Physica A 424 (2015) 207–216

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Evidence in support of seismic hazard following Poisson distribution

J.P. Wang [a,*], Su-Chin Chang [b]

[a] Department of Civil & Environmental Eng., The Hong Kong University of Science and Technology, Hong Kong

[b] Department of Earth Sciences, The University of Hong Kong, Hong Kong

HIGHLIGHTS

- Evidence in support of seismic hazard following Poisson distribution.
- A novel application of Monte Carlo Simulation to seismic hazard assessment.
- Detailed procedure of the unique Monte Carlo Simulation.

ARTICLE INFO

Article history:
Received 8 July 2014
Received in revised form 15 October 2014
Available online 13 January 2015

Keywords:
Seismic hazard
The Poisson distribution
Monte Carlo Simulation

ABSTRACT

Unlike earthquake frequency that was proved following the Poisson distribution, seismic hazard (the annual rate of earthquake ground motions) is assumed to be the same type of random variables without tangible support. Instead of using total-probability algorithms currently employed, this study applied Monte Carlo Simulation (MCS) to obtain the probability function of seismic hazard, and then compared it to the Poisson distribution to see if it is really close to the model prediction as assumed. On the basis of a benchmark calculation, the analysis shows a very good agreement between the two, providing some evidence for the first time that seismic hazard should follow the Poisson distribution, although the relationship has been commonly employed in earthquake studies.

1. Introduction

Given that earthquakes are not predictable [1,2], seismic hazard analysis has become one of the practical approaches for earthquake hazard mitigation [1,2]. But before introducing probabilistic seismic hazard analysis (PSHA), it is worth clarifying the definition of seismic hazard: rather than casualty or economic loss associated with earthquakes, seismic hazard refers to the annual rate of a given ground motion of exceedance, e.g., PGA > 0.1 g $= 0.01$ per year.[1]

With the mean hazard rate calculated, the next step of PSHA is to estimate the probability for the seismic hazard (e.g., PGA > 0.1 g) to occur in a given period of time (e.g., 50 years), by assuming it is a random variable following the Poisson distribution [3]. For example, if the mean rate (λ) of PGA > 0.1 g is estimated at 0.005 per year, the probability for the event to occur in next 50 years is equal to 22%:

$$\Pr(T \leq 50 \; years; \lambda = 0.005 \; per \; year) = 1 - e^{-\lambda t} = 1 - e^{-0.005 \times 50} = 0.22 \tag{1}$$

where $\Pr(T \leq t; \lambda) = 1 - e^{-\lambda t}$ is the cumulative density function of the exponential distribution that can satisfactorily model the event's temporal probability function, as the stochastic process is governed by the Poisson model [3,4].

* Corresponding author.
E-mail addresses: jpwang@ust.hk (J.P. Wang), suchin@hku.hk (S.-C. Chang).

1 PGA = peak ground acceleration.

http://dx.doi.org/10.1016/j.physa.2015.01.026
0378-4371/

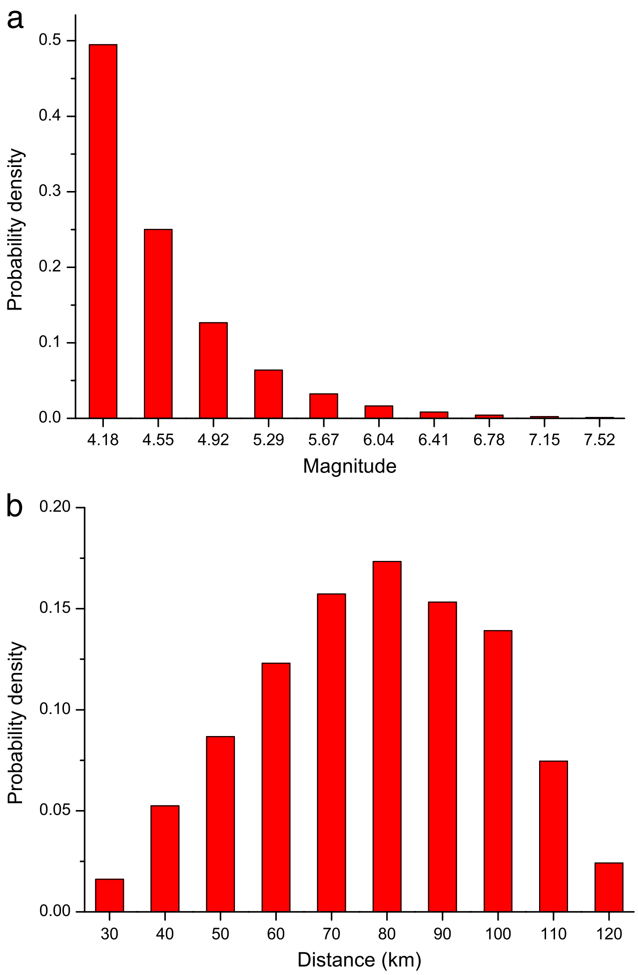

Fig. 1. The probability functions of earthquake magnitude and source-to-site distance of a benchmark example in the literature [3].

However, without any tangible support from the literature, the ''seismic-hazard-and-Poisson'' assumption has been an engineering judgment at best. As a result, the key scope of this study is to examine if seismic hazard should follow the Poisson distribution as commonly adopted in some earthquake studies.

Monte Carlo simulation (MCS) is one of the common approaches used in a variety of probabilistic analyses [5–11]. But unlike total-probability and FOSM[2] algorithms, Monte Carlo Simulation allows us to obtain a variable's probability function in addition to its mean value and standard deviation. Therefore, instead of using total-probability algorithms that are currently employed, this study applied a novel MCS calculation to probabilistic seismic hazard assessments, aiming to obtain the hazard's probability function, and to see if it is really following the Poisson distribution as assumed.

The paper is organized as follows: an overview of probabilistic seismic hazard analysis, followed by the introduction to the novel MCS application to this study. Next, the MCS calculations were demonstrated with a benchmark example from the literature, as well as the statistical tests examining the (Poisson) model's goodness-of-fit to the probability distribution of seismic hazard.

2. Probabilistic seismic hazard analysis (PSHA)

The framework of probabilistic seismic hazard analysis was first proposed in the late 1960s [12], and in the past decade it has become a common approach for developing site-specific earthquake-resistant designs [13–19]. Different from deterministic assessments, PSHA takes the uncertainties of earthquake magnitude, location, and motion attenuation into account. For instance, Fig. 1 shows the uncertainties or probability functions of earthquake magnitude and source-to-site distance for a benchmark example Ref. [3].

[2] FOSM: first-order second-moment.