cases can be found in the Appendix.

Conclusion

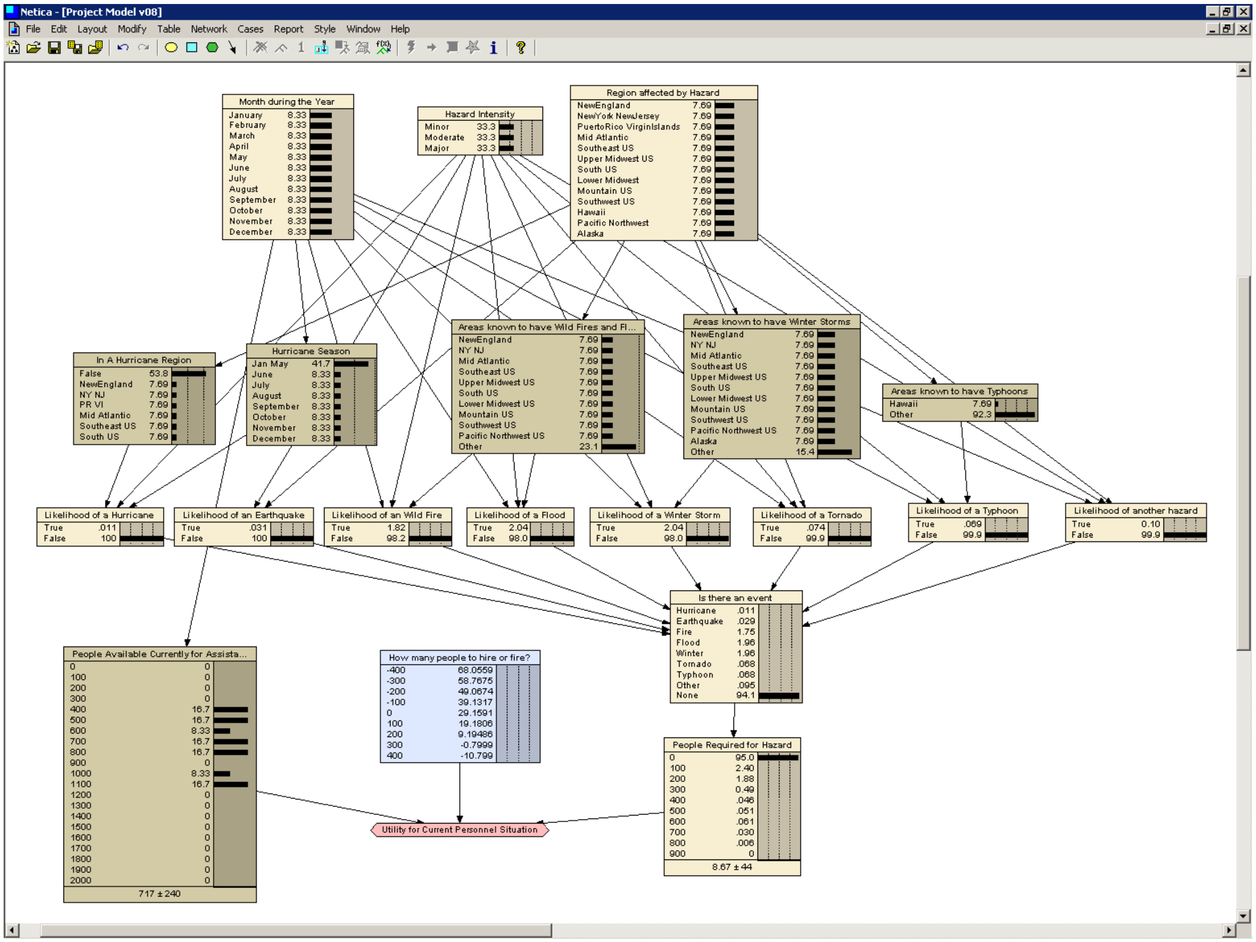
Using a Bayesian Network to determine the correct personnel decisions to make appears to be a viable approach to the problem. The separation of hazards and resources allows the user to concentrate on the area in question. The results can then be easily interpreted given the knowledge entered into the model.

The model can be used for several purposes or by users with different perspectives on the same problems. The intended purpose of the model is to estimate the decision that should be made on how many people to fire or hire given the current situation of amount of hazards and timing of the decision. However, the model can also be used in a predictive manner. A user can input a scenario in which they wish to estimate the amount of people needed given the timing and a specific hazard. The use of Netica allows both situations to be easily configured and entered into the model.

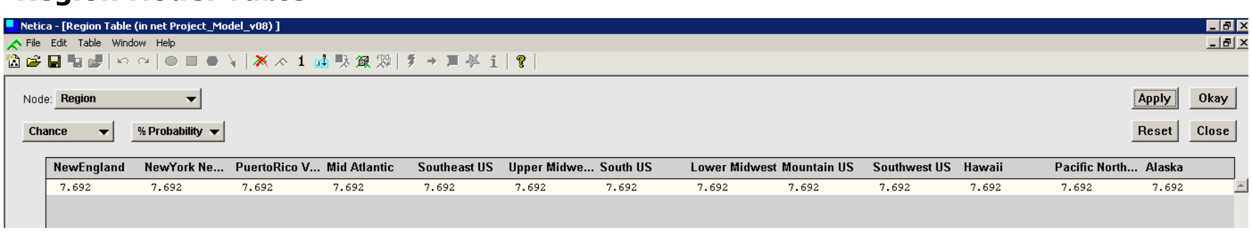
Appendix

Netica Model

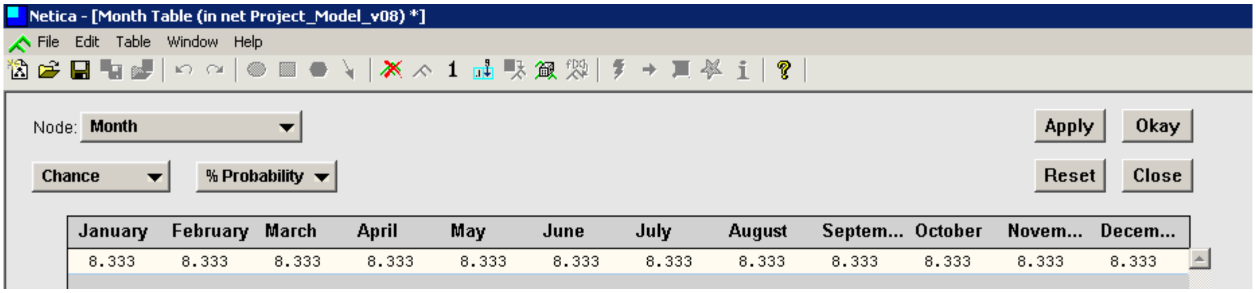
Overview



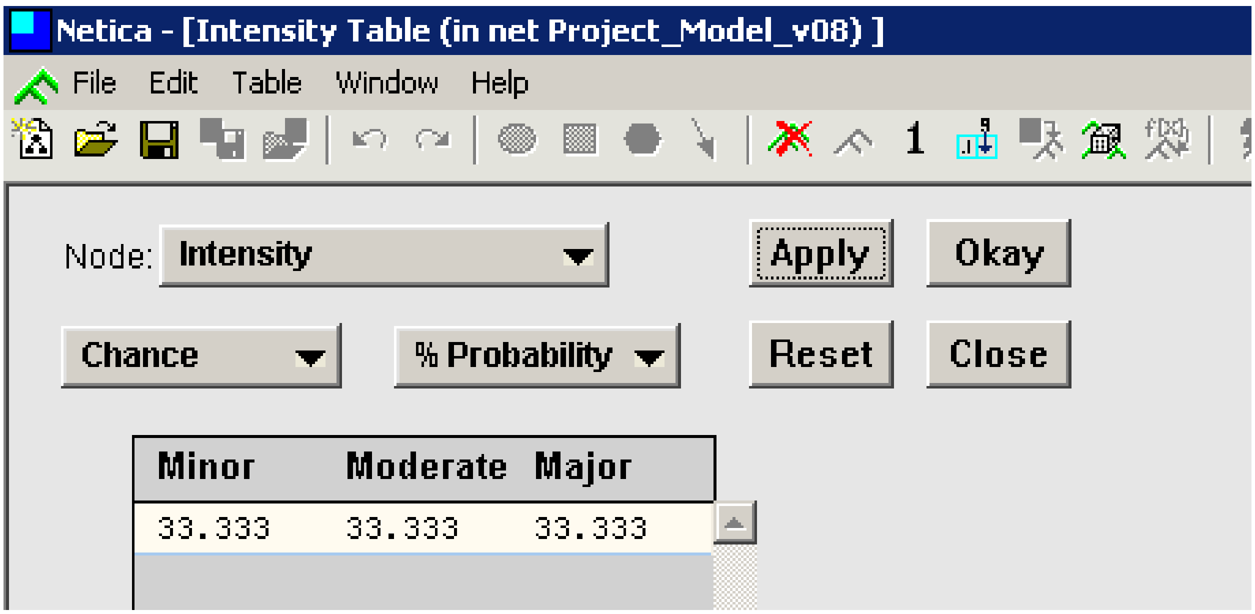
Region Node: Table



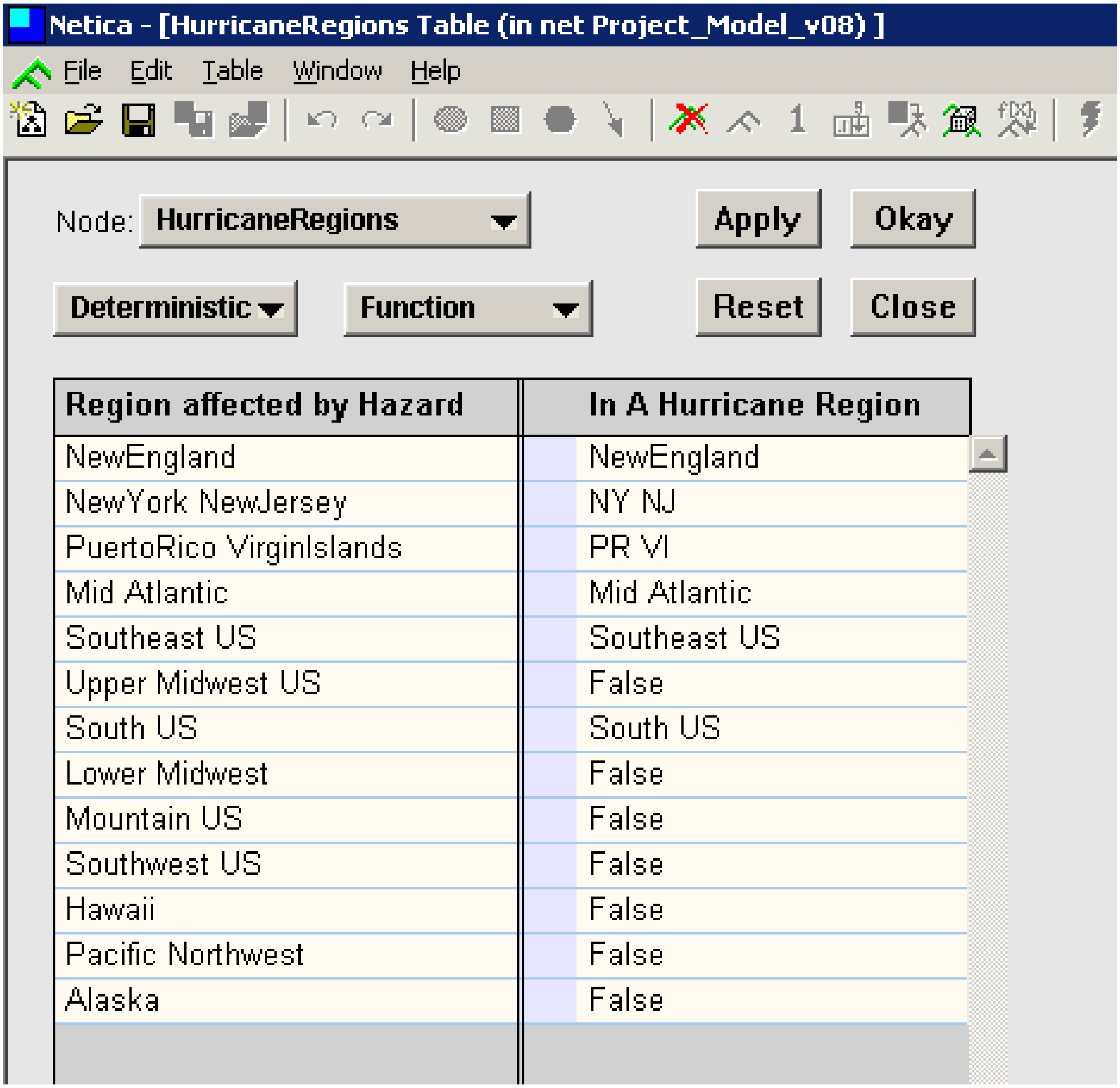
Month Node: Table



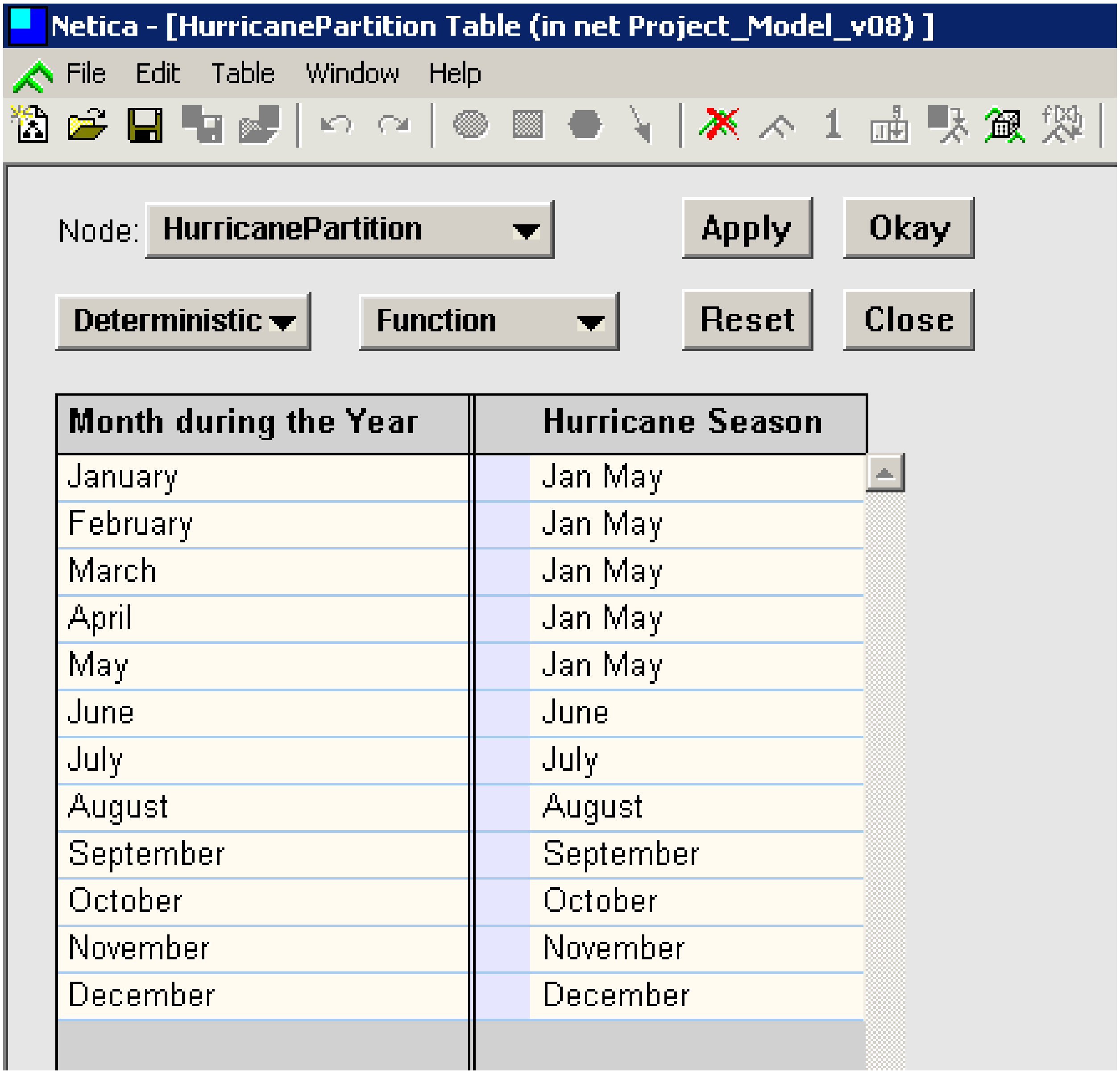
Intensity Node: Table



Hurricane Region Partition: Conditional Probability Table

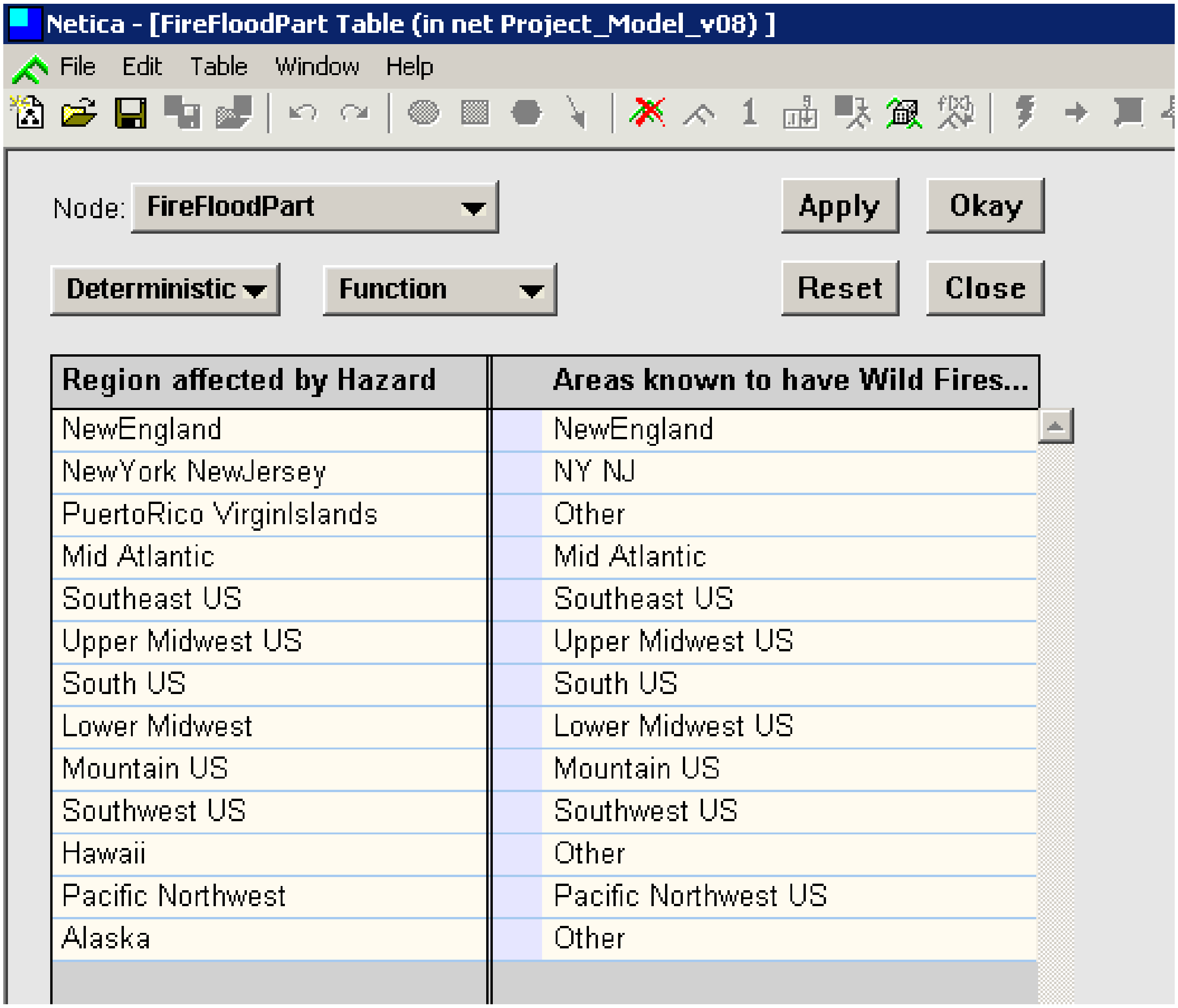


Hurricane Season Partition: Conditional Probability Table

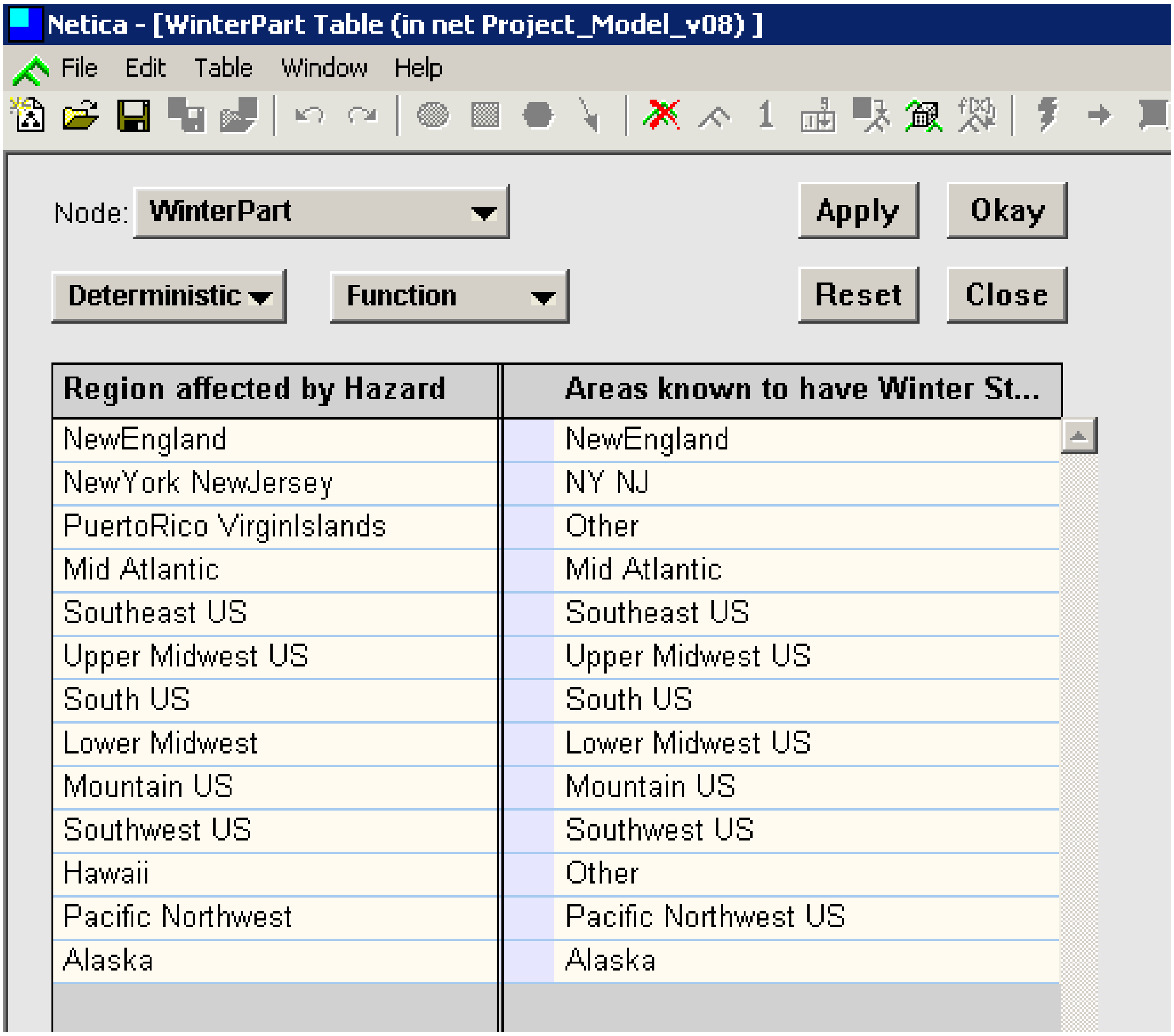


Month during the Year	Hurricane Season
January	Jan May
February	Jan May
March	Jan May
April	Jan May
May	Jan May
June	June
July	July
August	August
September	September
October	October
November	November
December	December

Wild Fire / Flood Region Partition: Conditional Probability Table

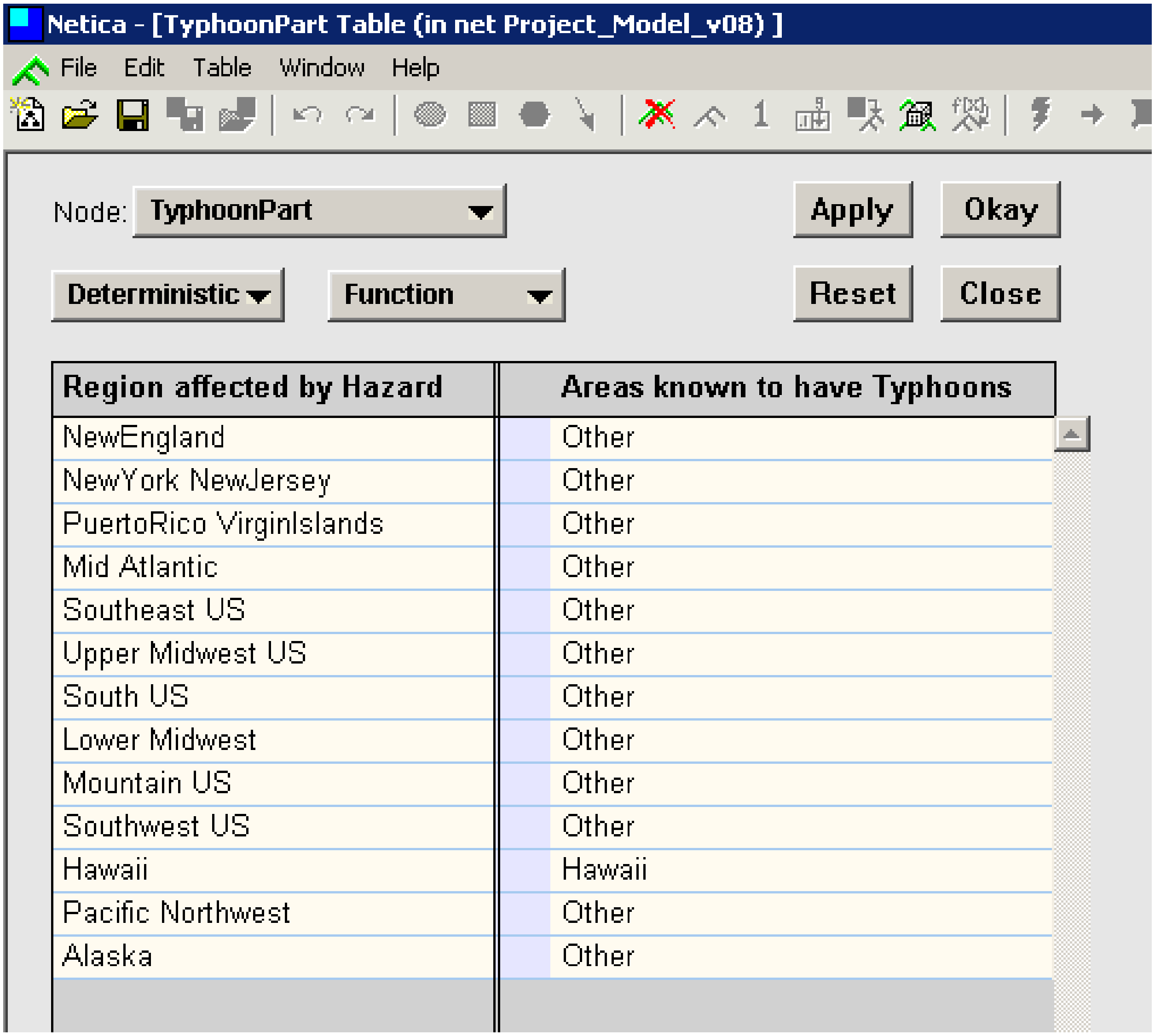


Winter Storm Region Partition: Conditional Probability Table



Region affected by Hazard	Areas known to have Winter St...
NewEngland	NewEngland
NewYork NewJersey	NY NJ
PuertoRico VirginIslands	Other
Mid Atlantic	Mid Atlantic
Southeast US	Southeast US
Upper Midwest US	Upper Midwest US
South US	South US
Lower Midwest	Lower Midwest US
Mountain US	Mountain US
Southwest US	Southwest US
Hawaii	Other
Pacific Northwest	Pacific Northwest US
Alaska	Alaska

Typhoon Region Partition: Conditional Probability Table



Region affected by Hazard	Areas known to have Typhoons
NewEngland	Other
NewYork NewJersey	Other
PuertoRico VirginIslands	Other
Mid Atlantic	Other
Southeast US	Other
Upper Midwest US	Other
South US	Other
Lower Midwest	Other
Mountain US	Other
Southwest US	Other
Hawaii	Hawaii
Pacific Northwest	Other
Alaska	Other

Hurricane Node: Conditional Probability Table

Netica - [Hurricane Table (in net Project_Model_v08)]

File Edit Table Window Help

Node: Hurricane | Apply | Okay

Chance | % Probability | Reset | Close

Hurricane Season	In A Hurricane Region	Hazard Intensity	True	False
Jan May	False	Minor	0	100
Jan May	False	Moderate	0	100
Jan May	False	Major	0	100
Jan May	NewEngland	Minor	0	100
Jan May	NewEngland	Moderate	0	100
Jan May	NewEngland	Major	0	100
Jan May	NY NJ	Minor	0	100
Jan May	NY NJ	Moderate	0	100
Jan May	NY NJ	Major	0	100
Jan May	PR VI	Minor	0	100
Jan May	PR VI	Moderate	0	100
Jan May	PR VI	Major	0	100
Jan May	Mid Atlantic	Minor	0	100
Jan May	Mid Atlantic	Moderate	0	100
Jan May	Mid Atlantic	Major	0	100
Jan May	Southeast US	Minor	0	100
Jan May	Southeast US	Moderate	0	100
Jan May	Southeast US	Major	0	100
Jan May	South US	Minor	0	100
Jan May	South US	Moderate	0	100
Jan May	South US	Major	0	100
June	False	Minor	0	100
June	False	Moderate	0	100
June	False	Major	0	100
June	NewEngland	Minor	2.59e-04	100
June	NewEngland	Moderate	6.32e-03	99.994
June	NewEngland	Major	6.67e-03	99.993
June	NY NJ	Minor	2.59e-04	100
June	NY NJ	Moderate	1.99e-03	99.998
June	NY NJ	Major	2.66e-03	99.997
June	PR VI	Minor	2.18e-04	100
June	PR VI	Moderate	1.13e-03	99.999
June	PR VI	Major	2.80e-03	99.997
June	Mid Atlantic	Minor	2.59e-04	100
June	Mid Atlantic	Moderate	1.34e-03	99.999
June	Mid Atlantic	Major	3.33e-03	99.997
June	Southeast US	Minor	4.32e-03	99.996
June	Southeast US	Moderate	0.0367	99.963
June	Southeast US	Major	0.0358	99.964
June	South US	Minor	3.65e-03	99.996
June	South US	Moderate	0.0182	99.982
June	South US	Major	0.0145	99.986
July	False	Minor	0	100
July	False	Moderate	0	100

Earthquake Node: Conditional Probability Table

Netica - [Earthquake Table (in net Project_Model_v08)]

File Edit Table Window Help

Node: Earthquake

Apply Okay

Chance % Probability

Reset Close

Region affected by Hazard	Hazard Intensity	True	False
NewEngland	Minor	0.0214	99.979
NewEngland	Moderate	2.71e-03	99.997
NewEngland	Major	0	100
NewYork NewJersey	Minor	0.0214	99.979
NewYork NewJersey	Moderate	2.71e-03	99.997
NewYork NewJersey	Major	0	100
PuertoRico VirginIslands	Minor	0.0107	99.989
PuertoRico VirginIslands	Moderate	0	100
PuertoRico VirginIslands	Major	0	100
Mid Atlantic	Minor	0.0214	99.979
Mid Atlantic	Moderate	2.71e-03	99.997
Mid Atlantic	Major	0	100
Southeast US	Minor	0.0961	99.904
Southeast US	Moderate	0.0122	99.988
Southeast US	Major	3.99e-04	100
Upper Midwest US	Minor	0.0961	99.904
Upper Midwest US	Moderate	0.0122	99.988
Upper Midwest US	Major	3.99e-04	100
South US	Minor	0.0961	99.904
South US	Moderate	0.0122	99.988
South US	Major	3.99e-04	100
Lower Midwest	Minor	0.0961	99.904
Lower Midwest	Moderate	0.0122	99.988
Lower Midwest	Major	3.99e-04	100
Mountain US	Minor	0.0534	99.947
Mountain US	Moderate	6.77e-03	99.993
Mountain US	Major	0	100
Southwest US	Minor	0.342	99.658
Southwest US	Moderate	0.0447	99.955
Southwest US	Major	4.78e-03	99.995
Hawaii	Minor	0.0534	99.947
Hawaii	Moderate	6.77e-03	99.993
Hawaii	Major	0	100
Pacific Northwest	Minor	0.107	99.893
Pacific Northwest	Moderate	0.0135	99.986
Pacific Northwest	Major	1.59e-03	99.998
Alaska	Minor	0.0534	99.947
Alaska	Moderate	6.77e-03	99.993
Alaska	Major	0	100

Wild Fire Node: Conditional Probability Table

Netica - [Fire Table (in net Project_Model_v08)]

File Edit Table Window Help

Node: Fire

Apply Okay

Chance % Probability

Reset Close

Month during the Year	Areas known to have Wild Fires...	Hazard Intensity	True	False
January	NewEngland	Minor	0.0436	99.956
January	NewEngland	Moderate	0	100
January	NewEngland	Major	0	100
January	NY NJ	Minor	0.174	99.826
January	NY NJ	Moderate	0	100
January	NY NJ	Major	0	100
January	Mid Atlantic	Minor	0.315	99.685
January	Mid Atlantic	Moderate	0.0314	99.969
January	Mid Atlantic	Major	0	100
January	Southeast US	Minor	2.325	97.675
January	Southeast US	Moderate	0.579	99.421
January	Southeast US	Major	0.0138	99.986
January	Upper Midwest US	Minor	0.13	99.87
January	Upper Midwest US	Moderate	0	100
January	Upper Midwest US	Major	0	100
January	South US	Minor	3.429	96.571
January	South US	Moderate	0.866	99.134
January	South US	Major	0.0208	99.979
January	Lower Midwest US	Minor	1.609	98.391
January	Lower Midwest US	Moderate	0.154	99.846
January	Lower Midwest US	Major	8.06e-03	99.992
January	Mountain US	Minor	3.048	96.952
January	Mountain US	Moderate	0.667	99.333
January	Mountain US	Major	0.0179	99.982
January	Southwest US	Minor	5.11	94.89
January	Southwest US	Moderate	1.691	98.309
January	Southwest US	Major	0.0815	99.918
January	Pacific Northwest US	Minor	2.232	97.768
January	Pacific Northwest US	Moderate	0.418	99.582
January	Pacific Northwest US	Major	0.0195	99.98
January	Other	Minor	0	100
January	Other	Moderate	0	100
January	Other	Major	0	100
February	NewEngland	Minor	0.0637	99.936
February	NewEngland	Moderate	0	100
February	NewEngland	Major	0	100
February	NY NJ	Minor	0.254	99.746
February	NY NJ	Moderate	0	100
February	NY NJ	Major	0	100
February	Mid Atlantic	Minor	0.46	99.54
February	Mid Atlantic	Moderate	0.0459	99.954
February	Mid Atlantic	Major	0	100
February	Southeast US	Minor	3.341	96.659
February	Southeast US	Moderate	0.843	99.157

Flood Node: Conditional Probability Table

Netica - [Flood Table (in net Project_Model_v08)]

File Edit Table Window Help

Node: Flood

Chance | % Probability

Apply | Okay | Reset | Close

Month during the Year	Areas known to have Wild Fires...	Hazard Intensity	True	False
January	NewEngland	Minor	2.967	97.033
January	NewEngland	Moderate	3.791	96.209
January	NewEngland	Major	0.0484	99.952
January	NY NJ	Minor	1.96	98.04
January	NY NJ	Moderate	2.522	97.478
January	NY NJ	Major	0.0312	99.969
January	Mid Atlantic	Minor	2.906	97.094
January	Mid Atlantic	Moderate	3.714	96.286
January	Mid Atlantic	Major	0.0473	99.953
January	Southeast US	Minor	5.058	94.942
January	Southeast US	Moderate	6.36	93.64
January	Southeast US	Major	0.087	99.913
January	Upper Midwest US	Minor	4.042	95.958
January	Upper Midwest US	Moderate	5.123	94.877
January	Upper Midwest US	Major	0.0677	99.932
January	South US	Minor	1.7	98.3
January	South US	Moderate	2.192	97.808
January	South US	Major	0.0269	99.973
January	Lower Midwest US	Minor	5.384	94.616
January	Lower Midwest US	Moderate	6.753	93.247
January	Lower Midwest US	Major	0.0935	99.907
January	Mountain US	Minor	2.216	97.784
January	Mountain US	Moderate	2.847	97.153
January	Mountain US	Major	0.0355	99.964
January	Southwest US	Minor	1.437	98.563
January	Southwest US	Moderate	1.856	98.144
January	Southwest US	Major	0.0226	99.977
January	Pacific Northwest US	Minor	1.96	98.04
January	Pacific Northwest US	Moderate	2.522	97.478
January	Pacific Northwest US	Major	0.0312	99.969
January	Other	Minor	0	100
January	Other	Moderate	0	100
January	Other	Major	0	100
February	NewEngland	Minor	3.445	96.555
February	NewEngland	Moderate	4.396	95.604
February	NewEngland	Major	0.0564	99.944
February	NY NJ	Minor	2.279	97.721
February	NY NJ	Moderate	2.93	97.07
February	NY NJ	Major	0.0364	99.964
February	Mid Atlantic	Minor	3.374	96.626
February	Mid Atlantic	Moderate	4.307	95.693
February	Mid Atlantic	Major	0.0552	99.945
February	Southeast US	Minor	5.853	94.147
February	Southeast US	Moderate	7.344	92.656

Winter Storm Node: Conditional Probability Table

Netica - [Winter Table (in net Project_Model_v08)]

File Edit Table Window Help

Node: Winter

Chance | % Probability

Apply | Okay | Reset | Close

Month during the Year	Areas known to have Winter St...	Hazard Intensity	True	False
January	NewEngland	Minor	2.967	97.033
January	NewEngland	Moderate	3.791	96.209
January	NewEngland	Major	0.0484	99.952
January	NY NJ	Minor	1.96	98.04
January	NY NJ	Moderate	2.522	97.478
January	NY NJ	Major	0.0312	99.969
January	Mid Atlantic	Minor	2.906	97.094
January	Mid Atlantic	Moderate	3.714	96.286
January	Mid Atlantic	Major	0.0473	99.953
January	Southeast US	Minor	5.058	94.942
January	Southeast US	Moderate	6.36	93.64
January	Southeast US	Major	0.087	99.913
January	Upper Midwest US	Minor	4.042	95.958
January	Upper Midwest US	Moderate	5.123	94.877
January	Upper Midwest US	Major	0.0677	99.932
January	South US	Minor	1.7	98.3
January	South US	Moderate	2.192	97.808
January	South US	Major	0.0269	99.973
January	Lower Midwest US	Minor	5.384	94.616
January	Lower Midwest US	Moderate	6.753	93.247
January	Lower Midwest US	Major	0.0935	99.907
January	Mountain US	Minor	2.216	97.784
January	Mountain US	Moderate	2.847	97.153
January	Mountain US	Major	0.0355	99.964
January	Southwest US	Minor	1.437	98.563
January	Southwest US	Moderate	1.856	98.144
January	Southwest US	Major	0.0226	99.977
January	Pacific Northwest US	Minor	1.764	98.236
January	Pacific Northwest US	Moderate	2.27	97.73
January	Pacific Northwest US	Major	0.0281	99.972
January	Alaska	Minor	0.196	99.804
January	Alaska	Moderate	0.252	99.748
January	Alaska	Major	3.12e-03	99.997
January	Other	Minor	0	100
January	Other	Moderate	0	100
January	Other	Major	0	100
February	NewEngland	Minor	3.445	96.555
February	NewEngland	Moderate	4.396	95.604
February	NewEngland	Major	0.0564	99.944
February	NY NJ	Minor	2.279	97.721
February	NY NJ	Moderate	2.93	97.07
February	NY NJ	Major	0.0364	99.964
February	Mid Atlantic	Minor	3.374	96.626
February	Mid Atlantic	Moderate	4.307	95.693

Tornado Node: Conditional Probability Table

Netica - [Tornado Table (in net Project_Model_v08)]

File Edit Table Window Help

Node: Tornado | Apply | Okay

Chance | % Probability | Reset | Close

Month during the Year	Region	Hazard Intensity	True	False
January	NewEngland	Minor	6.70e-03	99.993
January	NewEngland	Moderate	3.15e-03	99.997
January	NewEngland	Major	0	100
January	NewYork NewJersey	Minor	8.64e-04	99.999
January	NewYork NewJersey	Moderate	2.44e-04	100
January	NewYork NewJersey	Major	0	100
January	PuertoRico VirginIslands	Minor	4.68e-06	100
January	PuertoRico VirginIslands	Moderate	0	100
January	PuertoRico VirginIslands	Major	0	100
January	Mid Atlantic	Minor	6.03e-03	99.994
January	Mid Atlantic	Moderate	2.46e-03	99.998
January	Mid Atlantic	Major	0	100
January	Southeast US	Minor	0.0405	99.959
January	Southeast US	Moderate	0.0661	99.934
January	Southeast US	Major	0	100
January	Upper Midwest US	Minor	0.0431	99.957
January	Upper Midwest US	Moderate	0.0398	99.96
January	Upper Midwest US	Major	0	100
January	South US	Minor	0.0574	99.943
January	South US	Moderate	0.0202	99.98
January	South US	Major	0	100
January	Lower Midwest	Minor	0.0247	99.975
January	Lower Midwest	Moderate	9.61e-03	99.99
January	Lower Midwest	Major	0	100
January	Mountain US	Minor	2.90e-03	99.997
January	Mountain US	Moderate	8.17e-04	99.999
January	Mountain US	Major	0	100
January	Southwest US	Minor	9.11e-04	99.999
January	Southwest US	Moderate	1.36e-04	100
January	Southwest US	Major	0	100
January	Hawaii	Minor	2.08e-05	100
January	Hawaii	Moderate	2.57e-06	100
January	Hawaii	Major	0	100
January	Pacific Northwest	Minor	1.26e-03	99.999
January	Pacific Northwest	Moderate	1.88e-04	100
January	Pacific Northwest	Major	0	100
January	Alaska	Minor	0	100
January	Alaska	Moderate	0	100
January	Alaska	Major	0	100
February	NewEngland	Minor	0.0593	99.941
February	NewEngland	Moderate	0.0279	99.972
February	NewEngland	Major	0	100
February	NewYork NewJersey	Minor	7.66e-03	99.992
February	NewYork NewJersey	Moderate	2.16e-03	99.998

Typhoon Node: Conditional Probability Table

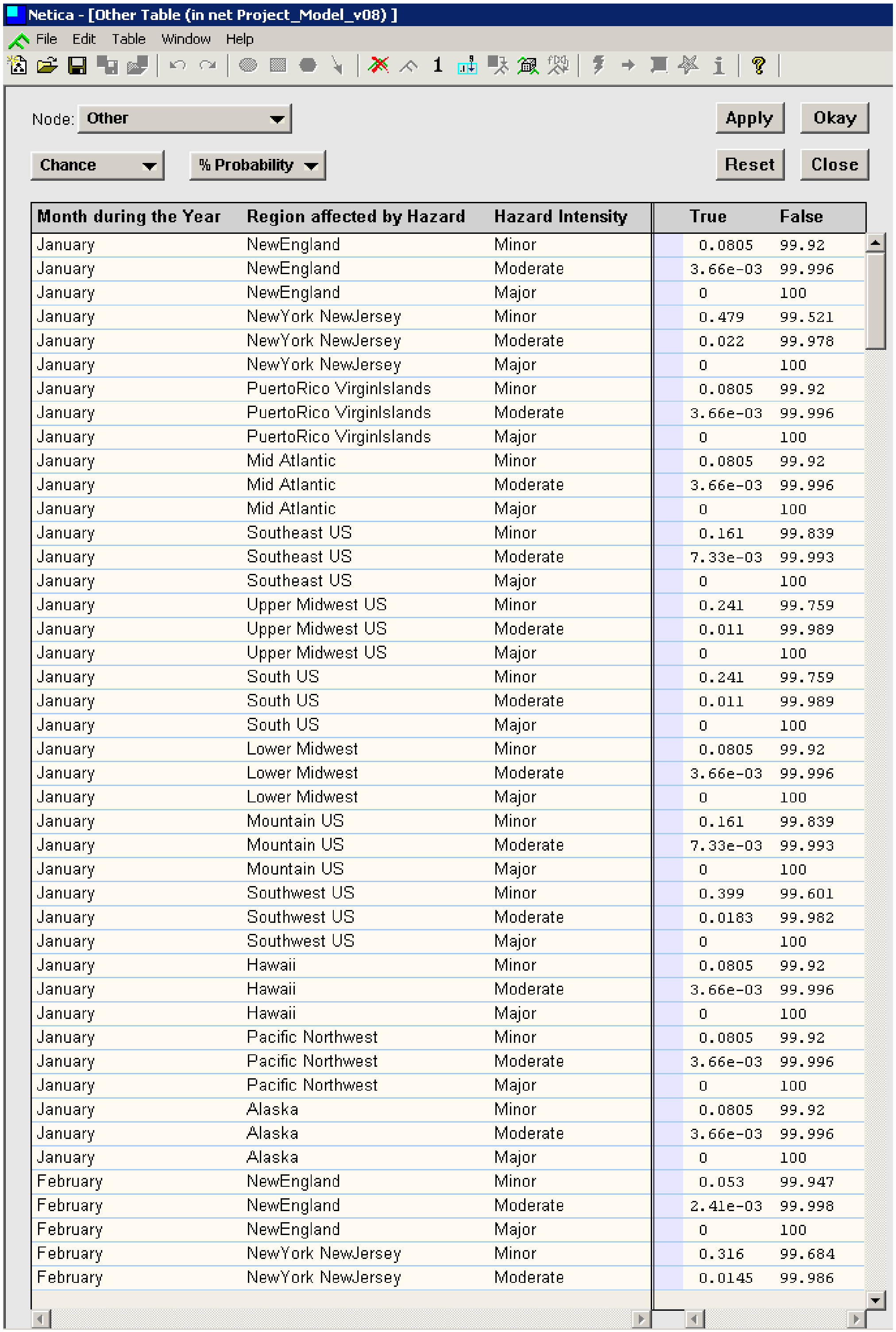
Netica - [Typhoon Table (in net Project_Model_v08)]

File Edit Table Window Help

Node: Typhoon | Chance | % Probability | Apply | Okay | Reset | Close

Month during the Year	Areas known to have Typhoons	Hazard Intensity	True	False
January	Hawaii	Minor	0.905	99.095
January	Hawaii	Moderate	0.707	99.293
January	Hawaii	Major	0	100
January	Other	Minor	0	100
January	Other	Moderate	0	100
January	Other	Major	0	100
February	Hawaii	Minor	0.601	99.399
February	Hawaii	Moderate	0.469	99.531
February	Hawaii	Major	0	100
February	Other	Minor	0	100
February	Other	Moderate	0	100
February	Other	Major	0	100
March	Hawaii	Minor	0.727	99.273
March	Hawaii	Moderate	0.568	99.432
March	Hawaii	Major	0	100
March	Other	Minor	0	100
March	Other	Moderate	0	100
March	Other	Major	0	100
April	Hawaii	Minor	0.935	99.065
April	Hawaii	Moderate	0.731	99.269
April	Hawaii	Major	0	100
April	Other	Minor	0	100
April	Other	Moderate	0	100
April	Other	Major	0	100
May	Hawaii	Minor	1.257	98.743
May	Hawaii	Moderate	0.984	99.016
May	Hawaii	Major	0	100
May	Other	Minor	0	100
May	Other	Moderate	0	100
May	Other	Major	0	100
June	Hawaii	Minor	1.656	98.344
June	Hawaii	Moderate	1.299	98.701
June	Hawaii	Major	0	100
June	Other	Minor	0	100
June	Other	Moderate	0	100
June	Other	Major	0	100
July	Hawaii	Minor	2.278	97.722
July	Hawaii	Moderate	1.793	98.207
July	Hawaii	Major	0	100
July	Other	Minor	0	100
July	Other	Moderate	0	100
July	Other	Major	0	100
August	Hawaii	Minor	2.932	97.068
August	Hawaii	Moderate	2.315	97.685

Other Hazard Node: Conditional Probability Table



Month during the Year	Region affected by Hazard	Hazard Intensity	True	False
January	NewEngland	Minor	0.0805	99.92
January	NewEngland	Moderate	3.66e-03	99.996
January	NewEngland	Major	0	100
January	NewYork NewJersey	Minor	0.479	99.521
January	NewYork NewJersey	Moderate	0.022	99.978
January	NewYork NewJersey	Major	0	100
January	PuertoRico VirginIslands	Minor	0.0805	99.92
January	PuertoRico VirginIslands	Moderate	3.66e-03	99.996
January	PuertoRico VirginIslands	Major	0	100
January	Mid Atlantic	Minor	0.0805	99.92
January	Mid Atlantic	Moderate	3.66e-03	99.996
January	Mid Atlantic	Major	0	100
January	Southeast US	Minor	0.161	99.839
January	Southeast US	Moderate	7.33e-03	99.993
January	Southeast US	Major	0	100
January	Upper Midwest US	Minor	0.241	99.759
January	Upper Midwest US	Moderate	0.011	99.989
January	Upper Midwest US	Major	0	100
January	South US	Minor	0.241	99.759
January	South US	Moderate	0.011	99.989
January	South US	Major	0	100
January	Lower Midwest	Minor	0.0805	99.92
January	Lower Midwest	Moderate	3.66e-03	99.996
January	Lower Midwest	Major	0	100
January	Mountain US	Minor	0.161	99.839
January	Mountain US	Moderate	7.33e-03	99.993
January	Mountain US	Major	0	100
January	Southwest US	Minor	0.399	99.601
January	Southwest US	Moderate	0.0183	99.982
January	Southwest US	Major	0	100
January	Hawaii	Minor	0.0805	99.92
January	Hawaii	Moderate	3.66e-03	99.996
January	Hawaii	Major	0	100
January	Pacific Northwest	Minor	0.0805	99.92
January	Pacific Northwest	Moderate	3.66e-03	99.996
January	Pacific Northwest	Major	0	100
January	Alaska	Minor	0.0805	99.92
January	Alaska	Moderate	3.66e-03	99.996
January	Alaska	Major	0	100
February	NewEngland	Minor	0.053	99.947
February	NewEngland	Moderate	2.41e-03	99.998
February	NewEngland	Major	0	100
February	NewYork NewJersey	Minor	0.316	99.684
February	NewYork NewJersey	Moderate	0.0145	99.986

Event Node: Conditional Probability Table

The values in the table take on the general form of the equation below.

$$h_i = hazard_i$$
$$P(h_i|h_j) = if(h_i = TRUE, 1 / \sum_{i|h_i=true} 1, 0)$$

Netica - [EventPart Table (in net Project_Model_v08)]

File Edit Table Window Help

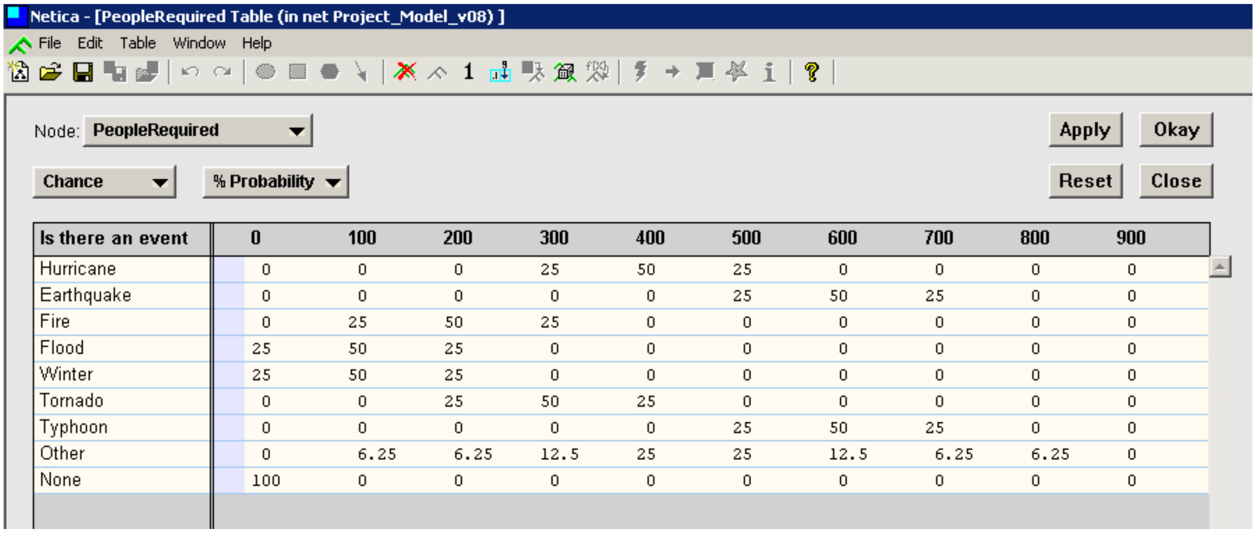
Node: EventPart

Chance | % Probability

Apply | Okay | Reset | Close

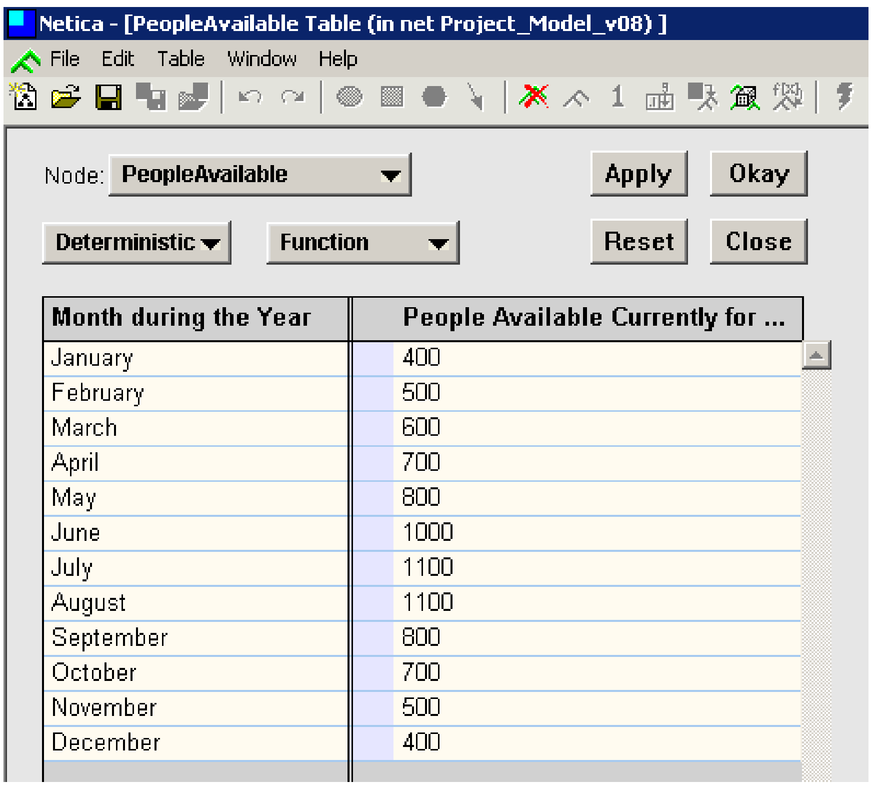
Likelihood ...	Likelihood...	Likelihood...	Likelihood...	Likelihood...	Likelihood...	Likelihood...	Likelihood...	Hurricane	Earthqu...	Fire	Flood	Winter	Tornado	Typhoon	Other	None
True	True	True	True	True	True	True	True	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	0
True	True	True	True	True	True	True	False	14.286	14.286	14.286	14.286	14.286	14.286	14.286	0	0
True	True	True	True	True	True	False	True	14.286	14.286	14.286	14.286	14.286	14.286	0	14.286	0
True	True	True	True	True	True	False	False	16.667	16.667	16.667	16.667	16.667	16.667	0	0	0
True	True	True	True	True	False	True	True	14.286	14.286	14.286	14.286	14.286	0	14.286	14.286	0
True	True	True	True	True	False	True	False	16.667	16.667	16.667	16.667	16.667	0	16.667	0	0
True	True	True	True	True	False	False	True	16.667	16.667	16.667	16.667	16.667	0	0	16.667	0
True	True	True	True	True	False	False	False	20	20	20	20	20	0	0	0	0
True	True	True	True	False	True	True	True	14.286	14.286	14.286	14.286	0	14.286	14.286	14.286	0
True	True	True	True	False	True	True	False	16.667	16.667	16.667	16.667	0	16.667	16.667	0	0
True	True	True	True	False	True	False	True	16.667	16.667	16.667	16.667	0	16.667	0	16.667	0
True	True	True	True	False	True	False	False	20	20	20	20	0	20	0	0	0
True	True	True	True	False	False	True	True	16.667	16.667	16.667	16.667	0	0	16.667	16.667	0
True	True	True	True	False	False	True	False	20	20	20	20	0	0	20	0	0
True	True	True	True	False	False	False	True	20	20	20	20	0	0	0	20	0
True	True	True	True	False	False	False	False	25	25	25	25	0	0	0	0	0
True	True	True	False	True	True	True	True	14.286	14.286	14.286	0	14.286	14.286	14.286	14.286	0
True	True	True	False	True	True	True	False	16.667	16.667	16.667	0	16.667	16.667	16.667	0	0
True	True	True	False	True	True	False	True	16.667	16.667	16.667	0	16.667	16.667	0	16.667	0
True	True	True	False	True	True	False	False	20	20	20	0	20	20	0	0	0
True	True	True	False	True	False	True	True	16.667	16.667	16.667	0	16.667	0	16.667	16.667	0
True	True	True	False	True	False	True	False	20	20	20	0	20	0	20	0	0
True	True	True	False	True	False	False	True	20	20	20	0	20	0	0	20	0
True	True	True	False	True	False	False	False	25	25	25	0	25	0	0	0	0
True	True	True	False	False	True	True	True	16.667	16.667	16.667	0	0	16.667	16.667	16.667	0
True	True	True	False	False	True	True	False	20	20	20	0	0	20	20	0	0
True	True	True	False	False	True	False	True	20	20	20	0	0	20	0	20	0
True	True	True	False	False	True	False	False	25	25	25	0	0	25	0	0	0
True	True	True	False	False	False	True	True	20	20	20	0	0	0	20	20	0
True	True	True	False	False	False	True	False	25	25	25	0	0	0	25	0	0
True	True	True	False	False	False	False	True	25	25	25	0	0	0	0	25	0
True	True	True	False	False	False	False	False	33.333	33.333	33.333	0	0	0	0	0	0
True	True	False	True	True	True	True	True	14.286	14.286	0	14.286	14.286	14.286	14.286	14.286	0
True	True	False	True	True	True	True	False	16.667	16.667	0	16.667	16.667	16.667	16.667	0	0
True	True	False	True	True	True	False	True	16.667	16.667	0	16.667	16.667	16.667	0	16.667	0
True	True	False	True	True	True	False	False	20	20	0	20	20	20	0	0	0
True	True	False	True	True	False	True	True	16.667	16.667	0	16.667	16.667	0	16.667	16.667	0
True	True	False	True	True	False	True	False	20	20	0	20	20	0	20	0	0
True	True	False	True	True	False	False	True	20	20	0	20	20	0	0	20	0
True	True	False	True	True	False	False	False	25	25	0	25	25	0	0	0	0
True	True	False	True	False	True	True	True	16.667	16.667	0	16.667	0	16.667	16.667	16.667	0
True	True	False	True	False	True	True	False	20	20	0	20	0	20	20	0	0
True	True	False	True	False	True	False	True	20	20	0	20	0	20	0	20	0
True	True	False	True	False	True	False	False	25	25	0	25	0	25	0	0	0

Personnel Required Node: Conditional Probability Table



Is there an event	0	100	200	300	400	500	600	700	800	900
Hurricane	0	0	0	25	50	25	0	0	0	0
Earthquake	0	0	0	0	0	25	50	25	0	0
Fire	0	25	50	25	0	0	0	0	0	0
Flood	25	50	25	0	0	0	0	0	0	0
Winter	25	50	25	0	0	0	0	0	0	0
Tornado	0	0	25	50	25	0	0	0	0	0
Typhoon	0	0	0	0	0	25	50	25	0	0
Other	0	6.25	6.25	12.5	25	25	12.5	6.25	6.25	0
None	100	0	0	0	0	0	0	0	0	0

Personnel Available Node: Conditional Probability Table



Month during the Year	People Available Currently for ...
January	400
February	500
March	600
April	700
May	800
June	1000
July	1100
August	1100
September	800
October	700
November	500
December	400

Utility Node: Conditional Probability Table

This node is based upon the function of the three inputs. The generalized equation is listed below:

$$x = available - required + hiredfired$$
$$if(x == 0, 100, if(x < 0, x/10, 100 - x/10))$$

Netica - [Utility Table (in net Project_Model_v08)]

File Edit Table Window Help

Node: Utility

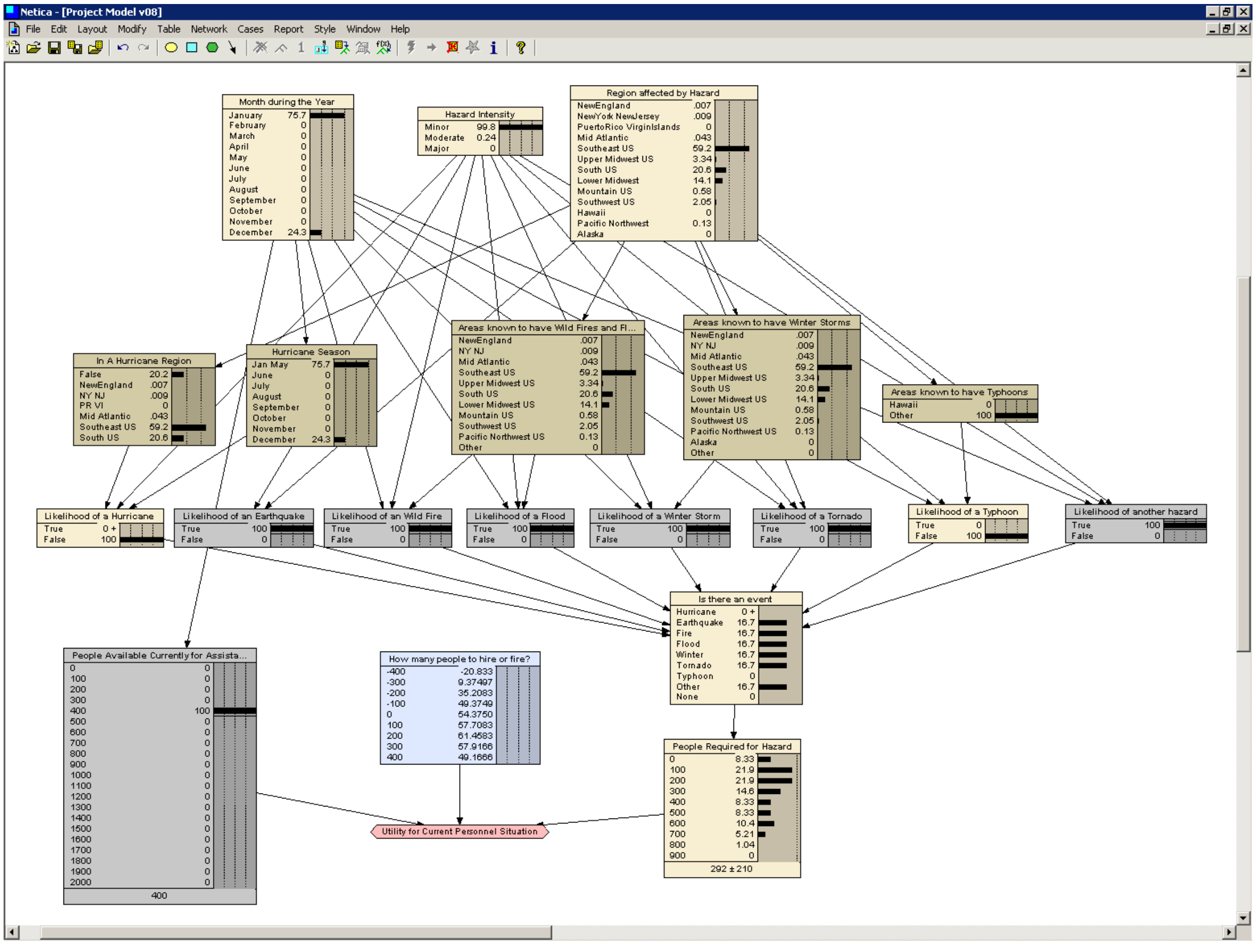
Deterministic Function

Apply Okay Reset Close

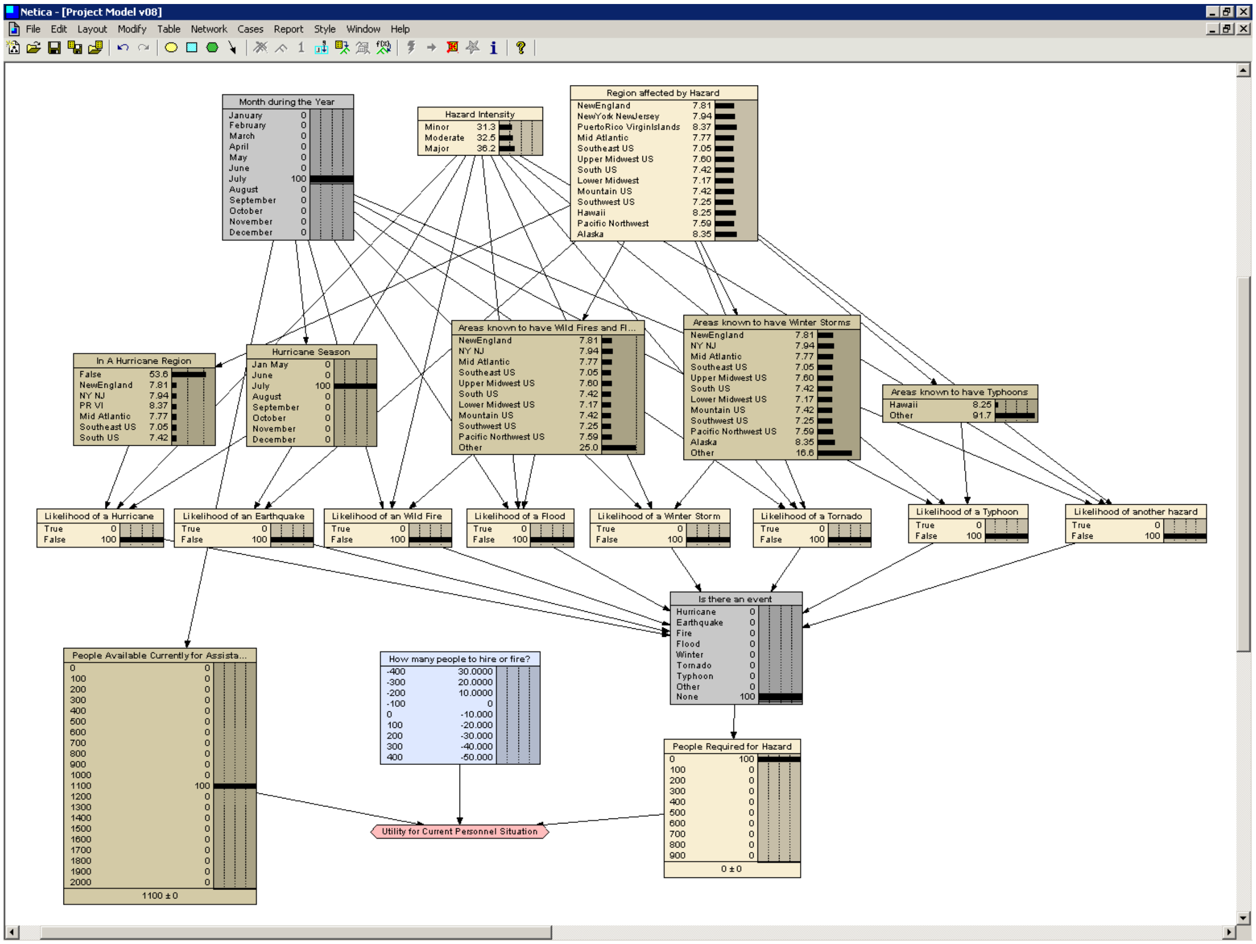
People Required for Hazard	People Available Currently for ...	How many people to hire or fire?	Utility for Current Personnel Situation
0	0	-400	-40
0	0	-300	-30
0	0	-200	-20
0	0	-100	-10
0	0	0	100
0	0	100	90
0	0	200	80
0	0	300	70
0	0	400	60
0	100	-400	-30
0	100	-300	-20
0	100	-200	-10
0	100	-100	100
0	100	0	90
0	100	100	80
0	100	200	70
0	100	300	60
0	100	400	50
0	200	-400	-20
0	200	-300	-10
0	200	-200	100
0	200	-100	90
0	200	0	80
0	200	100	70
0	200	200	60
0	200	300	50
0	200	400	40
0	300	-400	-10
0	300	-300	100
0	300	-200	90
0	300	-100	80
0	300	0	70
0	300	100	60
0	300	200	50
0	300	300	40
0	300	400	30
0	400	-400	100
0	400	-300	90
0	400	-200	80
0	400	-100	70
0	400	0	60
0	400	100	50
0	400	200	40
0	400	300	30

Test Cases for Model Analysis

Case 1: Multiple hazards with little personnel available



Case 2: Busy time with no event



Bibliography

FEMA: About FEMA. (2009, 10 30). Retrieved 05 07, 2010, from FEMA.GOV: http://www.fema.gov/about/index.shtm#0

FEMA: HAZUS-MH Models. (2009, 09 18). Retrieved 05 07, 2010, from FEMA.GOV: http://www.fema.gov/plan/prevent/hazus/hz_models.shtm

Weather Research. (2010, 03 30). Retrieved 05 07, 2010, from NOAA.GOV: http://www.research.noaa.gov/weather/