Hazard, Exposure, and Combined Risk Scoring

The approach used for this project involves three types of risk scores: hazard scores, exposure scores, and combined scores. Each of the three risk scores describe different aspects of the vulnerability in a given region:

- **Hazard Scores**. Hazard scores measure the average impact of different hazard types in a region. The hazard score in a region is a function of the geography and natural recurrence of disasters over time in an area. Thus, hazard scores are inherent to a region and theoretically cannot be lowered through mitigation or other intervention. A hazard score is computed for each hazard type and each subregion considered. Hazard scores can be combined within a subregion or across multiple subregions to evaluate aggregate hazard risk levels.

- **Exposure Scores**. Exposure scores measure the level of assets, populations, or resources within a given region. The exposure score is a function of the built environment, demographics, and environmental uses of a given region. Exposures scores can be combined within a subregion or across multiple subregions to evaluate aggregate exposure levels.

- **Combined Scores**. Combined scores represent the product of individual hazard and exposure scores, measuring the effects of hazards on the exposure of a given region. Combined scores are useful results for policymaking and risk mitigation, as they indicate the key hazard/exposure combinations that exist in a region. Combined risk scores are calculated for each subregion, and can then be aggregated to measure overall scores for the study region or other combinations of subregions by summation.

Note that the significance of the scores is relative in nature. A given score does not correspond to a dollar loss level or other direct measure of risk. Instead, the risk scores are intended to provide a framework for understanding the aggregate distribution of hazard and exposure combinations across a study region. Detailed analysis of direct risk measures, such as dollar loss, can be conducted for the key hazard/exposure combinations identified by this approach, using software like HAZUS.

Hazard Score

Overview of Scoring Procedure

Scoring Approach

The hazard score for each hazard type is computed using the following formula:

HAZARD SCORE = (FREQUENCY SCORE) * (AREA IMPACT SCORE)*
(INTENSITY SCORE)

The individual factors in the hazard score are:

- Frequency Score. This score is a measure of how often a given hazard occurs, in terms of number of events per year.
- Area Impact Score. This score is a measure of how much geographic area would be affected by a hazard event, in terms of either gross area or relative area (see discussion below).
- Intensity Score. This score is a measure of the level of intensity of a hazard. For each hazard, a different measure is used, based on the type of forces that characterize the hazard (e.g. wind for a hurricane, ground shaking for an earthquake).

The procedure for determining each component of the hazard score is described below.

Frequency Score

Frequency scores are based on the average number of events per year of the hazard type.

Five levels of frequency are considered, based on commonly used benchmarks in both the insurance and building design fields. Table 2 summarizes the frequency score and subjective description of each frequency level.

Table 2. Frequency Lookup Table

Return Period (years)	Frequency Score	Number of events per year	Subjective Description
1	5	1	Frequently recurring hazards, multiple recurrences in one lifetime
50	4	0.02	Typically occurs at least once in lifetime of average building
100	3	0.004	25% chance of occurring at least once in lifetime of average building
500	2	0.002	10% chance of occurring at least once in lifetime of average building
1000	1	0.001	Highly infrequent events, like maximum considered earthquake

Area Impact Score

Two methods of determining area impact score were used, depending on the type of hazard distribution (see description of individual hazards below):

- Relative Area Impact. This method relates the area impact score to the percentage of a subregion impacted by the event considered (such as the % area of a census tract). Scoring for this method is shown in Table 3 below.

- Absolute Area Impact. This method relates the area impact score to the average impact in square miles of the event considered. The scores used are shown in Table 4 below.

Table 3: Area Impact Lookup Table, Relative Method

Relative Area Impact (% subregion covered)	Score	Subjective Description
0	0	No affected area - 0% impact
0.1	1	10% tract impact
0.25	2	25% tract impact
0.5	3	50% tract impact
0.75	4	75% tract impact
1	5	100% tract impact

Table 4. Area Impact Score, Absolute Method

Absolute Area Impact (sq. miles)	Score
0	0
0.001	1
0.01	2
0.1	3
1	4
10	5

Intensity Score

To determine intensity scores, an intensity measure was selected for each hazard type, as follows:

- Extreme Wind (Nor'easters and Hurricanes): 3-sec gust windspeed (mph) and wind pressure on buildings (psf)
- Earthquake: Spectral acceleration (1-sec), %g

- Tornado: Fujita scale
- Flood: Base Flood Elevation (ft)
- Hail: Particle size (in)
- Snow: Snowfall (in)
- Extreme Temperature: Heating and cooling degree days

For each hazard type, the intensity measure was related to a lookup table of intensity scores ranging from 1 (lowest intensity) to 5 (highest intensity). The intensity scores therefore provided a somewhat uniform method of relating intensities from very different hazards.

NOTE: These intensity measures are intended for use in the Northeast region of the U.S. only. Different relative intensities should be considered for other regions of the country.

Extreme Wind (Nor'easter and Hurricane)

Extreme wind hazards were analyzed using an approach that is consistent with ASCE 7-98, "Design Loads for Buildings and Other Structures". ASCE 7-98 serves as the basis for building codes throughout the United States and employs a generally accepted procedure for determining wind force levels for design of buildings.

The frequency of winds used for design is typically 100 years, and therefore this frequency level was selected for wind analysis in this study. Because of the large geographic nature of hurricanes and nor'easters, the area impact score used was 5 in all cases.

Extreme wind intensity scores were based on a combination of geographic windspeed distribution and wind pressure figures, both of which are taken from ASCE 7-98. This process consisted of two steps:

The first step was to determine the average wind speed that a tract was likely to experience in a 100 year hurricane event. This varies across the state and was divided into three categories. These categories were 90-100 miles per hour wind speeds, 100-110 miles per hour wind speeds, and 110 – 120 miles per hour wind speed. The windspeed for each tract was taken from ASCE 7-98 Figure **6-1c,** "Basic Wind Speed – Mid and Northern Atlantic Hurricane Coastline", and corresponds to the 3-sec gust windspeed at 33 ft above ground for Exposure C category (see description of categories below).

The second step was to determine the average degree of exposure within each census tract. The exposure score is determined by the ground cover, topography, and constructed features of a tract and is labeled as A, B, C, or D. The exposure categories were taken from the ASCE 7-98 building code, and are standard categories used in the design of buildings nationwide:

- Exposure A is applied to large city centers with buildings averaging over 70' in height. All tracts with a population of over 10,000 people were classified as Exposure A.
- Exposure B is for urban and suburban areas. Tracts with populations between 2,500 and 10,000 people were classified as Exposure B.
- Exposure C is for open terrain, with populations of less than 2,500.
- Exposure D is for flat, unobstructed areas exposed to wind flowing over water. All tracts within one mile of the ocean were classified as Exposure D.

NOTE: The application of these exposures is very coarse. In actuality, individual sites within a census tract may have widely varying exposures. However, for the purposes of this study, which focuses on statewide levels of risk, an average exposure for each census tract was judged to be sufficient for the analysis of each census tract.

Once the exposure category and wind speeds were determined, these values were used in a matrix (shown in Table 5) to determine the average force of wind pressure that would affect a typical building, in pounds per square foot. For example, if a tract has an exposure of category B and is in a 110 mile per hour wind speed zone, the average pressure would be approximately 20 pounds per square foot. This measurement corresponds to the ASCE 7-98 method for determining hurricane forces on structures.

Finally, the value of wind pressure determined was entered into Table 6 below, which resulted in a score of 1 to 5 for extreme wind intensity score. Higher wind pressure levels are assigned higher intensity scores. Thus, the extreme wind hazard score for a census tract is proportional to the average wind pressure experienced by buildings within that census tract for a building code level wind event.

Table 5. Basic Pressure, Simplified Method (based on ASCE 7-98), psf

	Windspeed (3 sec gust)			
Exposure	90	100	110	120
A	12.6	15.3	18	21.6
B	14	17	20	24
C	19.6	23.8	28	33.6
D	23.24	28.22	33.2	39.84

Table 6. Intensity Score Lookup Table based on Pressure

Pressure (psf)	Intensity Score
<12	0
12	1
15	2
20	3
25	4
>30	5

Earthquake

Earthquake scoring was computed with the aid of HAZUS-99, FEMA's software for hazard and loss estimation from earthquakes. To determine the earthquake score, the following process was followed:

- A single earthquake frequency level was selected as a basis for analysis. For the purposes of this study, all scores were based on a 500 year recurrence event. Note that other return periods could also be used to determine earthquake hazard scores, but the 500 year event was selected as most representative of a "design basis" earthquake frequency for the state of Rhode Island based on the judgment of the project team.

- HAZUS was then used to calculate the average spectral accelerations for each census tract, using a 500 year probabilistic event for the state of Rhode Island. The HAZUS output included maps of spectral acceleration and numerical tables corresponding to the maps. The spectral acceleration values output by HAZUS account for the major factors that influence ground motions in an earthquake, including soil types and distance from earthquake sources.

- Area Impact scores were taken to be 5 for all Rhode Island census tracts due to the complete coverage which would occur during a statewide earthquake event.

- Intensity scores were constructed using spectral acceleration, in units of gravitational acceleration, for a 1 second period building. These values were created using judgment, such that they would be consistent with hazard levels used in building codes for earthquake design.

- Finally, frequency, area impact, and intensity scores were multiplied together to determine the earthquake hazard score for each census tract.

Table 7. Earthquake Intensity Score

Spectral Acceleration (1sec), g	Intensity Score	Subjective Description
0	0	No effects
0.005	1	Felt indoors, light vibration
0.01	2	Indoors, strong vibration
0.025	3	Outdoors, house shakes
0.05	4	Walls crack, ground waves
0.1	5	Violent, building structures damaged

Hailstorm

Hail frequency scores were based on historic data for hail events over the last 50 years. Area impact was computed using an absolute scale for an area of 1 square mile. Intensity scores were based on particle size of the worst case recorded event in a census tract, as shown in the table below.

Table 8. Hail (Particle Size, in)

Particle Size (in)	Intensity Score	Subjective Description
0	0	No Effect
0.5	1	Foliage damaged
1	2	Cars dented
2	3	Windows smashed
3	4	Moderate Injuries
4	5	Serious injury & damage

Severe Snowstorms

Snowstorms were also calculated on the basis of a historical record from the NWS. Area impact was determined using a relative scale due to the nature of the hazard. Intensity was determined by the depth of snowfall of the worst case event recorded in a census tract, as outlined in the table below.

Table 9. Snowstorm (Depth, in)

Depth (in)	Intensity Score	Subjective Description
0	0	Ground visible
3	1	Moderate cover
6	2	Thick ground cover
9	3	Trees collapse
12	4	Roads impassable
>24	5	Light structural damage

Temperature Extremes

The frequency scores for temperature extremes are based upon seasonal averages over a 50 year period. The area impact scores were statewide, thus resulting in consistent scores of 5. Intensity scores were determined by the difference between the number of heating degree days and cooling degree days. These values were evaluated per the table below.

Table 10. Temp Extremes (Heating Deg. Days - Cooling Deg. Days)

Degree Days	Intensity Score	Subjective Description
0	0	No temp. extremes
100	1	Light variation
1000	2	Medium variation
2500	3	Serious temperatures
7500	4	Cold/Heat Wave

10000	5	Frigid/Burning Temp.

Tornado

Frequency values were derived from historic tornado data over a 30 year period, culled from the National Weather Service Severe Weather Center. Area impact was computed based on the average length and width of the damage path, as cited also by the National Weather Service. Finally, Intensity scores were based on the Fujita Scale, as illustrated below.

Table 11. Tornado (Fujita Scale)

Fujita Scale	Intensity Score	Subjective Description
0	0	Light damage
1	1	Moderate damage
2	2	Significant damage
3	3	Severe damage
4	4	Devastating damage
5	5	Incredible damage

Flooding

Flood frequency was based on the 100 and the 500 year flood events as follows:

- A 100-year frequency flood score was determined for each census tract by taking the % area covered by flood zone A (for the area impact score) and the average base flood elevation (for the intensity score, see Table 12 below).

- A 500 year frequency flood score was determined for each census tract by taking the % area covered by flood zone X500 (for the area impact score) and the average base flood elevation (for the intensity score, see Table 12 below).

The flood hazard score was determined by averaging these two scores together.

Note that flood area impact scores were analyzed using both relative and absolute area figures. For the final study, relative area covered was chosen because it more accurately measured the potential damage caused to small tracts while not biasing scores towards their favor. However, both absolute and relative area figures are included in the database for different types of analysis if deemed desirable at a later date.

Table 12. Flood (BFE, Base Flood Elevation, ft)

Base Flood Elevation	Intensity Score	Subjective Description
0	0	No effect
14	1	Light flooding
18	2	Moderate flooding
20	3	Moderate-heavy flooding
22	4	Heavy Flooding
24	5	Severe Flooding