Intensity of earthquake ground shaking: An application of Kaplan Meier Estimation

ABSTRACT
In practice, we will typically look for earthquake patterns. The time between two or more earthquakes is an example of time-to-event data that is examined using a statistical method known as survival analysis. This paper's main goal is to estimate how severely certain regions of the planet have been affected by a series of earthquakes. The indicator of censorship is the interval between two or more subsequent earthquakes. The data are frequently fitted to a survival model, like Kaplan Meier Estimation or the Hazard curve, depending on the discrepancy between the earthquake's timing of occurrence and its intensity. This will spread knowledge about earthquakes in certain regions where they commonly happen. This has been proved supported by application to real data "Earthquake Shaking Intensity Data Analysis".

KEYWORDS:
Earthquake Intensity, Kaplan Meier, Hazard Curve, Survival Analysis Log Run Test

INTRODUCTION:
A natural calamity known as an earthquake happens when the earth's crust moves and releases energy in the form of seismic waves. This quick release of energy has the potential to produce shaking and ground movement, harming natural resources, infrastructure, and structures while posing a serious threat to human life. The shifting of the tectonic plates that make up the earth's crust is what causes earthquakes.

Over time, these plates move slowly, and when they collide or one plate slides under another, an earthquake may result. A number of variables, such as the size of the relevant plates, the type of fault, and the depth of the earthquake, affect the epicentre and magnitude of an earthquake. The Richter scale, which spans from 1 to 10, is used to determine how severe an earthquake is.Each step up the scale corresponds to a tenfold increase in the seismic wave amplitude, which signifies the earthquake's power. Major earthquakes, defined as those with a magnitude of 7 or greater, are capable of causing severe destruction and fatalities.

The Kaplan-Meier estimator, named after Edward L. Kaplan and Paul Meier, is a non-parametric statistical method used to estimate the survival function (probability of survival) from time-to-event data. It is commonly applied in medical research and other fields to analyse the time it takes for events such as death, failure, or success to occur. The Kaplan-Meier estimator provides a way to calculate and visualise the survival probability over different time intervals, even when data may be censored (events not observed for all subjects).

SURVIVAL PROBABILITY

Let T be the positive random variable related to survival time with density function $f\left(t\right)$ and cumulative distribution function $f\left(t\right)$

The survival function is defined as the likelihood that a person will live past certain period t:

$S(t) = P(T > t) = 1 - F(t)$ (1) **(M. A GHOUSE BASHA AND M. RAMADURAI)**

When the strength of the shaking is very low, the censored value is 0, and when the intensity of the shaking is high or moderate, the censored value is 1. The likelihood of surviving in an earthquake is determined by a number of factors, including the magnitude of the earthquake, distance from the epicentre, depth of the earthquake, type of soil and geology in the area, building construction standards, and individual preparedness. Here are several significant characteristics that can influence the likelihood of surviving in an earthquake: The Earthquake's Magnitude: Larger earthquakes often inflict broad damage and are more likely to result in fatalities. Proximity to the Epicentre: The closer you are to an earthquake's epicentre, the more violent the shaking, which can raise the risk of structure damage and personal injury. Construction of Buildings: The quality of building construction is critical to survival. Buildings that are well-built and meet earthquake-resistant design requirements are more likely to endure shaking. Building Age: Older buildings, particularly those constructed before to the adoption of contemporary seismic building rules, are more vulnerable to damage during earthquakes. Soil and Geology: The kind of soil and geology in a place can influence seismic wave amplification, making some areas more prone to ground shaking and liquefaction, increasing the risk to buildings and infrastructure. Preparedness: Individuals and communities who are well-prepared for earthquakes, with emergency plans, supplies, and understanding on how to "Drop, Cover, and Hold On" during shaking, have a better chance of survival. Early Warning Systems: In some areas, earthquake early warning systems can provide seconds to minutes of warning before substantial shaking occurs, allowing people and automated systems to take preventive measures. Evacuation Plans: Having evacuation plans and routes in place in places prone to tsunamis or other earthquake-related dangers can save lives. Government Response and Infrastructure: The effectiveness of government response, emergency services, and essential infrastructure resilience (such as hospitals and utilities) can all have an impact on survival rates. It's vital to remember that earthquake survival isn't exclusively dependent on one component, but rather on a combination of them. Individuals and communities must be prepared, educated, and informed in order to lessen the danger of injury and death during an earthquake. Following safety recommendations and building codes, as well as participating in earthquake drills and stocking up on emergency supplies, can considerably improve your chances of surviving in the case of an earthquake.

The survivor function -

An individual's actual survival time t, can be thought of as the observed value of a variable T, which can take any non-negative value. The various values of T have a probability distribution, and we refer to T as the random variable associated with the survival time. Assume this random variable has a probability distribution with a probability density function $f(t)$. Then, the distribution function of T is given by-

$$F(t) = P(T < t) = \int_0^t f(u)\,du, \qquad (1.1)$$

and represents the probability that the survival time is less than some value t. This function is also called the cumulative incidence function, since its summaries the cumulative probability of death occurring before time t. REF- (**DAVID COLLETT) .**We assume that the survival odds for patients enrolled early and late in the research are the same. In a long-term observational study of cancer patients, for example, the case mix may alter over time, or there may be a breakthrough in auxiliary treatment. This assumption can be checked if enough data is available to predict survival curves for different subsets of the data .Second, we suppose that the event occurs at the provided time. This is not a problem for the conception statistics, but it may be if the occurrence were a recurrence of a malignancy that would be found during a routine test. All we'd know is that the incident occurred between two examinations. This imprecision would increase the chances of survival. When the observations are at regular intervals, this can be easily accommodated using the actuarial technique. Ref- National Institutes Of Health

Survival analysis-Survival analysis is a statistical technique used to analyse time-to-event data in a variety of domains, including medical, economics, engineering, and social sciences. It is concerned with the time until an event of interest occurs, such as death, machine failure, customer churn, or any other event for which the precise time of occurrence is known or may be approximated.

Censoring-Censoring is an important concept in survival analysis, which is a statistical tool for analysing time-to-event data. The "event" of interest in survival analysis can be anything that takes time to occur, such as the breakdown of a machine, the death of a patient, or the occurrence of a specific event in a research. Censorship occurs when we fail to record the precise time of an event for some of the subjects in the study.

Three main types of censoring-

Right Censoring , Left Censoring , Interval-Censoring

Kaplan-Meier estimate

The Kaplan-Meier estimator is a statistical tool used in survival analysis to assess the probability of an event's survival through time. While it is most usually connected with medical studies (for example, predicting the survival rate of individuals with a given condition), it can also be used to examine other phenomena, such as earthquakes. In the context of earthquakes, the Kaplan-Meier estimator could be used to assess the likelihood of a certain magnitude earthquake occurring within a given time frame. Let d_j be the n observed survival periods. Then, arrange the time in ascending order, at the start of each interval, count the number of places where shaking intensity feels at least one time.

Let d_j be the number of $\frac{events}{rate}$ that occurred during the j^{th} period. For each time interval, the survival probability can be determined using $\left(\frac{n_{j-}d_j}{n_j}\right)$. The likelihood of surviving across the time-interval is the Kaplan-Meier estimate of the survival function for a given period t from t_k to $t_{(k+1)}$.

(M. A GHOUSE BASHA AND M. RAMADURAI)

$$S(t)=\begin{cases}1 & ;t<t_{(1)}\\ \prod_{j=1}^{k}\left(\frac{n_j-d_j}{n_j}\right); & t_{(k)}\le t<t_{(k+1)},\ k=1,2,3,\dots,\mathrm{r}.\end{cases} \qquad (2)$$

Where $n_{(j)}$ = event , $d_{(j)}$ = risk

and $t_{(k)}$ and $t_{(k+1)}$ = Time interval

The Kaplan-Meier estimator can be used to estimate the cumulative distribution function (CDF) of earthquake occurrence times or inter arrival periods (i.e., the time between subsequent earthquakes) in the context of earthquakes. This can be useful for analysing seismic hazard and determining the likelihood of earthquakes in a specific area. Researchers and engineers in earthquake analysis often utilise a variety of tools and models to examine seismic events, such as: Structural Analysis: Engineers utilise structural analysis methods to evaluate the seismic performance of buildings, bridges, and other infrastructure. Methods such as finite element analysis (FEA) and response spectrum analysis are frequently used. Ground Motion Simulation: To understand how seismic waves propagate through the Earth and how they influence structures and the ground surface, researchers utilise computer models and simulations. Seismological data and physics-based modelling are used in these simulations. Risk Assessment: In earthquake-prone locations, risk assessment entails combining seismic hazard analysis, structural analysis, and vulnerability assessments to evaluate the possible impact of earthquakes on a community or region. The Kaplan-Meier curves show the result of interest, censoring, and the number of participants at risk or the likelihood of survival. The Kaplan-Meier method is based on the assumption that censoring is independent of the chance of developing the event of interest and that survival probabilities in participants enrolled early and later in the trial are comparable. In the case of a comparison of numerous groups, these assumptions must also be met for each group. The Kaplan-Meier technique is demonstrated using data from the life table to clarify the principles. All individuals are at risk at time = 0 (baseline), hence the survival probability is 1 (or 100%). The main limitation of Kaplan–Meier estimate is that it cannot be used for multivariate analysis as it only studies the effect of one factor at a time. (Sushmita Rai, Prabhakar Mishra & Uday C. Ghoshal)

Hazard Function

The hazard function is extensively used to indicate the risk or hazard of an event occurring at some time t. such as death. This function is derived from the likelihood that a person will die at time t, if he or she has survived to that point. Consider the probability that the random variable associated with an individual's survival time, T, lies between t and $t+\partial t$, conditional on T being larger than or equal to t, represented as the hazard function. And written as $h(t)$. This conditional probability is then expressed as a probability per unit time by dividing by the time interval, ∂t, to give a rate. The hazard function, $h(t)$, is then the limiting value of this quantity, as ∂t tends to zero, so that

$$h(t) = \lim_{\delta t \to 0} \left\{ \frac{P(t \le T < t + \partial t \mid T \ge t)}{\partial t} \right\} \qquad (3)$$

The hazard function is a fundamental concept in earthquake research that describes the likelihood of an earthquake of a certain magnitude occurring during a specific time frame at a given place. It is an important part of seismic hazard assessment, which is necessary for earthquake risk reduction and building code development.

Estimating the cumulative hazard function-

The derivative of the cumulative hazard function is the hazard function itself, the slope of the cumulative hazard function provides information about the shape of the underlying hazard function. For example, a linear cumulative hazard function over some time interval suggests that the hazard is constant over this interval. Methods that can be used to estimate this function will now be described.

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Log Run Test:The Log Run Test is a statistical hypothesis test used to assess the significant difference in survival probabilities between individuals who are out of India and those within India. The null hypothesis suggests no significant difference, while the alternative hypothesis posits a substantial disparity in survival probabilities between the two groups. The test helps analyse and compare survival rates,aiding in drawing conclusions regarding the impact of location (inside or outside India) on survival outcomes.

4. **Earthquake Shaking Intensity Data Analysis**

In this study, earthquake intensity data, a classical survival data set with time-dependent covariates, are reanalyzed. Known datasets have been repeatedly considered and analysed. The Kaplan-Meier method with censoring was applied to the data to obtain survival probability estimates. The data set contains 148 observations. 84 of them survived the earthquake. The censoring rate was 56% and adjusted for analysis. The response variable is survival time.

This Kaplan-Meier survival analysis of earthquake shaking intensity examined a cohort of 148 observations over 3–4 months (March–July 2023). We grouped the data into two sub-categories based on location: inside India and outside India. Through survival analysis, certain insights can be gained from the data.

Attributes of the earthquake

An earthquake is a natural occurrence that might have important characteristics in terms of its impact. Key characteristics of an earthquake include:

Magnitude: Magnitude is the size of the earthquake. An earthquake has a single magnitude. The shaking that it causes has many values that vary from place to place based on distance, type of surface material, and other factors. See the Intensity section below for more details on shaking intensity measurements.

Place:The nation that contains the earthquake's epicenter.This characteristic aids in determining the earthquake's larger geographic setting. for example : Afghanistan, Nepal, Tajikan, Xizang,Mexico, Japan etc. And States such as Karnataka , Utter pradesh, Himachal Pradesh etc.

Time (in GMT):The date and time, in Coordinated Universal Time (UTC/GMT), that the earthquake happened.It offers a Standardised reference for the earthquake's time of occurrence.

Time(in minutes):The amount of time that has passed from a given starting time, such as a reference point, to the present earthquake occurrence This characteristic facilitates the investigation of survival analysis and recurring patterns.IST is 5:30 hours ahead of GMT.

Intensity:The intensity of shaking during an earthquake is a measurement of its severity. An earthquake will have a single magnitude but many intensities.The degree of shaking, damage, and impact on individuals and structures are frequently measured using the Modified Mercalli Intensity (MMI). It can decide the censored value in our data, such as if the intensity was feeling very weak and weak, it will be considered '0,' and if the intensity was feeling light and moderate, it will be considered '1'.

Location:The locations mentioned, including those within India and outside India, offer a diverse and multi-dimensional perspective to the research. Examining data from both within and outside India can provide a more comprehensive understanding of the subject under investigation. It allows researchers to explore global trends, compare regional variations, and potentially draw insightful conclusions about the broader implications of their research. Therefore, carefully considering the geographic scope of a study is fundamental in ensuring the research's relevance and applicability to a wider audience, while also highlighting the need for context-specific interpretations.

Depth: An earthquake's depth has a significant impact on how much damage it does. Deeper earthquakes are less likely to cause substantial damage than shallow earthquakes, which happen less than 70 km beneath the surface of the earth.

Survival Curve: This survival chart typically uses all 148 observations to look for common earthquake patterns. The x-axis shows the time in minutes and the y-axis shows the survival probability from 0 to 1.

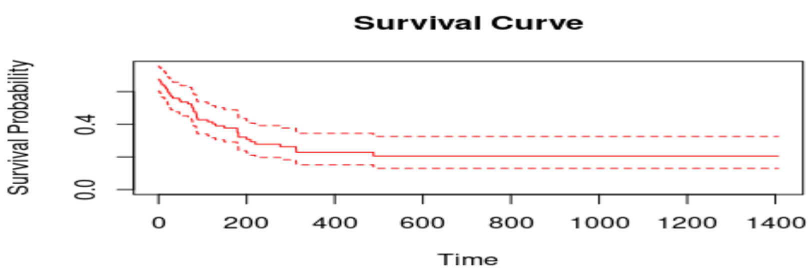

Fig 1.1

This Kaplan-Meier survival curve fig1.1 shows the probability of experiencing different changes in tremor strength over time. A steep step on the curve represents an event with the required intensity. It basically tells you how long it takes for a certain intensity to reach the desired intensity. Using this curve, during the first 500 minutes (approximately) the probability of surviving the tremor gradually decreases from 1 to 0. After 500 minutes, the chart tends to stabilise. Using Kaplan-Meier survival tables will give you more accurate results.

The Kaplan-Meier survival table below provides a comprehensive view of the seismic hazard faced by various locations over a four-month period. Note that the probability of survival decreases over time.A precise time interval of 5 minutes reduces the survival rate of high intensity shocks. At initial time 0, 48 events out of 148 hazards occur. After 540 minutes of repeated viewing, the event will stop. Therefore, this finding shows that the first 540 minutes will be crucial for an enhanced earthquake preparedness.

time	n.risk	n.event	survival	std.err	95% CI lower	95% CI upper
0	148	48	0.676	0.0385	0.604	0.755
5	58	1	0.665	0.0394	0.592	0.747
10	55	2	0.641	0.0413	0.565	0.728
15	54	1	0.63	0.0422	0.552	0.718
20	53	1	0.618	0.043	0.539	0.708
25	51	2	0.595	0.0444	0.514	0.688
30	49	2	0.571	0.0456	0.489	0.668
35	48	1	0.56	0.0462	0.476	0.658
40	48	0	0.56	0.0462	0.476	0.658
45	48	0	0.56	0.0462	0.476	0.658
50	47	1	0.548	0.0467	0.464	0.648
55	46	1	0.536	0.0471	0.452	0.637
60	46	0	0.536	0.0471	0.452	0.637
90	35	9	0.427	0.0496	0.34	0.537

time	n.risk	n.event	survival	std.err	95% CI lower	95% CI upper
180	25	6	0.349	0.0498	0.264	0.462
270	18	5	0.278	0.0488	0.197	0.392
360	10	3	0.229	0.0478	0.152	0.345
450	10	0	0.229	0.0478	0.152	0.345
540	8	1	0.206	0.0482	0.13	0.326
630	7	0	0.206	0.0482	0.13	0.326
720	6	0	0.206	0.0482	0.13	0.326
810	4	0	0.206	0.0482	0.13	0.326

Table 1.1

According to table 1.1 survival probability is calculated through Kaplan-Meier formula:

Survival probability(S(t)):

S(t)=s(t-1)*(1-dn))

Where:
- S(t) is the survival probability at time "t."
- S(t-1) is the survival probability at the previous time point.
- d is the number of events (e.g., Shaking Intensity) that occurred at time "t."
- n is the number of subjects at risk just before time "t."

Standard Error:

SE=S(t)*1-S(t)n

Where:
- SE is the standard error for the survival probability at time t.
- S(t) is the survival probability at time t.
- n is the number of subjects at risk just before time t.

95% Confidence Interval for Survival Probability: The confidence interval at specific time ‘t’ can be calculated as follows:

CI Lower=S(t)*exp(-1.96*SE)
CI Upper=S(t)*exp(1.96*SE)

Where:

- CI_lower is the lower bound of the 95% confidence interval.
- CI_upper is the upper bound of the 95% confidence interval.
- S(t) is the survival probability at time t.
- SE is the standard error calculated as mentioned earlier.
- 1.96 corresponds to the critical value for a 95% confidence interval (assuming a normal distribution).

Hazard plot:A hazard plot, or the rate at which earthquakes of differing intensities occur over time, is a graphical depiction that aids in understanding the hazard rate in the context of earthquake study.The Hazard plot based on shaking events which will help to understand the evolving risk of earthquakes reaching a specific shaking intensity level.

In our research, we found something surprising in the earthquake shaking intensity data. The chance of experiencing strong shaking started at zero but quickly shot up to 1.5 within just 500 minutes. This means that the risk of encountering intense earthquakes escalated rapidly in a very short time.

This discovery highlights the need for immediate earthquake precautions and monitoring, especially in the initial 500 minutes when the risk is exceptionally high. The sudden spike in the chance of strong shaking underlines the importance of being prepared and having a plan in place to stay safe during these early moments of seismic activity.

To put it simply, our study shows that the risk of a strong earthquake increases significantly within the first 500 minutes, stressing the urgency of being earthquake-ready in areas prone to seismic activity. These findings can guide better earthquake safety strategies and help protect lives and property.(fig 1.2)

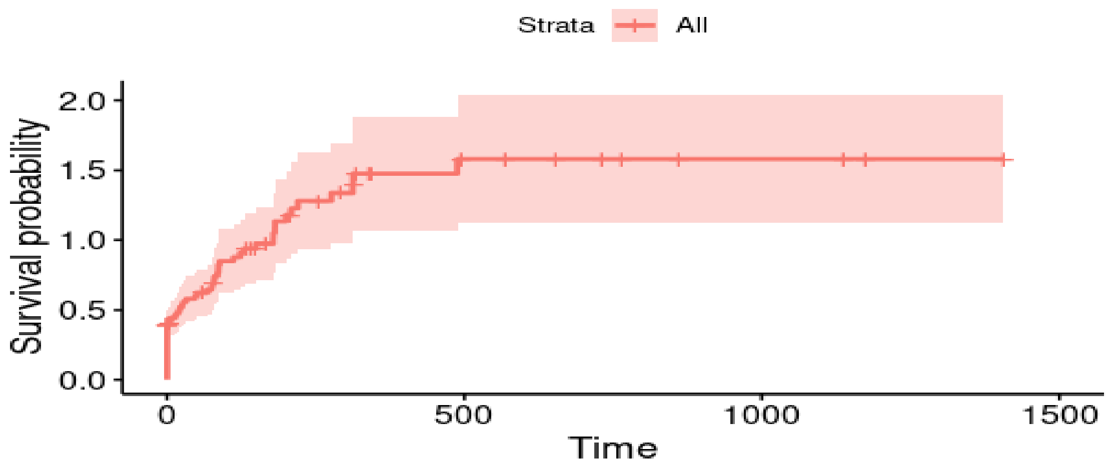

Fig1.2

Proceeding Further in Research we will group data based on locations.We will try to group the data into two subgroups i.e Within India and Outside India.Based on these two categories,we will perform a log-rank test which quantifies the strength of evidence between the two groups in fig 1.3

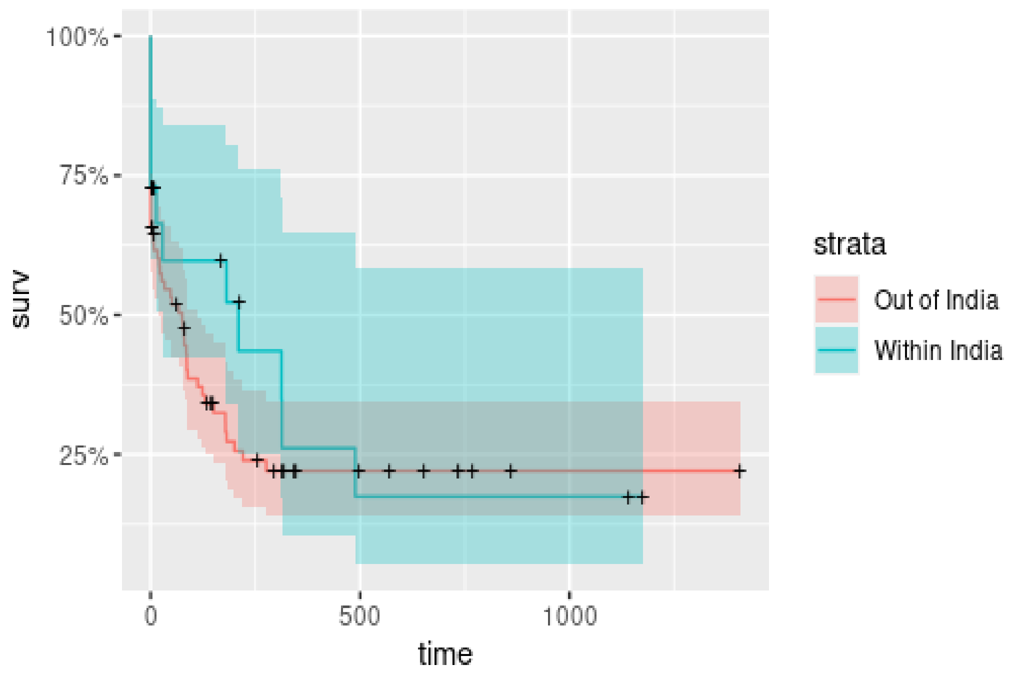

Fig1.3

Location Within India:

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
0	37	10	0.73	0.073	0.5998	0.888
13.8	11	1	0.663	0.0917	0.506	0.87
27.6	10	1	0.597	0.1038	0.4247	0.839
181.2	8	1	0.522	0.1145	0.3399	0.803
209.1	6	1	0.435	0.1242	0.2489	0.762
311.9	5	1	0.348	0.1262	0.1711	0.709
312.7	4	1	0.261	0.121	0.1053	0.648
488	3	1	0.174	0.1075	0.0519	0.584

Table 1.2

Location Outside India

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
0	111	38	0.658	0.045	0.575	0.752
2.53	48	1	0.644	0.0461	0.56	0.741
5.78	46	1	0.63	0.0472	0.544	0.73
7.52	45	1	0.616	0.0482	0.528	0.718
16.88	44	1	0.602	0.0491	0.513	0.706
20.17	43	1	0.588	0.0499	0.498	0.694

21.6	42	1	0.574	0.0506	0.483	0.682
25.57	41	1	0.56	0.0513	0.468	0.67
32.42	40	1	0.546	0.0519	0.453	0.658
47.08	39	1	0.532	0.0524	0.439	0.645
50.23	38	1	0.518	0.0529	0.424	0.633
66.82	36	1	0.504	0.0533	0.409	0.62
75.17	35	1	0.489	0.0537	0.394	0.607
76.58	34	1	0.475	0.054	0.38	0.593
79.3	32	1	0.46	0.0543	0.365	0.58
80.15	31	1	0.445	0.0546	0.35	0.566
85	30	1	0.43	0.0547	0.335	0.552
86.2	29	1	0.415	0.0548	0.321	0.538
86.55	28	1	0.401	0.0548	0.306	0.524
88.53	27	1	0.386	0.0548	0.292	0.51
111.93	26	1	0.371	0.0546	0.278	0.495
122.97	25	1	0.356	0.0544	0.264	0.48
129.57	24	1	0.341	0.0541	0.25	0.466
149.57	20	1	0.324	0.0541	0.234	0.45
178.55	19	1	0.307	0.0538	0.218	0.433

178.92	18	1	0.29	0.0535	0.202	0.416
181.42	17	1	0.273	0.053	0.187	0.399
200.12	16	1	0.256	0.0524	0.171	0.382
219.9	15	1	0.239	0.0516	0.156	0.365
276.23	13	1	0.221	0.0508	0.14	0.346

Table 1.3

Log run test

Null Hypothesis: There is no significant difference between survival probability of Out of India and Within India.

Alternative Hypothesis: There is a significant difference between survival probability of Out of India and within India.

Results:

N Observed

Location=Out of India 111 67

Location=Within India 37 17

Expected

Location=Out of India 63.3

Location=Within India 20.7

(O-E)^2/E

Location=Out of India 0.214

Location=Within India 0.656

(O-E)^2/V

Location=Out of India 1.07

Location=Within India 1.07

Chisq= 1.1 on 1 degrees of freedom, p= 0.3

Based on the results of the chi-squared (χ^2) test with 1 degree of freedom and a chi-squared statistic of 1.1, and considering a significance level (alpha) of 0.05, here's the conclusion:The p-value associated with the chi-squared test is 0.3, which is greater than the significance level (0.05). In hypothesis testing, when the p-value is greater than alpha, we fail to reject the null hypothesis.

APPENDIX-1

MEAN	MAGNITUDE	PLACE	DATE	TIME (GMT)	TIME (IST)	DIFFERENCE TIME	DIFFERENCE TIME.1	Initial time	SHAKING INTENSITY	Status	Location
3.3	2.4	XIZANG	4/3/2023	4:52:28	23:22:28	3:39:54	219.9	1402.47	LIGHT	1	Out of India
4.1	4.3	TAJIKAN	4/2/2023	16:33:01	11:03:01	12:12:42	732.7	2103.02	WEAK	0	Out of India
4	4.5	NEPAL	4/1/2023	11:12:30	5:42:30	8:08:00	488	1782.5	LIGHT	1	Within India
4.2	4.3	AFGHANAN	3/29/2023	13:39:20	8:09:20	5:12:37	312.6167	1929.33	VERY WEAK	0	Out of India
3.86	3.9	TAJIKAN	3/29/2023	7:13:14	1:43:14	4:15:30	255.5	1543.23	VERY WEAK	0	Out of India
3.9	3.9	XINJIANG	3/25/2023	22:10:05	16:40:05	1:20:09	80.15	2440.08	LIGHT	1	Out of India
3.75	4	Myanmar	3/25/2023	17:33:44	12:03:44	5:11:56	311.9333	2163.73	LIGHT	1	Within India
4.93	4.4	TAJIKAN	3/23/2023	11:02:41	5:32:41	1:01:02	61.0333	1772.68	VERY WEAK	0	Out of India
3.97	3.9	AFGHANAN	3/22/2023	0:33:14	19:03:14	23:26:30	1406.5	1143.23	WEAK	0	Out of India

2.7	3.3	UTTARAKHAND	3/13/2023	21:43:00	16:13:00	18:58:00	1138	2413	VERY WEAK	0	Within India
2.55	2.3	HIMACHAL	4/3/2023	0:37:00	19:07:00	0:01:00	1	1147	WEAK	0	Within India
2.85	2.6	KARNATAKA	5/23/2022	9:09:32	3:39:32	0:00:18	0.3	1659.53	WEAK	0	Within India
2.8	2.8	UTTAR PRADESH	4/3/2023	4:33:00	23:03:00	3:27:57	207.95	1383	WEAK	0	Within India
2.9	2.9	KARNATAKA	6/29/2022	2:47:00	21:17:00	2:47:00	167	1277	WEAK	0	Within India
2.8	2.8	KARNATAKA	6/28/2022	19:35:00	14:05:00	19:35:00	1175	2285	WEAK	0	Within India
4.15	4.5	UTTAR PRADESH	4/2/2023	19:42:16	14:12:16	3:01:11	181.1833	2292.27	LIGHT	1	Within India
4.26	4.7	J&K	3/15/2023	8:02:22	2:32:22	3:29:03	209.05	1592.37	LIGHT	1	Within India
4.63	4.5	New Zealand	7/18/2023	20:16:38	14:46:38	2:12:14	132.2333333	2326.63	Very Weak	0	Out of India
4.83	4.6	Mexico	7/18/2023	10:36:22	5:06:22	0:32:25	32.41666667	1746.37	Light	1	Out of India
4.75	5.2	Indonesia	7/17/2023	9:46:36	4:16:36	8:14:01	494.0166667	1696.6	Moderate	0	Out of India
4.56	4.8	Japan	7/17/2023	0:37:11	19:07:11	0:47:05	47.08333333	1147.18	Light	1	Out of India
4.5	4.6	Alaska	7/16/2023	7:51:40	2:21:40	2:29:34	149.5666667	1581.67	Light	1	Out of India
4.63	4.4	Russia	7/16/2023	6:52:49	1:22:49	14:18:47	858.7833333	1522.82	Very Weak	0	Out of India

4.5	4.4	New Zealand	7/15/2023	13:36:47	8:06:47	9:27:45	567.75	1926.78	NOT Felt	0	Out of India
4.7	5.2	Japan	7/13/2023	15:52:08	10:22:08	5:44:25	344.4166667	2062.13	Very Weak	0	Out of India
4.5	4.8	Philippines	7/10/2023	12:05:26	6:35:26	3:20:07	200.1166667	1835.43	Moderate	1	Out of India
4.53	4.4	China	7/4/2023	11:09:21	5:39:21	1:25:00	85	1779.35	Light	1	Out of India
4.65	4.4	USA	7/18/2023	11:06:32	5:36:32	10:52:33	652.55	1776.53	Weak	0	Out of India
4.7	4.6	Indonesia	7/13/2023	21:41:11	16:11:11	0:50:14	50.23333333	2411.18	Light	1	Out of India
4.65	4.8	China	7/11/2023	22:49:47	17:19:47	0:00:38	0.633333333	2479.78	Very Weak	0	Out of India
4.3	4.3	Iceland	7/7/2023	3:28:37	21:58:37	0:25:34	25.56666667	1318.62	Light	1	Out of India
4.65	4.9	Vietnam	7/7/2023	2:48:04	21:18:04	0:04:58	4.966666667	1278.07	Weak	0	Out of India
4.7	4.6	Iceland	7/5/2023	9:50:07	4:20:07	1:28:32	88.53333333	1700.12	Light	1	Out of India
4.85	5.1	Indonesia	7/5/2023	12:06:52	6:36:52	1:26:33	86.55	1836.87	Strong	1	Out of India
5.1	5.2	New Zealand	7/4/2023	16:05:09	10:35:09	4:36:14	276.2333333	2075.15	Moderate	1	Out of India
4.6	4.5	China	7/4/2023	10:58:31	5:28:31	1:15:10	75.16666667	1768.52	Moderate	1	Out of India
5.25	4.8	Vanuatu	7/3/2023	21:14:39	15:44:39	0:16:53	16.88333333	2384.65	Moderate	1	Out of India

4.5	4.4	Chile	7/3/2023	10:31:03	5:01:03	12:46:08	766.1333333	1741.05	Weak	0	Out of India
4.6	4.5	China	7/2/2023	10:40:25	5:10:25	2:09:34	129.5666667	1750.42	Moderate	1	Out of India
4.9	4.6	Philippines	6/29/2023	13:52:38	8:22:38	2:22:18	142.3	1942.63	Weak	0	Out of India
4.75	4.6	Fiji	6/29/2023	10:08:39	4:38:39	4:52:49	292.8166667	1718.65	Very Weak	0	Out of India
5.05	5.4	Tonga	6/28/2023	10:54:13	5:24:13	0:20:10	20.16666667	1764.22	Light	1	Out of India
4.3	4.3	Mexico	6/28/2023	5:41:58	0:11:58	0:21:36	21.6	1451.97	Moderate	1	Out of India
4.45	4.3	Japan	6/28/2023	4:27:30	22:57:30	1:19:18	79.3	1377.5	Light	1	Out of India
5.15	4.8	Indonesia	6/27/2023	18:58:15	13:28:15	2:02:58	122.9666667	2248.25	Moderate	1	Out of India
4.55	4.7	India	6/26/2023	18:05:44	12:35:44	5:12:41	312.6833333	2195.73	Moderate	1	Within India
4.6	4.8	Indonesia	6/26/2023	8:39:22	3:09:22	5:16:52	316.8666667	1629.37	NOT Felt	0	Out of India
4.55	4.4	India	6/26/2023	11:18:34	5:48:34	0:13:51	13.85	1788.57	Light	1	Within India
4.85	4.9	Chile	6/25/2023	13:26:53	7:56:53	1:51:56	111.9333333	1916.88	Light	1	Out of India
5.05	4.7	Tonga	6/25/2023	11:25:28	5:55:28	2:58:55	178.9166667	1795.47	Light	1	Out of India
4.95	4.6	Japan	6/25/2023	2:24:11	20:54:11	1:06:49	66.81666667	1254.18	Moderate	1	Out of India

4.55	4.7	China	6/24/2023	21:40:21	16:10:21	3:01:25	181.4166667	2410.35	Moderate	1	Out of India
5.15	4.7	Atlantic Ridge	6/23/2023	21:50:57	16:20:57	0:02:32	2.533333333	2420.95	Moderate	1	Out of India
4.8	4.7	New Zealand	6/23/2023	9:55:48	4:25:48	2:29:18	149.3	1705.8	Very Weak	0	Out of India
4.45	4.5	Myanmar	6/21/2023	21:58:51	16:28:51	0:00:39	0.65	2428.85	Very Weak	0	Within India
5.1	5	Tonga	6/20/2023	17:07:57	11:37:57	1:26:12	86.2	2137.95	Moderate	1	Out of India
4.65	4.7	Kazakhstan	6/20/2023	7:21:16	1:51:16	0:05:47	5.783333333	1551.27	Moderate	1	Out of India
4.7	4.5	Russia	6/19/2023	20:44:18	15:14:18	2:58:33	178.55	2354.3	Moderate	1	Out of India
4.65	4.6	Indonesia	6/19/2023	13:44:01	8:14:01	5:40:44	340.7333333	1934.02	Weak	0	Out of India
4.5	4.7	Kazakhstan	6/19/2023	7:34:55	2:04:55	1:19:04	79.06666667	1564.92	Moderate	0	Out of India
4.4	4.4	Myanmar	6/19/2023	4:14:36	22:44:36	0:27:38	27.63333333	1364.6	Light	1	Within India
5.1	4.6	Tonga	6/17/2023	23:21:33	17:51:33	0:07:31	7.516666667	2511.55	Moderate	1	Out of India

Table 1.4

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