

## VECTOR-VALUED GROUND MOTION INTENSITY MEASURES

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Among the goals of Performance-Based Earthquake Engineering is estimation of the demand on a structure from a given earthquake. This is often done by calculating an “Intensity Measure” (IM) for a given earthquake ground motion, and then computing the probability that the earthquake will cause a given level of demand in the structure as a function of this IM. Traditional IMs (e.g., peak ground acceleration and spectral acceleration at the first-mode period of vibration) consist of a single parameter. In contrast, vector-valued IMs consist of two (or more) parameters. These vector-valued IMs have the potential to reduce the variability in structural response predictions, leading to more efficient estimation of demand (i.e., a reduction in the number of analyses needed).

I am currently investigating two promising categories of vector-valued IMs:

### **1. Spectral acceleration and a measure of spectral shape**

The first IM considered is a vector consisting of spectral acceleration at the first-mode period of vibration along with a measure of spectral shape (the ratio of spectral acceleration at a second period to the original spectral acceleration value). This vector shows great promise in reducing the record-to-record variability in structural response among a suite of records with the same IM value. This conclusion is consistent with previous work by other researchers on the effect of spectral shape.

### **2. Spectral acceleration and “Epsilon”**

The second vector IM under consideration consists of spectral acceleration at the first-mode period of vibration along with the “Epsilon” of the record. A record’s Epsilon value represents the distance (number of standard deviations) between the record’s spectral acceleration from the spectral acceleration predicted by an attenuation relationship (at a given period). A positive Epsilon value corresponds to a record with larger spectral acceleration than predicted for an event with the given magnitude and distance. It has been found that records with large (positive) Epsilon values cause a systematically smaller response in structures than records with small (negative) Epsilon values, given that the Spectral Acceleration of the two records is equal. It is believed that this effect occurs because Epsilon is an indicator of peaks and valleys in the spectral shape. From disaggregation on Epsilon in Probabilistic Seismic Hazard Analysis, it can be seen that at long return periods a site’s ground motion hazard is dominated by large-Epsilon events. These events cause a smaller response than the (on average) zero-Epsilon records that we typically use to estimate demand. This means that estimation of structural response at long return periods is conservative when using traditional scalar IMs. Use of a vector-valued IM consisting of spectral acceleration and Epsilon eliminates this problem.

Along with the proposed IMs, a method for predicting the probability distribution of demand using a vector IM has been developed. This method accounts for the effect of collapses on the distribution of demand. Two complimentary methods for determining the optimum vector IM have also been developed, and an improvement in the accuracy of demand predictions using a vector-valued IM has been demonstrated.