



Valparaiso
University

Probabilistic
Analysis of the
Economic
Impact of
Earthquake
Prediction
Systems

Ruyue Yuan

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Probabilistic Analysis of the Economic Impact of Earthquake Prediction Systems

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Advantages of a Prediction System

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- Save lives
- Minimize damage
- Lower cost of damage and loss
- Allow time for decision-making
- Capable of dealing with natural hazards



Disadvantages of a Prediction System

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- Cause public panic
- Force large-scale evacuation
- Make possible false predictions
- Potential waste of time and resources
- Significant economic loss



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Are earthquake prediction systems helping?



The Richter Scale

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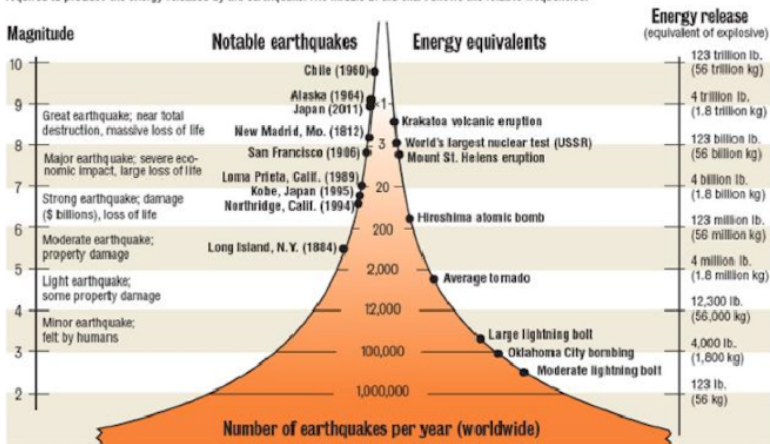
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Earthquake frequency and destructive power

The left side of the chart shows the magnitude of the earthquake and the right side represents the amount of high explosive required to produce the energy released by the earthquake. The middle of the chart shows the relative frequencies.





- M_O : Observed magnitude of an earthquake
- M_P : Predicted magnitude of an earthquake
- T : Lead time, the period before an earthquake occurs
- C_P : Cost of an earthquake prediction
- C_A : Avoided cost from having an earthquake prediction
- L : Number of lives saved



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- Collect variables to model the net cost of a prediction system, M_O , M_P , T .
- Use the net cost and number of lives saved to find the cost per life saved.
- Use probabilistic method to estimate the cost per life saved



- The net cost $C = C_P - C_A$
- The cost per life saved = $\frac{C}{L}$
- The expected value of cost per life saved
$$E[X] = E \left[\frac{C}{L} \right]$$



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The expected value of cost per life saved is

$$E[X] = \frac{E[C]}{E[L]} = \frac{E[C_P - C_A]}{E[L]}$$



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- $E[X] = E \left[\frac{C}{L} \right] \neq \frac{E[C]}{E[L]}$
- C is not a deterministic function of M_O , M_P , T , but a random function of M_O , M_P , T .



- $E[X] = E \left[\frac{C}{L} \right] \neq \frac{E[C]}{E[L]}$

- C is not a deterministic function of M_O , M_P , T , but a random function of M_O , M_P , T .

These two major invalid derivations lead to a much smaller expected value of cost per life saved with a prediction system.



Theorem 1.

The expected value of cost per life saved:

$$E[X] = \sum_T \sum_{M_P} \sum_{M_O} [(\mu_P(M_O, M_P, T) - \mu_A(M_O, M_P, T)) \cdot$$

$$\frac{1 - e^{-\lambda(M_O, M_P, LT)}}{\lambda(M_O, M_P, LT)} \cdot p(M_O) \cdot p(M_P|M_O) \cdot p(T|M_P)].$$



Theorem 2.

The expected value of cost per life saved when the observed magnitude is greater than 8:

$$E[X|M_O = 8+] = \sum_T \sum_{M_P} [(\mu_P(M_P, T) - \mu_A(M_P, T)) \cdot$$

$$\frac{1 - e^{-\lambda(M_P, LT)}}{\lambda(M_P, LT)} \cdot P(M_P = j | M_O = k) \cdot P(T = i | M_P = j)].$$



The cost per life saved in an earthquake of magnitude 8+:

- Paté's result: approximately \$1.56 million.
- Our result: approximately \$2.50 million.

From this comparison, we see that both of the results are on the same scale, and our new result is significantly greater than Paté's result.



- With the cost of \$6.30 million for life saving without a prediction system, we conclude that prediction systems are needed, especially for large-scale earthquakes.
- The humanity factor of this research cannot be neglected. The value of lives is not only a number in the cost function, but also by itself significant.



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- Improve numerical results
- Submit to a journal



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- Advised by Dr. Tiffany Kolba.

Thank you for listening!



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