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Identification of Dominant Shape

Weibull Probability Distribution Model

Highlights

Imaging Technique for Aggregates

Specification in Structural Construction

Discovering Thoughts, Inventing Future

VOLUME 21 ISSUE 1 VERSION 1.0

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Identification of Dominant Shape Characteristic for Particle Packing Models using an Imaging Technique for Aggregates

By Madhuri N. Mangulkar, Sudddhasheel Ghosh & Sanjay S. Jamkar

Abstract- Aggregates occupy most of the volume of concrete. A proper packing of aggregates with binding material ensures reduction in voids and thereby better performance of concrete. A good packing of the aggregates in a mix can be achieved by filling up the void space left by large or coarse aggregates by the finer aggregates, followed by standard process of compaction. Therefore, precise evaluation of characteristics of ingredients of concrete is highly essential. Various mathematical models for studying concrete mix proportions have been proposed in the literature. Most of these models have remained restricted to studying spherical or near-spherical particles. Therefore there is a need to understand whether there is a possibility of extending the existing theories to non-spherical particles also. The paper also presents the development of Digital Image Processing (DIP) based system for the measurement of volume, equivalent volume diameter, sphericity, roundness index of coarse aggregate particles.

Keywords: aggregate, shape characteristics, particle packing, DIP.

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Identification of Dominant Shape Characteristic for Particle Packing Models using an Imaging Technique for Aggregates

Madhuri N. Mangulkar [α], Sudddhasheel Ghosh [σ] & Sanjay S. Jamkar [ρ]

Abstract- Aggregates occupy most of the volume of concrete. A proper packing of aggregates with binding material ensures reduction in voids and thereby better performance of concrete. A good packing of the aggregates in a mix can be achieved by filling up the void space left by large or coarse aggregates by the finer aggregates, followed by standard process of compaction. Therefore, precise evaluation of characteristics of ingredients of concrete is highly essential. Various mathematical models for studying concrete mix proportions have been proposed in the literature. Most of these models have remained restricted to studying spherical or near-spherical particles. Therefore there is a need to understand whether there is a possibility of extending the existing theories to non-spherical particles also. The paper also presents the development of Digital Image Processing (DIP) based system for the measurement of volume, equivalent volume diameter, sphericity, roundness index of coarse aggregate particles. The system is calibrated using standard objects such as marbles, coins and then used for the measurement of coarse aggregate particles having varied characteristics. The dimensions of the aggregates i.e. the longest, the intermediate and the shortest dimensions and obtained using mathematical morphological operations. A detailed analysis of the various shape characteristics shows that sphericity is the most effective measure. The authors are currently working in the direction of extending the mathematical model using this shape characteristic.

Keywords: aggregate, shape characteristics, particle packing, DIP.

I. Introduction

Aggregates occupy bulk of the volume of concrete. Their characteristics such as size, grading, shape and texture have significant effect on the properties of concrete in both fresh and hardened state. The effect is more significant in the case of high strength concrete. The properties of concrete such as strength, workability, cohesiveness and durability depend upon the properties of its constituents and their relative proportion in the mix.

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Evolutions in concrete mix proportioning procedures are taking place since long. Particle packing theories have been under development to further refine the mix proportioning process. Particle packing models proposed by the researchers include (a) continuous, (b) analytical and (c) discrete element. Out of these, analytical particle packing models provide relatively better solution for concrete mix proportioning. The analytical model assumes that each class of particle will pack to its maximum density in the available volume. Theoretically, it gives the packing density of a mix based on particle size distribution and individual packing densities of various size fractions that are present in the distribution.

a) Research Significance

It is understood that the aggregate particles present in a concrete mix would interact based on their respective sizes and shapes. Our work is in the context of analytical modelling of this inter-particulate interaction. De Larrard [1] and Yu et al. [7] have attempted to model this interaction between the various aggregate particles in a mix, based on size fractions. Therefore, it is important to discuss the sizes and shapes of the aggregate particles and the consequent inter-particulate interactions. In this paper we describe a scanning system for aggregates, to identify the various shape descriptors, and choose the most effective one, and identify an effective modelling system based on the literature.

b) Estimation of packing density in a mix

De Larrard [2,3,4,5] has constrained his study on two types of aggregates namely rounded and crushed. In his study, the interaction between the coarse and fine particles in a concrete mix are modelled using the wall effect and loosening effect functions. These functions are finally used to determine the packing density in a concrete mix.

$$\gamma_i = \frac{\beta_i}{1 - \sum\left[1 - \beta_i + b_{ij}\beta_i(1 - 1\beta_j)\right] y_j - \sum\left[1 - a_{ij}\beta_i\beta_j\right] y_i} \tag{1}$$

Where the function a_{ij} and b_{ij} represent the wall effect and the loosening effect respectively, and are given by the following equations.

$$a_{ij} = \sqrt{1 - \left(1 - \frac{d_j}{d_i}\right)^{1.02}} \tag{2}$$

$$b_{ij} = 1 - \left(1 - \frac{d_i}{d_j}\right)^{1.50} \tag{3}$$

However, in reality, it is seen that aggregates are available in different shapes and sizes, see Figure 1.

Figure 1: Various dimensions of the aggregates

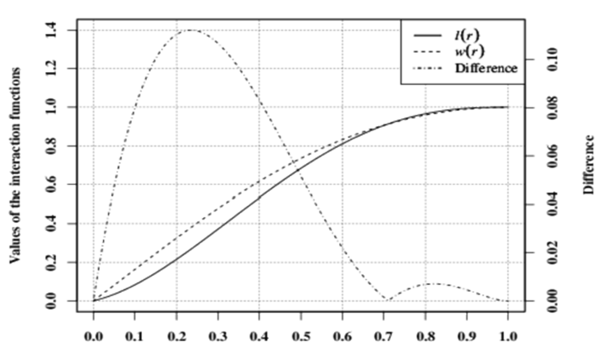
In their study, Yu et al. [7] had considered sphericity as an additional input to be given to the interaction function for the wall and loosening effects. The interaction functions proposed by Yu et al. [7,8] are given in the following equations.

$$l(r) = 1 - (1 - r)^{3.3} - 2.8r(1 - r)^{2.7} \tag{4}$$

$$w(r) = 1 - (1 - r)^{2.0} - 0.4r(1 - r)^{3.7} \tag{5}$$

where, r is defined as the ratio of equivalent packing diameters, with the value of r ranging between 0 and 1. The equivalent packing diameter d_p, for a particular aggregate is given as:

$$d_p = \frac{d_r}{\psi^{2.785} e^{2.946(1-\psi)}}.$$



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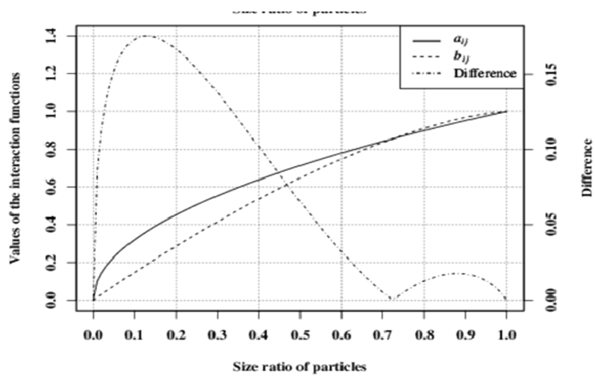

Figure 2: Activation functions for (a) de Larrard (1988) and (b) Yu et al. (2005)

Therefore, it would be interesting to investigate whether the other measures can also contribute to improvising the modelling system for interaction.

c) *Assessment of the shape and classification of aggregates*

Several researchers have studied the shape and classified aggregates. These studies can be categorised into the following groups: (a) based on computer tomography, (b) based on laser scanning, and (c) based on camera based scanning. It is realised that computer tomography and laser scanning based techniques are difficult to be applied on the field, and are also expensive. Therefore, in this study camera based scanning techniques are discussed and implemented.

Most camera based study techniques developed till date use an arrangement that image the aggregate from two different sides to assess the longest, intermediate and the smallest sides of the minimal box containing the aggregate, represented as a triplet (dl, di, ds). However, a complete three dimensional picture of a complex shaped aggregate can be obtained only if it is imaged from multiple sides. Therefore, there is a need to develop a new system which can image an aggregate to obtain its precise dimensions.

d) *Shape characteristics of an aggregate*

The shape characteristics of an aggregate have been traditionally expressed in terms of sphericity, elongation, flatness and shape factor. The various formulae for determining these characteristics for a given triplet (dl, di, ds) are given in Table [1].

Table 1: Shape characteristics of an aggregate with triplet (dl, di, ds)

FACTOR	FORMULA	REFERENCE
Shape factor	$\frac{dl \times ds}{di^2}$	Barksdale et al.[10]
Flatness	$\frac{di}{ds}$	Barksdale et al.[10]
Elongation	$\frac{dl}{di}$	Kuo et al.[11]
Sphericity	$\sqrt[3]{\frac{di \times ds}{dl^2}}$	Kuo et al.[11]

e) *Research questions*

Based on the above discussions, we pose the following research questions for this paper:

1. Which is the most effective shape parameter for distinguishing various shapes of aggregates?
2. Can a system be designed which can image an aggregate from more than two sides?
3. Can the de Larrard's [4] CPM theory be extended to include more shapes of aggregates?

II. Methodology

This section presents the design of a system for imaging various facets of aggregates, analysing the shapes of aggregates and the possible extension of de Larrard's [1] theory, in the light of the discussion and the questions proposed in the previous section.

a) DIPAM: An imaging system for aggregates

For imaging the aggregates from various angles, we design the DIPAM (Digital Image Processing based Aggregate Measurement) system. The proposed system consists of (a) Conveyor, (b) Turntable, (c) Illumination arrangement, (d) Image acquisition and e) Control system integrated with each other. Conveyor arrangement facilitates movement of aggregate particle from a sample to the required position where image is acquired and back to the original position after image acquisition is over. Image acquisition system consisted of three Logitech Pro 9000 web cameras having 8 Mega-pixel resolution placed in an orthogonal manner (bottom, top and front). In order to acquire images of more faces of the aggregate, a turntable is added to the system. It is mounted on the shaft of the stepper motor which rotates the aggregate moved on a horizontal semi-transparent milky sheet by a predefined angle and enables the acquisition of more than three images of the aggregate. Illumination arrangement consisted of LED module which takes care of required illumination. In order to eliminate shadow effect the system is designed in such a way that camera and LED light both face each other, and camera exposure is set to maximum with minimum gain. A semi-transparent milky acrylic sheet is mounted in between the camera and the focus light. The sheet gets illuminated uniformly providing white background for acquiring the image of target aggregate. The control system controls the activities of (a) Stepper motor for Turntable, (b) DC motor for linear movement of conveyor along with Aggregate Tray, (c) Optical sensor of Encoder Disk, (d) Home position limit switch. The entire system is interfaced with the computer through MATLAB (Mathworks Inc.) software. The integrated Digital Image Processing based Aggregate Measurement (DIPAM) System is shown in Figure 3.

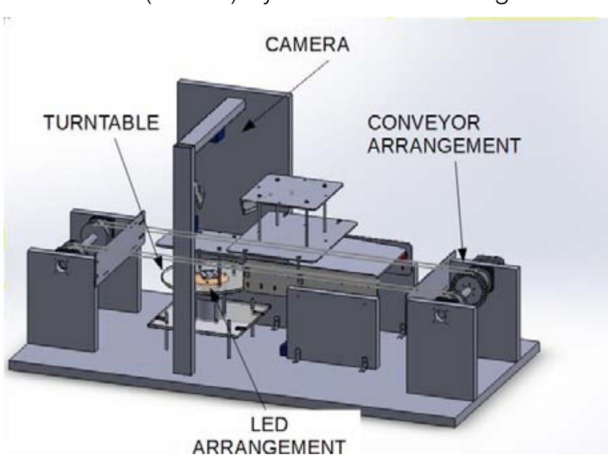

Figure 3: Digital Image processing Based Aggregate Measurement system

In order to measure the various characteristics of an aggregate, it is placed on the aggregate tray mounted on a conveyor. The conveyor arrangement moves the tray linearly to the first position (in front of bottom camera) where the first LED lamp illuminates the aggregate. The bottom camera captures the first image. The aggregate tray then moved to a second position on the turn table where a second image is captured by the top camera. The third camera at the front also captures an image simultaneously. It also captures images by turning the tray through 90, 180 and 270 degrees. The turntable rotates the tray by 270 degrees in opposite direction and conveyor brings it to the original position. The steps are repeated till the image acquisition of all the aggregate particles in the sample is completed.

The system is calibrated using standard objects of known dimensions such as coins, rectangular prisms and marbles. The dimensions of the objects are measured manually using standard vernier calliper. Digital images of these objects are acquired by placing the objects one at a time, at a distance of 10cm from each camera. Six images are taken at an interval of 5 seconds. Each camera in the system provided an image of dimensions 1600 pixels x 1200 pixels. The images are processed using MATLAB through the following steps: (a) conversion of RGB images to gray scale, (b) noise filtering, (c) detection of boundary, and (d) computation of longest (*dl*), intermediate (*di*), and shortest (*ds)* dimensions of the object. Based on the results, it is observed that 1600 pixels correspond to 62.4 mm i.e. 0.039 mm/pixel.

b) Analysis of shape characteristics

In this study, four different categories of aggregates are tested, viz. Elongated, rounded, angular and cylindrical. 30 aggregate pieces of each of the types are passed through the imaging arrangement (DIPAM), and the measurements of their longest, intermediate and shortest dimensions were obtained. In addition, the volumes of the respective aggregates were also found out using a measuring cylinder. To identify the shape characteristic that distinguishes the aggregates the most, a linear separability analysis is conducted.

c) Extension of the CPM theory

It was pointed out earlier that the CPM theory proposed by de Larrard [1,4] was limited to rounded and crushed aggregates. His theory proposes two activation functions, which have already been denoted by equations (1,2) and (3). The activation functions proposed by Yu et al. [6,7] consider the sphericity of the aggregates as an additional parameter. The activation functions proposed by de Larrard intersect with each other, see Figure 2. In his work, Fennis [8,9] points out that this intersection of the two function may cause problems in “scaling”. Further, in the works proposed by de Larrard [1-5], Yu et al. [6,7] and Fennis [7,8], the curves for interaction function are convex. Thus, in this context, it might be said that (a) the interaction functions must not intersect with each other, (b) must be convex, and (c) must be inclusive of the shape parameters.

III. Results and Discussion

a) Calculation of the shape parameters

Aggregates of different shapes and sizes were passed through the imaging system. The dimensions of each of the aggregates were obtained. Further, the volumes of each of the aggregates was also calculated. The shape parameters calculated for each of the types of aggregates are given in (as shown in Table 1).

b) Choosing the most distinguishing factor

It is seen from a separability analysis and also (as shown in Table 2), that sphericity is the most discriminating factor amongst all types of aggregates. Hence, in this study, sphericity is chosen.

Table 2a: Evaluation of shape characteristics of aggregates

AGGRE-GATE TYPE	SIEVE SIZE FRACTION IN MM	AVERAGE DIMENSIONS IN MM AS PER DIP			VOLUME IN MM^3 AS PER			PERCENTAGE ERROR IN VOLUME		EQUIVALENT DIAMETER OF SPHERE (MM)	SHAPE MEASURES BY DIP			
		LONGEST (DL)	INTE-MEDIATE (DI)	SHORTEST (DS)	ARCHIMEDES PRINCIPLE	EQUIVALENT CYLINDER	EQUIVALENT ELONGATED PRISM	EQUIVALENT ELONGATED PRISM	EQUIVALENT CYLINDER		SPHERICITY	SHAPE FACTOR	ELONGATION RATIO	FLATNESS RATIO
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	4.75-6.3	16.10	5.40	4.30	300.00	293.61	186.92	71.20	8.99	8.25	0.45	0.46	2.98	3.74
	6.3-10	16.69	10.75	6.31	850.00	889.39	566.20	48.36	-5.55	11.93	0.62	0.47	1.55	2.64
Type-A-Elongated	10-12.5	20.57	10.75	8.71	1500.00	1513.54	963.55	55.67	-0.89	14.25	0.60	0.59	1.91	2.36
	12.5-16	27.40	12.75	10.88	3000.00	2983.87	1899.59	57.93	0.54	17.86	0.57	0.58	2.15	2.52
	16-20	43.70	23.00	12.50	8000.00	9867.55	6281.88	59.19	1.34	26.61	0.53	0.39	1.90	3.50
	20-25	30.10	23.30	14.00	8500.00	7711.53	4909.31	62.96	3.74	24.51	0.71	0.53	1.29	2.15

Table 2b: Evaluation of shape characteristics of aggregates

AGGRE-GATE TYPE	SIEVE SIZE FRACTION IN MM	AVERAGE DIMENSIONS IN MM AS PER DIP			VOLUME IN MM^3 AS PER			PERCENTAGE ERROR IN VOLUME		EQUIVALENT DIAMETER OF SPHERE (MM)	SHAPE MEASURES BY DIP			
		LONGEST (DL)	INTER-MEDIATE (DI)	SHORTEST (DS)	ARCHIMEDES PRINCIPLE	EQUIVALENT CYLINDER	EQUIVALENT PYRAMID	EQUIVALENT PYRAMID	EQUIVALENT CYLINDER		SPHERICITY	SHAPE FACTOR	ELONGATION RATIO	FLATNESS RATIO
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	4.75-6.3	9.20	5.43	5.28	120.00	263.28	131.64	-8.84	-54.42	6.31	0.70	0.75	1.70	1.74
	6.3-10	12.15	6.08	5.90	200.00	435.49	217.74	-8.15	-54.07	7.46	0.62	0.69	2.00	2.06
Type-B Angular	10-12.5	16.65	9.68	9.48	750.00	1526.32	763.16	-0.41	-50.21	11.34	0.69	0.75	1.72	1.76
	12.5-16	20.40	11.83	11.50	1350.00	2774.15	1387.07	0.21	-49.89	13.84	0.69	0.74	1.73	1.77
	16-20	27.80	16.30	15.70	3000.00	7114.30	3557.15	-15.66	-57.83	18.94	0.69	0.74	1.71	1.77
	20-25	31.25	19.65	18.85	5000.00	11575.08	5787.54	-13.61	-56.80	22.28	0.72	0.76	1.59	1.66

Table 2c: Evaluation of shape characteristics of aggregates

AGGRE - GATE TYPE	SIEVE SIZE FRACTION IN MM	AVERAGE DIMENSIONS IN MM AS PER DIP			VOLUME IN MM³ AS PER			PERCENTAGE ERROR IN VOLUME		EQUIVAL-ENT DIAMETE R OF SPHERE (MM)	SHAPE MEASURES BY DIP			
		LONGE - ST (DL)	INTER-MEDIA TE (DI)	SHORTES T (DS)	ARCHI-MEDES PRINC-IPLE	EQUIV-ALENT CUBOID	EQUIVA-LENT ELON-GATED PRISM	EQUIVA-LENT ELON-GATED PRISM	EQUIVA-LENT CUBOID		SPHER - ICITY	SHAPE FACTO R	ELON-GATION RATIO	FLATNES S RATIO
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Type-C Cubical	4.75-6.3	9.40	5.25	5.20	270.00	256.62	201.55	35.95	6.77	7.88	0.68	0.74	1.79	1.81
	6.3-10	10.75	6.33	6.08	450.00	413.06	324.42	35.63	6.52	9.24	0.69	0.74	1.70	1.77
	10-12.5	15.15	9.68	9.53	1500.00	1396.14	1096.52	38.62	8.87	13.87	0.74	0.79	1.57	1.59
	12.5-16	22.90	14.48	14.10	3500.00	4673.83	3670.82	-4.65	-25.11	20.74	0.73	0.77	1.58	1.62
	16-20	26.30	14.48	14.10	6000.00	5367.76	4215.83	55.37	22.02	21.72	0.67	0.72	1.82	1.87
	20-25	30.10	18.28	17.80	8000.00	9791.38	7690.13	-85.70	-88.77	26.54	0.71	0.76	1.65	1.69

Table 2d: Evaluation of shape characteristics of aggregates

AGGRE - GATE TYPE	SIEVE SIZE FRACTIO N IN MM	AVERAGE DIMENSIONS IN MM AS PER DIP			VOLUME IN MM³ AS PER		PERCENTAGE ERROR IN VOLUME			EQUIV-ALENT DIAMET ER OF SPHERE (MM)	SHAPE MEASURES BY DIP			
		LONG-EST (DL)	INTER-MEDIA TE (DI)	SHORT-EST (DS)	ARCHIM-EDES PRINCIPL E	EQUIVA-LENT CYLINDE R	EQUIVA-LENT ELONGA-TED ELLIPSOI D	EQUIVA-LENT ELONGA-TED ELLIPSOI D	EQUIVA-LENT CYLINDER		SPHER - ICITY	SHAPE FACTO R	ELON-GATIO N RATIO	FLATNES S RATIO
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Type-D Rounde d	4.75-6.3	7.82	5.83	4.75	100.00	379.38	151.752	-34.10	163.59	8.98	0.84	0.70	0.90	1.36
	6.3-10	8.40	9.30	6.18	300.00	1312.14	524.856	-42.84	128.63	13.58	0.87	0.68	0.99	1.47
	10-12.5	13.45	12.60	9.13	750.00	2120.68	848.24	-11.59	253.66	15.94	0.88	0.69	1.00	1.46
	12.5-16	15.83	15.75	10.83	1450.00	4157.68	1663.73	-12.81	248.75	19.95	0.83	0.62	0.95	1.58
	16-20	20.95	19.90	12.65	2000.00	5775.17	2310.69	-13.42	246.31	22.26	0.85	0.68	0.95	1.43
	20-25	21.50	21.00	15.03	5200.00	13229.38	5291.50	13.38	353.54	29.34	0.89	0.72	1.02	1.39

c) Choice of the interaction functions

Both de Larrard and Yu et al. [6,7] have proposed interaction functions for modelling the interparticle interactions in the CPM theory. Furthermore, both the theories use particle size ratio r. In contrast to de Larrard's approach where r is taken an a ratio of particle diameters, Yu et al [6,7] have represented r as a ratio of equivalent packing diameters, where they have considered sphericity as a shape factor. It was argued earlier, in this paper, that Fennis [8,9] objected to the interaction functions intersecting between the values or $r = 0$ and $r = 1$, where r denotes the particle size ratio.

It is seen that the model of the interaction functions proposed by Yu et al [6,7] are mathematically simpler, and than the changes in the different coefficients and the exponents can change the shape of the function. Further, based on the respective choices, these functions may or may not intersect with each other. It remains to be investigated as to what could be these choices for coefficients and exponents.

IV. Conclusion

In this work, we have presented the design of an imaging system, which improvises on the past imaging systems to give a more complete picture of the dimensions of an aggregate. The dimensions captured by the imaging system are analysed for shape characteristics of the aggregates. It was found that sphericity is the most prominent measure of shape amongst the four considered in this study. It was also seen that the model of interaction functions proposed by Yu et al [6,7] are more appropriate to extend the study of the CPM theory proposed by de Larrard [1-5]. The tuning of the coefficients and the exponents in the model of the Yu et al [6,7] remains to be seen and will be conducted by the authors in the future research work.

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Attitude to Safety and Adherence to Project Specification in Structural Construction

By Vincent K. Akortia & Charles K. Kankam

Abstract- Personal and Project Safety are crucial in structural construction, whereas extensive studies have been conducted in the past on personal safety, very little is known about project safety. This study evaluated operatives' attitude to safety in construction and its effect on structural specifications adherence. Specifically, determined attitude to safety, and relationship between attitude to safety, supervision and project structural specifications adherence. The study adopted survey to collect data. It sampled 110 participants from 8 public and 14 private ongoing projects in Ghana. A convenient random sampling was adopted to administer questionnaire. In total, 101 operatives responded to the questionnaire. The data was analyzed using descriptive statistics and inferential- ANOVA, student 't' test, Pearson's correlation and regression. Results showed that respondents had good attitude to safety, and significant positive relationship exists between attitude to safety and project structural specification adherence which was further strengthened by safety supervision.

Keywords: attitude to safety, safety supervision, adherence to structural specification, operatives, construction projects.

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ATTITUDETOSAFETYANDADHERENCETOPROJECTSPECIFICATIONINSTRUCTURALCONSTRUCTION

Strictly as per the compliance and regulations of:

Attitude to Safety and Adherence to Project Specification in Structural Construction

Vincent K. Akortia [α] & Charles K. Kankam [σ]

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Keywords: attitude to safety, safety supervision, adherence to structural specification, operatives, construction projects.

I. Introduction

Safety concern in construction industry is key because it is a means of preventing accidents on site and from structural collapses, defects in buildings among others. It is the basis of design of structures by the engineer to ensure structural stability, durability, serviceability and safety in their life span without endangering life or yielding to adverse condition easily(Gilbert et. al. 2017).Hence, buildings are defined as structures for human activities, which must be safe for the occupants (Odulami, 2002).In the light of that designs are accompanied by strict detailed specification to be followed in executing whatever project in question to avoid collapse and defects such as excessive cracking and deflection during and after execution. However, safety consciousness of operatives in construction is rather not encouraging. Hamid et al. (2008) found from a study in Malaysia that construction site accident results from workers' negligence, failure to obey work procedures, failure to use personal protective equipment, low knowledge and skill level of workers and poor workers' attitude to safety. Similarly, Fordjour (2015) in Ghana concluded that poor health and safety performance was due to negligence/ carelessness on the part of construction managers and workers. If operatives ignore simple personal safety, would they be concerned with the safety of the structure they are working on? Would they pay particular attention to given specifications of the projects they work on? Can there be a link between observation of personal safety and innate adherence to project specification? The effect could result in collapse of buildings killing the occupants(e.g., MELCOM Limited shop in Ghana in 2012 leading to 14 deaths and 70 injuries (Asante and Sasu, 2018)and loss of investment. According to Windapo and Rotimi (2012) majority of structural collapses in Nigeria were attributable to human action or inaction, including largely poor supervision and workmanship, disregard for approved drawings and faulty designs (Windapo and Rotimi, 2012); non-compliance with building specifications and regulations (Oloyede et al., 2010).Ghana recorded 123 injuries and 28 deaths from year 2000 to 2016 out of fifteen (15) reported structural collapses. Out of the fifteen collapses, eight (8) occurred in the capital city (Accra) and its suburbs (Asante and Sasu, 2018). Similarly, Bangladesh recorded 1000 injuries and 150 deaths in 2013 as a result of the collapse of an eight-storey factory building (Asante and Sasu, 2018). These collapses were blamed on the use of weak materials, neglect of proper building procedure, negligence on the part of operatives among others. To curb this, prevention through strict observance of safety regulation is paramount.

Personal and Project Safety are crucial in structural construction, and whereas extensive studies have been conducted in the past on personal safety, none so far have been done on the project safety. For example Abdelhamid and John (2000) found that the major factors affecting unsafe condition include actions and inactions of Management; unsafe behaviour of workers and unsafe working site conditions. This study therefore aimed to determine the attitude of operatives to safety on construction site, and

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if the attitude affects adherence to project structural specification during construction to ensure safety of structures. Specifically determined operatives' level of attitude to safety; how operative groups and education level affect safety attitude; andif attitude to safety and supervision affects adherence to project structural specifications.

II. Proposed Framework

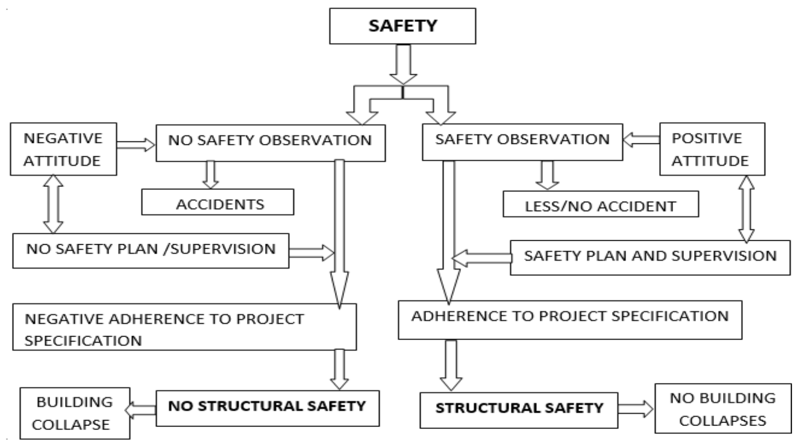

Figure 1: Proposed framework

The model illustrated in figure 1 presents the argument for this study. Conscious Safety Observation may reflect in Adherent to Project Structural Specification. The resultant effect would be attainment of safe structure to preventing cracks, defects and possible collapse of buildings; while accident cases lessen. However, attitude can affect safety observation while safety plan coupled with supervision may be influencing factors to safety attitude and the relationship between safety observation and adherence to project structural specification. Operatives may be conscious of safety because of strict supervision and implementation of safety rules on site, and vice versa (Akortia, 2020).

III. Methodology

The Population considered for the study consists construction operatives (management and labour teams) working on public and private projects in Ghana. A total of 110 participants were conveniently but randomly selected, however, 101 responded to the questionnaire. They were predominantly male workers and mature adults who were largely Ghanaians (Akortia, 2020). Their responses were analyzed to form the basis for findings of this study. Survey design was used with questionnaire (open/close) to collect data from operatives on selected construction project sites except store keepers and security officers. The questionnaire was in two major parts, demographic and constructs-attitude to safety and adherence to structural specification - questions. As a procedure, list of ongoing projects were taken from selected District Assemblies which were further selected at random and narrow down to eight (8) state projects and total of fourteen (14) private projects from communities in which the state projects were located for observation. At every site, self-introduction was made and questionnaire distributed and explained where necessary while observing kingly activities on site. Respondents who could not read and write were supported. The responses were scored and analyzed for discussion. The Scoring was in two parts. The demographic part of the questionnaire helped in categorization of respondents and the construct questions were scored on a 5 point Likert scale in both direct and reverse manner depending on the direction of the specific question. Descriptive, Student 't' test, one way ANOVA, correlation and hierarchical multiple regression were used to analyze the data.

IV. Analysis of Results

a) Demographics

A total of 101 (92%) recovery of the data instrument was made out of 110 participants. Respondents were largely males(91% of respondents) and adult Ghanaian (84% of respondents against 14% Togolese) of various levels of formal education. Private (14) and 8 government projects were considered. Out of 91% male, 39% and 61% for government and private projects respectively. Two categories of labour team 61 and management team 40 respondents in all were observed. Figure 2 indicates that 33.7% (34/101) and 32.7% (33/101) of the respondents had Secondary and Tertiary educations respectively, while 33.6% (34/101) had elementary education. Thus every one of the respondents has some level of formal education which is a good sign to the industry, especially where good number of them had secondary and tertiary education.

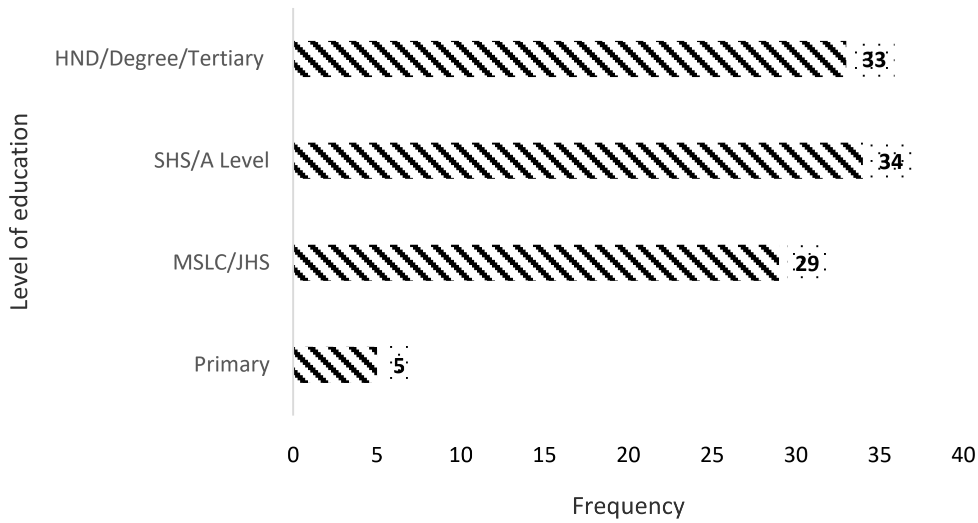

Figure 2: Level of Education

b) *Attitude to Safety*

Table 1 presents Student 't'test result in which the mean M = 55.82 (Sd = 16.16) and a test value of 51. The result, $t_{(100)} = 2.99$, $P < 0.05$ disclosed that the mean value was significant at 0.05 level of significance. Consequently the respondents have significantly or largely Good Attitude to safety

Table 1: Summary of Student 't' test on attitude to safety

Item	N	Mean	Std	df	t	p-value	p	Test value
General Attitude to safety	101	55.82	16.16	100	2.99	0.003	<0.05	51

However, from table 2, the score of Management team on the attitude scale largely influenced Good Attitude to safety than that of Labour team. The one-way ANOVA test result in tables 3 shows the detail.

Table 2: A Mean and Standard Deviation of Attitude to Safety

Category	N	Mean	sd
Labour team	61	51.02	16.27
Management team	40	63.16	13.08
Total	101	55.82	16.16

From Table 3 the results $F_{(1, 99)} = 15.61$, $P < 0.05$ indicates that significant difference exists between Labour and Management teams at 0.05 level of significance as indicated by their means. Hence Management team observed safety measures more than Labour team.

Table 3: One-way ANOVA summary for Labour and Management teams' attitude to safety

Group	Sum of squares	df	Mean	F	p-value	p
Between groups	335.71	1	3556.71	15.61	0.00	<0.05
Within groups	22552.08	99	227.80			
Total	26108.79	100				

F is test statistic

Similarly, as illustrated in table 4, respondents with tertiary education show better attitude to safety than those with pre-tertiary education as confirmed in table 5.

Table 4: Mean and Standard Deviation of the Educational level to Safety

Education level	N	Mean	sd
Primary	5	43.80	10.92
MSLC/JHS	29	51.72	16.58
SHS/A & O levels	34	54.74	16.28
Tertiary	33	62.36	14.28
Total	101	55.82	16.16

Table 5: One-way ANOVA on Attitude to Safety by Education Levels

Group	Sum of squares	df	Mean square	F	p-value	p
Between groups	2661.95	3	887.32	3.67	0.015	<0.05
Within group	23446.85	97	241.72			
Total	26108.79	100				

F is test statistic

From table 5 the result $F_{(3, 97)} = 3.67$, $P < 0.05$ indicates a significant difference exists between at least two of the means of the educational levels on Attitude to Safety. From the post hoc results in Table 6, the values F = 7.92, P > 0.05; F = 10.94, P > 0.05 and F = -3.01, P > 0.05 indicates that there is no significant difference between the mean attitude to safety score of pre-tertiary groups. However, the result F = 18.56*, 10.64* and 7.63* indicated a significant difference between the tertiary group and pre-tertiary educational levels compared at 0.05 level of significance.

Table 6: Post hoc result on Attitude to Safety for Education Level

Educ. level	1	2	3
Primary			
MSLC/JHS	-7.92		
SHS/A & O levels	-10.94	-3.01	
Tertiary	-18.56*	-10.64*	7.63*

** means significant at 0.05*

This may be due to the higher level of knowledge they probably acquire along their educational ladder about the importance of safety and their experiences. So this class of operatives with tertiary education in the industry must be empowered to ensure observation of safety regulation during construction process through resources and further refresher programs.

c) Project Structural Specification Adherence

The result of $t_{(100)} = 8.11$, $P < 0.05$ shown in table 7 indicated that the respondents' adherence to project structural specification is high since the mean value was significant at 0.05 level of significance.

Table 7: Student 't' on level of Adherence to Project Structural Specification

Item	N	Mean	Std	df	t	p-value	p	Test value
Specification adherence	101	68.22	13.90	100	8.11	0.00	<0.05	57

However, from Table 8, result $t_{(100)} = -1.33$, $P > 0.05$ indicates that respondents disregard observation of project details during construction as a safety measure at 0,05 level of significance

Table 8: Student 't' on 'Observation of Project Details against safety'

Item	N	Mean	Std	df	t	p-value	p	Test value
Project Details as safety?	101	2.85	1.13	100	-1.33	0.00	>0.05	3

This finding is an indication of the need for immediate reorientation of players in construction to begin thinking that adherence to project structural specification is equally a safety measure to ensure safety of structures.

Pearson's correlation of general attitude to safety, management attitude to safety supervision and project structural specification was tested and the results are presented in table 10.

Test for normality and homogeneity using skewness and kurtosis was within the acceptable range of ±2 (Tabachnick et al. 2007) while the Crombach alpha (α) indicates the reliability of constructs as illustrated in table 9.

Table 9: Summary of the Means, Standard Deviation, Skewness and Kurtosis (N=101)

	Min	Max	Mean	SD	Skewness	Kurtosis	Cronbach alpha (α)	N
Knowledge of safety	29	56	47.34	5.831	0.352	0.255	0.77	101
General Attitude to safety	28	82	55.82	16.16	-0.331	0.210	0.84	101
Managt Attitude to safety	20	69	48.66	15.03	-0.331	0.210	0.87	40
Safety supervision	8	30	22.91	6.51	0.811	0.396	0.81	40
Adherence to project specification	40	91	68.22	13.90	0.111	0.509	0.73	101

Table 10: Summary of Pearson Correlation between Independent, Dependent and Moderating Variables

	Variables	1	2	3	4	5
1	Knowledge of safety	-				
2	General Attitude to safety	0.72**	-			
3	Management Attitude to safety	0.68**	0.83**	-		
4	Safety supervision	0.64**	0.78**	0.96**	-	
5	Adherence to project specification	0.57**	0.80**	0.57**	0.59**	-

***p<0.01, N=40 for Management N=101 for all operatives*

Results from table 10indicate that almost all the independent variables related significantly with at least one dependent variable as a requirement to analyze for moderation (Holmbeck, 1997). The descriptive result is detailed in Table 9.

The results of Pearson correlation are given in table 10. The value r= 0.80, N = 101, p < 0.01 indicates a very high/strong association (Davis, 1971) and positively significant correlation between attitude to safety and project structural specification adherence of the respondents at 0.01 significance level. Thus, an increase in the attitude to safety or positive safety behaviour results in increase in project structural specification adherence by operatives. Similarly, from the same table, Pearson's correlation, r= 0.59, N = 40, p < 0.01 indicates a substantial association (Davis, 1971), significantly positive correlation between management attitude to safety supervision and project structural specification adherence at 0.01 level of significance. This shows that an increase in the management attitude to safety supervision would result in the increase project structural specification adherence and vice versa.

d) Influence of Safety plan/supervision on the relation between Safety Observation and Project Structural Specification Adherence

The hierarchical regression in which three distinct steps are stipulated was conducted. The main effect (Attitude to Safety) was entered first, the main effect of moderator (safety supervision) was entered second, and the interaction term (Attitude to Safety X Safety Supervision) was entered third (Aiken & West, 1991). The basic requirement for testing for moderation effect that there should be a relationship between the predictor variable(s) and the criterion variables (Holmbeck, 1997) was met as illustrated in Table 10 (correlation table). The results of the moderation analyzed are shown in Table 11.

Table 11: Hierarchical Multiple Regression for moderation effect of safety supervision on the relationship between safety attitude and adherence to project structural specification

Model		B	Std. Error	β	P
Step 1	(Constant)	57.723	3.388		
	safety attitude	-0.403	0.07	-0.434***	0.000

	(Constant)	32.856	5.582		
Step 2	safety attitude	-0.237	0.076	-0.255**	0.002
	safety supervision	0.406	0.076	0.436***0.000	
	(Constant)	-3.157	14.071		
	safety attitude	0.636	0.323	0.684*	0.051
Step 3	safety supervision	1.264	0.318	1.360**	0.000
	safety attitude * safety supervision	-0.021	0.008	-1.030**0.006	

*R^2= .188 for step1, R^2= .346 for step 2, R^2= .387 for step 3ΔR^2=.188 for step 1,ΔR^2=.158 for step 2ΔR^2=.041 for step 3, ***p< .001, **p< .01,*p< .05*

From Table 11, it can be inferred from the first step that Safety Attitude had a significant influence on Adherence to Project Specification (β = -.434, p < 0.001). In the second step, Safety Supervision also explained a significant increase in variance of Adherence to Project Specification (ΔR^2 = .158, β =.436, p <0.001). In the third step of the regression analysis, the interaction term between attitude to safety and Safety Supervision explained a significant increase in variance in Adherence to Project Specification (ΔR^2 = .041, β= -1.030, p <0.01). Thus, Safety Supervision significantly moderated the relationship between Safety Attitude and Adherence to Project Specification such that Safety Supervision strengthens the relationship between Attitude to Safety and Adherence to Project Specification. Hence, safety plan/supervision will influence the relation between Safety Observation and Project Structural Specification Adherence.

e) Outcome of the Framework

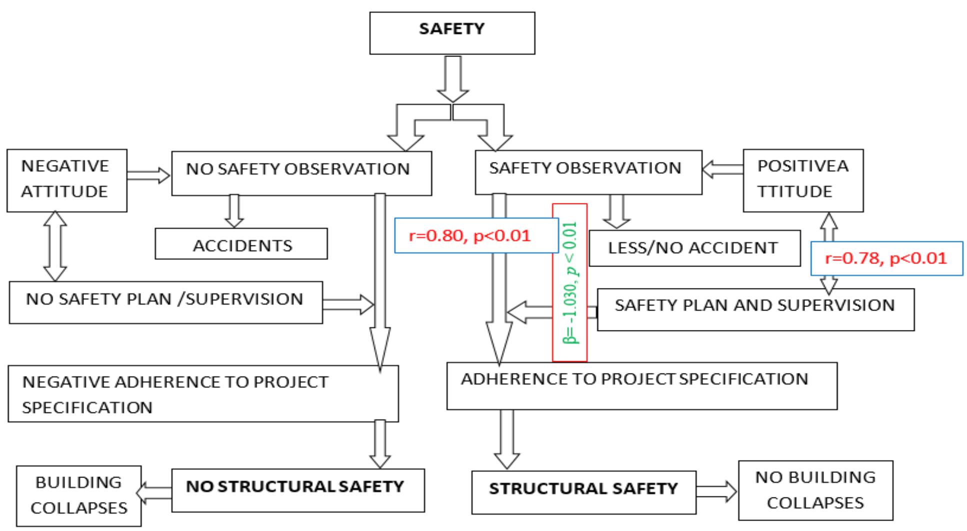

Figure 3: Results of the model

V. Discussion of Results

In the first place respondents generally exhibited good attitude to safety on site, and this was more obvious with the Management team than Labour team. This observation is inconsistent with Fordjour (2015) who concluded that poor health and safety performance was due to negligence and or carelessness on the part of construction Managers and workers. The present finding indicates that the both groups- management and labour teams – have relatively good Attitude to Safety but differ in reaction to safety guidelines.

Meanwhile Education influence on Attitude to Safety between pre-tertiary and tertiary groups of education is consistent with Gharibi et al. (2016) that as educational level increases workers' safety attitude correspondingly significantly changes positively. However, it does not support the education level among pre-tertiary groups, contradicting the conclusion of Gharibi et al. (2016) that either occupational accident experience or the level of education could affect positively on changing safety attitudes. So this class of operatives with high educational level in the industry must be empowered to ensure observation of safety regulation during construction process through resources and further refresher programs. According to Sanaei Nasab et al. (2009) it is of utmost importance to educate workers regarding the fact that level of knowledge or education about occupational health and safety enhances attitude to safety.

Furthermore, Adherence to Project Structural Specification by respondents is generally good on the adherence scale though they specifically disregard observation of project details as safety. Attitude to Safety and Safety Supervision positively and significantly correlate with Project Structural Specification Adherence. The significant positive correlation of the direct relationship between Attitudes to Safety, Safety Supervision and Specification Adherence variables is the primary reason for which nobody in the construction industry should take safety for granted. What it means is that reduction in either of these variables (Attitudes to Safety and Safety Supervision) may lead to reduction in the other (Specification Adherence) and the consequences may be detrimental to life and property. Hence, attitude such as Workers' negligence to Safety, Disregard for Work Procedures, Operating Equipment without Safety Devices, Poor Site Management, Harsh Work Operation, Low Knowledge and Skill level of Workers and Failure to use Personal Protective Equipment (Hamid et al., 2008); Disregard for Approved Drawings and Faulty Designs (Windapo and Rotimi, 2012); Non-compliance with Building Specifications and Regulations (Oloyede et al., 2010) should not be tolerated on projects

Finally, Safety Supervision significantly moderated the relationship between Attitude to Safety and Adherence to Project Structural Specification such that Safety Supervision strengthens the relationship between Attitude to Safety and Adherence to Project Specification. This is an indication that supervision has its own improving factor on the system to further perform better though from the above discussion, Observation of Safety/Attitude to Safety already has very high or strong association (Davis, 1971) and positive correlation with Project Structural Specification Adherence. Hence this is a revelation that a reduction in the strength of supervision would lead to reduction in Attitude to Safety and then Structural Specification Adherence, and vice versa. No wonder, Windapo and Rotimi (2012) indicated that majority of structural collapses in Nigeria were attributable to human action or inaction, including largely poor supervision and workmanship. Therefore, supervisors who have the most frequent contacts with workers should be the directly responsible persons to guarantee good safety performance on site (Hofmann et al., 2003; Kapp, 2012; Zohar, 2002).Thus, the better choice here is to encourage functioning supervision at all times to increase the probability of Adherence to both Safety measures and Project Structural Specifications.

VI. Summary and Conclusion

In conclusion, attitude to safety was generally good among the respondents especially the management team while level of education could not be left out in how they vary on attitude to safety between pre-tertiary and tertiary groups. Again, positive relationship exists between Attitude to Safety, Safety Supervision and Project Structural Specification Adherence. Finally, Safety Supervision significantly influences or moderates the relationship between Attitude to Safety and Adherence to Project Structural Specification. Hence the better choice here is encouraging functioning supervision at all times to increase the probability of adherence to both Safety measures and Project Structural Specifications. Thus, conscious Safety Attitude is a recipe for Project Structural Specification Adherence.

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May God bless you allabundantly.

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Modelling Earthquake's Inter-event Recurrence Intervals (IRIs) in Central India and Adjoining Regions using Weibull Probability Distribution Model – A Zone-Wise Approach

By Ranjeet Joshi, Sudhir S. Bhadauria & Suresh S. Kushwah

Abstract- This study analyzes and model zone-wise earthquakes inter-event recurrence interval (IRIs) using a stochastic Weibull probabilistic distribution model. The study region between 19–28°N and 72–84°E up to 200 km peripheral boundaries of Central India (Madhya Pradesh) is divided into four zones (Zone South, West, North, and East), respectively, based on different clusters of earthquakes with shared seismo-tectonic regimes. Seismic events' catalog from different national and international resources for a period of more than 100 years are considered in this study. The seismic data is grouped into two categories based on a different range of earthquake magnitudes ($3 \leq M_w < 4$ & $4 \leq M_w \leq 6$). Zone-wise results are produced in the form of hazard curves and conditional probabilities of occurrence for a range of elapsed time from 3 to 30 years from last recorded earthquakes in various zones.

Keywords: conditional probability · weibull · madhya pradesh · earthquake recurrence · seismic hazard.

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Modelling Earthquake's Inter-event Recurrence Intervals (IRIs) in Central India and Adjoining Regions using Weibull Probability Distribution Model – A Zone-Wise Approach

Ranjeet Joshi [α], Sudhir S. Bhadauria [σ] & Suresh S. Kushwah [ρ]

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I. Introduction

Just like all natural events, earthquakes are random in occurrence. This randomness makes the use of statistics and probabilistic theory extremely suitable for analyzing earthquakes inter-event recurrence intervals (IRIs). Many studies have been conducted in India and around the world to substantiate the suitability of various distribution models for fairly assessing the conditional probabilities of earthquake recurrences. All such studies investigated the distribution of recurrence interval using established probabilistic models and analyzing their best fit employing various goodness-of-fit tests.

In India, extensive work has been done by researchers towards assessing earthquake inter-event recurrence intervals in various regions including western and northwestern parts Kachch (Tripathi and Nath (2001), Rajendran and Rajendran (2003)), north-eastern regions (Yadav et al. (2010)) and Himalayan region (Bungum et al. (2017)). These studies are conducted considering various probabilistic models like Lognormal, Gamma, Weibull, Exponential, Brownian Passage Time (BPT), and Poisson model with parameter estimation using maximum likelihood method and validating data fitting through Kolmogorov-Smirnov statistical method and Anderson-Darling method.

Similarly, a considerable amount of work has been done globally, like the one done by Yilmaz et al. Bayrak et al. (2015) for north Anatolian fault zone in Turkey using Weibull, lognormal, exponential and gamma models with Kolmogorov- Smirnov test; Kinasih et al. Kinasih et al. (2014) for the Lesser Sunda Islands using Weibull distribution over different categories of earthquake magnitudes (low, medium and high) and the most recent one by the Coban et. Coban and Sayil (2019) et al., towards evaluating the earthquake recurrence in western Antatolia using five different probabilistic models with an estimation of model parameters using the maximum likelihood method.

Most of these studies concluded Weibull as the best approximation model for earthquake IRI estimation. Hardly any research has been conducted for central India to analyze the probabilities of recurrence of earthquakes, especially for earthquakes with a magnitude greater than 4 in the region. Present study attempts to analyze the pattern of recurrence of earthquakes in the region by analyzing IRIs using the Weibull distribution model.

II. Methodology

a) Study Region for this research

Although higher magnitude earthquakes are infrequent in central India, the catalog for central India suggests a notable frequency of earthquakes with magnitude ranging from 3 to 5. One of the most significant and damaging earthquakes (Mw 5.8) ever experienced in this region is the one that struck on 21st May 1997 in the city of Jabalpur, which lies on the Central Indian Tectonic Zone (CITZ). The central part of the Indian subcontinent mainly consists of four tectonic regimes i.e., the Bundelkhand Craton, the Satpura Mobile Belt, Kotri-Dongergarh Mobile Belt, and the Bastar Craton. Besides, the Narmada-Son Lineament and Central Indian Suture (CIS) are also critical tectonic

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elements of this regime. The faults and lineaments considered under this study are taken from the Seismotectonic Atlas of India and its Environs published by Geological Survey of India. The records have been digitized and using GIS application QGIS in different layers along with historical seismic records over the map of the study region. Based on the cluster of sources and historical seismicity, the study region is divided into four zones as potential seismic sources to study the earthquake recurrence pattern as shown in Figure 1.

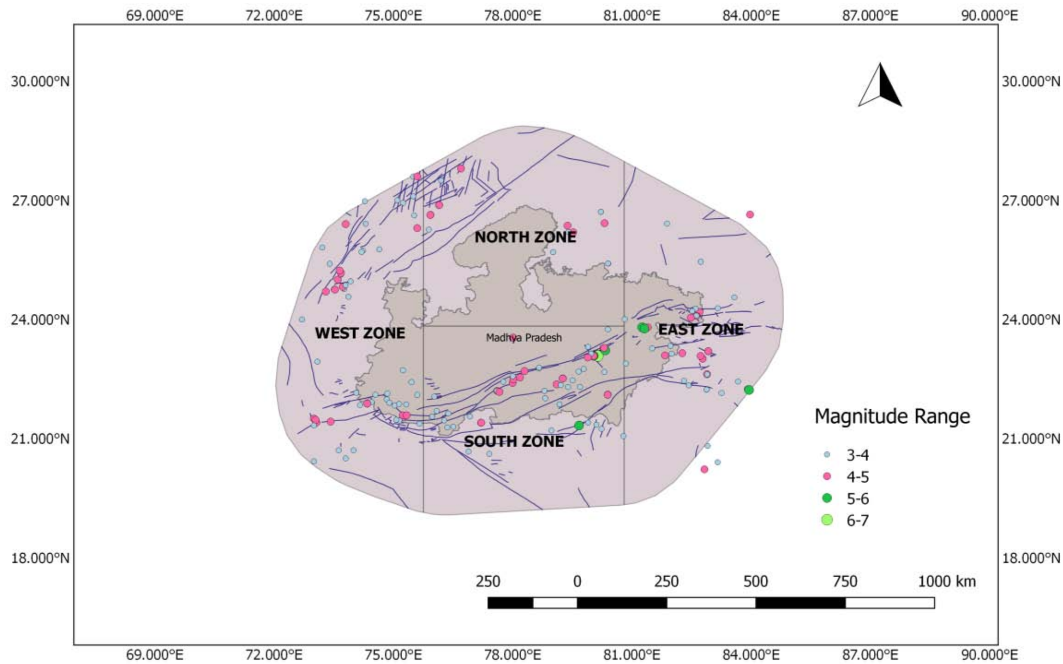

Figure 1: Figure highlights various zones within the study region, classified based on of shared clusters of seismogenic features such as faults and historical seismicity

b) Catalog Preparation

In this study, a new earthquake catalog for the study region has been compiled using various national and international resources with an aim to perform consistent seismic hazard assessment. A total of 187 seismic events are considered in earthquake data from 1995. The catalog is uniformly harmonized in terms of Mw. In the absence of any dedicated conversion formula for the study region, the global conversion formulae proposed by E. M. Scordilis (2006) have been used for magnitude conversion. After zone-wise distribution of seismic events, for each zone, the catalog has been de-clusterized in order to remove the foreshocks and aftershock events. In order to the catalog, an algorithm proposed by Reasenberg (1985) has been used using ZMAP software. The algorithm assumes the inter-connectivity of seismic events both in terms of space and time. The algorithm correctly filtered all foreshocks and aftershocks from events. The region is divided into four zones (*South, West, North, and East*), and these four zones are further analyzed by clustering earthquakes into two categories of magnitudes, as shown in Tables 1, 2, 3, and 4.

Table 1: Earthquake catalog for South (a) & (b) category in Madhya Pradesh and adjoining regions

S. No.	Longitude	Latitude	Year	Month	Day	Magnitude	Depth	Hour	Minute
South (a) category Earthquake Catalog									
1	77.60	22.20	1996	1	10	3.90	33	10	37
2	78.00	22.57	1998	7	19	3.80	33	0	57
3	76.09	21.69	1998	10	20	3.10	2	0	5
4	76.23	21.62	1998	10	24	3.00	1	0	48
5	76.38	21.63	1998	11	5	3.50	10.8	0	42
6	77.19	22.12	1999	5	11	3.00	5	0	56

7	79.18	21.86	2000	6	30	3.60	15	0	57
8	79.51	22.47	2001	1	3	3.20	33	0	45
9	74.78	20.63	2002	2	6	3.00	5	0	15
10	79.21	22.35	2002	3	6	3.20	45.7	0	24
11	75.66	21.37	2002	8	31	3.20	10	0	42
12	80.79	21.06	2002	9	21	3.20	10	0	7
13	76.36	21.28	2002	11	2	3.30	10	0	57
14	77.41	20.61	2003	1	19	3.10	7.7	0	48
15	80.24	21.24	2003	11	29	3.20	13.3	0	5
16	76.89	20.67	2003	12	26	3.20	13.2	0	37
17	75.80	21.69	2004	3	1	3.00	10	0	38
18	78.98	21.20	2004	5	12	3.20	4	0	29
19	76.28	21.46	2005	4	1	3.30	17.1	0	40
20	77.77	22.43	2006	3	7	3.20	15	0	39
21	79.39	22.30	2006	8	5	3.40	10	0	57
22	78.66	22.77	2007	6	6	3.40	8.2	0	15
23	78.67	22.79	2008	1	10	3.40	10	0	48
24	79.70	22.30	2009	8	1	3.50	10	0	49
25	76.93	21.56	2010	1	25	3.30	10	0	0
26	78.82	22.01	2012	6	12	3.40	35	0	9
27	76.51	21.30	2012	9	12	3.20	20	0	34
28	79.90	21.40	2015	7	23	3.90	10	14	36
29	77.20	19.50	2017	8	16	3.00	10	6	35
South (b) category Earthquake Catalog									
1	78.30	22.70	1995	5	2	4.30	33	0	46
2	77.67	22.17	1996	1	10	4.40	10	10	37
3	78.19	22.54	1998	3	9	4.50	20.6	0	41
4	79.26	22.51	1998	3	29	4.30	33	0	54
5	78.01	23.54	1999	4	3	4.20	30	0	38
6	79.11	22.37	2000	9	12	4.10	8.9	0	46
7	79.67	21.33	2001	7	26	5.30	10	0	5
8	77.21	21.40	2003	3	10	4.30	22.7	22	45
9	75.97	21.55	2003	11	22	4.00	10.5	0	18
10	80.11	21.35	2015	7	23	4.00	10	14	36

Table 2: Earthquake catalog for West (a) & (b) category in Madhya Pradesh and adjoining regions

S. No.	Longitude	Latitude	Year	Month	Day	Magnitude	Depth	Hour	Minute
West (a) category Earthquake Catalog									
1	75.46	22.42	1998	9	13	3.30	15	0	42
2	73.76	24.76	1998	12	26	3.40	5	0	14

3	75.15	21.45	1999	3	3	3.30	20	0	43
4	74.16	21.84	1999	7	17	3.40	5	0	48
5	74.45	21.92	2000	4	14	3.40	10	0	41
6	75.03	21.83	2000	7	10	3.50	20	0	6
7	74.85	22.13	2000	7	24	3.30	15	0	19
8	75.24	22.72	2001	1	12	3.40	2.9	0	36
9	73.09	22.94	2002	1	23	3.20	19.8	0	11
10	75.07	21.47	2002	5	19	3.90	30.9	0	25
11	73.87	24.57	2002	9	13	3.40	10	0	35
12	73.62	20.71	2002	12	1	3.10	1.6	0	33
13	74.55	22.10	2003	12	23	3.70	5	0	9
14	74.07	22.15	2003	12	24	3.10	40.6	0	47
15	75.32	21.86	2004	10	28	3.20	13.4	0	41
16	73.92	24.96	2005	6	1	3.60	33	0	28
17	73.68	25.12	2005	11	28	3.20	3.5	0	27
18	73.00	21.33	2008	5	2	3.80	12	0	53
19	73.80	24.86	2008	6	27	3.60	10	0	53
20	74.65	25.77	2008	7	5	3.60	17.2	0	59
21	74.30	26.41	2010	8	15	3.80	10	0	8
22	76.03	22.06	2012	11	20	3.40	15	0	15
23	74.83	21.99	2013	6	30	3.40	19.1	0	44
24	74.00	20.71	2014	1	7	3.30	15	0	50
25	75.14	21.87	2014	8	20	3.60	6.5	1	29
26	72.70	24.00	2015	3	19	3.50	5	9	41
27	73.00	20.43	2015	11	2	3.20	18.1	0	39
28	73.21	25.81	2016	3	18	3.60	7.7	0	37
29	74.24	25.73	2016	12	26	3.40	10	0	17
West (b) category Earthquake Catalog									
1	73.30	24.70	1996	1	4	4.20	33	7	30
2	73.04	21.47	1996	11	17	4.60	10	18	12
3	73.60	25.00	1997	7	29	4.50	33	9	43
4	75.25	21.55	1997	11	13	4.70	8	20	17
5	73.73	24.82	2002	1	22	4.10	1.9	0	28
6	74.34	21.88	2003	7	27	4.20	20	0	35
7	73.53	24.75	2004	6	17	4.10	10	0	41
8	75.24	21.59	2009	1	4	4.40	8.4	0	20
9	73.65	25.23	2010	11	9	4.90	13.5	22	46
10	75.60	26.30	2013	2	24	4.10	5	0	57
11	73.42	21.43	2014	6	21	4.20	35	0	59
12	73.80	26.40	2017	11	18	4.20	10	9	51

Table 3: Earthquake catalog for North (a) & (b) category in Madhya Pradesh and adjoining regions

S. No.	Longitude	Latitude	Year	Month	Day	Magnitude	Depth	Hour	Minute
North (a) category Earthquake Catalog									
1	76.45	26.40	1999	7	3	3.00	10	0	59
2	79.02	25.69	2000	10	7	3.40	33	0	32
3	76.20	27.50	2012	12	20	3.60	5	13	0
4	75.00	27.20	2013	3	31	2.30	5	14	43
5	75.52	26.62	2013	9	5	3.20	11.1	0	29
6	79.40	26.20	2013	9	23	3.50	5	13	26
7	75.50	27.60	2014	4	27	3.40	5	9	14
8	75.50	27.10	2016	1	28	3.80	10	22	47
9	75.25	26.94	2016	4	7	3.40	10	0	3
North (b) category Earthquake Catalog									
1	80.31	26.42	1999	10	13	4.10	15	6	56
2	80.22	26.71	2001	1	8	4.00	33	0	44
3	79.38	26.36	2005	1	14	4.20	33	5	16
4	75.93	26.63	2006	12	23	4.30	1.2	22	43
5	75.89	26.26	2013	2	24	4.00	35	0	57
6	79.52	26.20	2013	9	23	4.50	10	0	26
7	75.60	27.60	2015	9	3	4.40	10	17	57
8	76.70	27.80	2016	11	16	4.40	10	22	58

Table 4: Earthquake catalog for East (a) & (b) category in Madhya Pradesh and adjoining regions

S. No.	Longitude	Latitude	Year	Month	Day	Magnitude	Depth	Hour	Minute
East (a) category Earthquake Catalog									
1	75.46	22.42	1998	9	13	3.30	15	0	42
2	73.76	24.76	1998	12	26	3.40	5	0	14
3	75.15	21.45	1999	3	3	3.30	20	0	43
4	74.16	21.84	1999	7	17	3.40	5	0	48
5	74.45	21.92	2000	4	14	3.40	10	0	41
6	75.03	21.83	2000	7	10	3.50	20	0	6
7	74.85	22.13	2000	7	24	3.30	15	0	19
8	75.24	22.72	2001	1	12	3.40	2.9	0	36
9	73.09	22.94	2002	1	23	3.20	19.8	0	11
10	75.07	21.47	2002	5	19	3.90	30.9	0	25
11	73.87	24.57	2002	9	13	3.40	10	0	35
12	73.62	20.71	2002	12	1	3.10	1.6	0	33
13	74.55	22.10	2003	12	23	3.70	5	0	9
14	74.07	22.15	2003	12	24	3.10	40.6	0	47

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15	75.32	21.86	2004	10	28	3.20	13.4	0	41
16	73.92	24.96	2005	6	1	3.60	33	0	28
17	73.68	25.12	2005	11	28	3.20	3.5	0	27
18	73.00	21.33	2008	5	2	3.80	12	0	53
19	73.80	24.86	2008	6	27	3.60	10	0	53
20	74.65	25.77	2008	7	5	3.60	17.2	0	59
21	74.30	26.41	2010	8	15	3.80	10	0	8
22	76.03	22.06	2012	11	20	3.40	15	0	15
23	74.83	21.99	2013	6	30	3.40	19.1	0	44
24	74.00	20.71	2014	1	7	3.30	15	0	50
25	75.14	21.87	2014	8	20	3.60	6.5	1	29
26	72.70	24.00	2015	3	19	3.50	5	9	41
27	73.00	20.43	2015	11	2	3.20	18.1	0	39
28	73.21	25.81	2016	3	18	3.60	7.7	0	37
29	74.24	25.73	2016	12	26	3.40	10	0	17
East (b) category Earthquake Catalog									
1	82.70	24.19	1995	12	10	4.30	33	8	24
2	82.62	24.09	1996	1	18	4.10	33	8	5
3	82.89	22.62	1996	2	12	4.20	33	20	39
4	80.14	23.08	1997	5	21	5.80	36	22	51
5	80.04	23.08	1997	6	4	4.30	31.4	19	29
6	80.39	22.10	1997	11	23	4.30	33	0	34
7	82.88	22.23	2000	2	27	4.00	33	11	42
8	82.31	22.46	2000	4	6	4.00	11.7	0	34
9	82.78	23.01	2000	10	10	4.50	17.6	0	11
10	80.29	23.27	2000	10	16	4.80	20.2	0	33
11	80.40	25.41	2001	2	12	4.00	15	0	16
12	82.92	23.20	2001	6	10	4.10	16.5	0	12
13	83.95	22.22	2001	6	12	5.10	33	12	41
14	82.48	24.04	2008	1	25	4.50	10	0	39
15	81.26	23.80	2012	10	18	5.30	35	0	33
16	79.89	23.04	2014	10	22	4.10	10	0	18
17	81.83	23.09	2015	2	24	4.10	35	0	28
18	82.00	23.14	2015	4	9	4.00	10	0	0
19	80.85	22.89	2016	7	17	4.00	0	0	1
20	82.27	23.15	2017	8	29	4.10	0	0	21

CategoryI	$3 \leq Mw < 4$	South(a), West(a), North(a) and East (a)
Category II	$4 \leq Mw \leq 6$	South(b), West(b), North (b) and East (b)

A wide range of magnitudes are considered in the second category to compensate for the fewer events of higher magnitude, especially those with magnitude ≥ 5.

c) Model Selection

Histograms plots are obtained for IRIs for different zones. All the plots thus obtained showed a tendency to left-skew, as shown in figures 2, 3, 4, and 5. This skewness reflects their belonging to a skewed-distribution family such as exponential, lognormal, or Weibull.

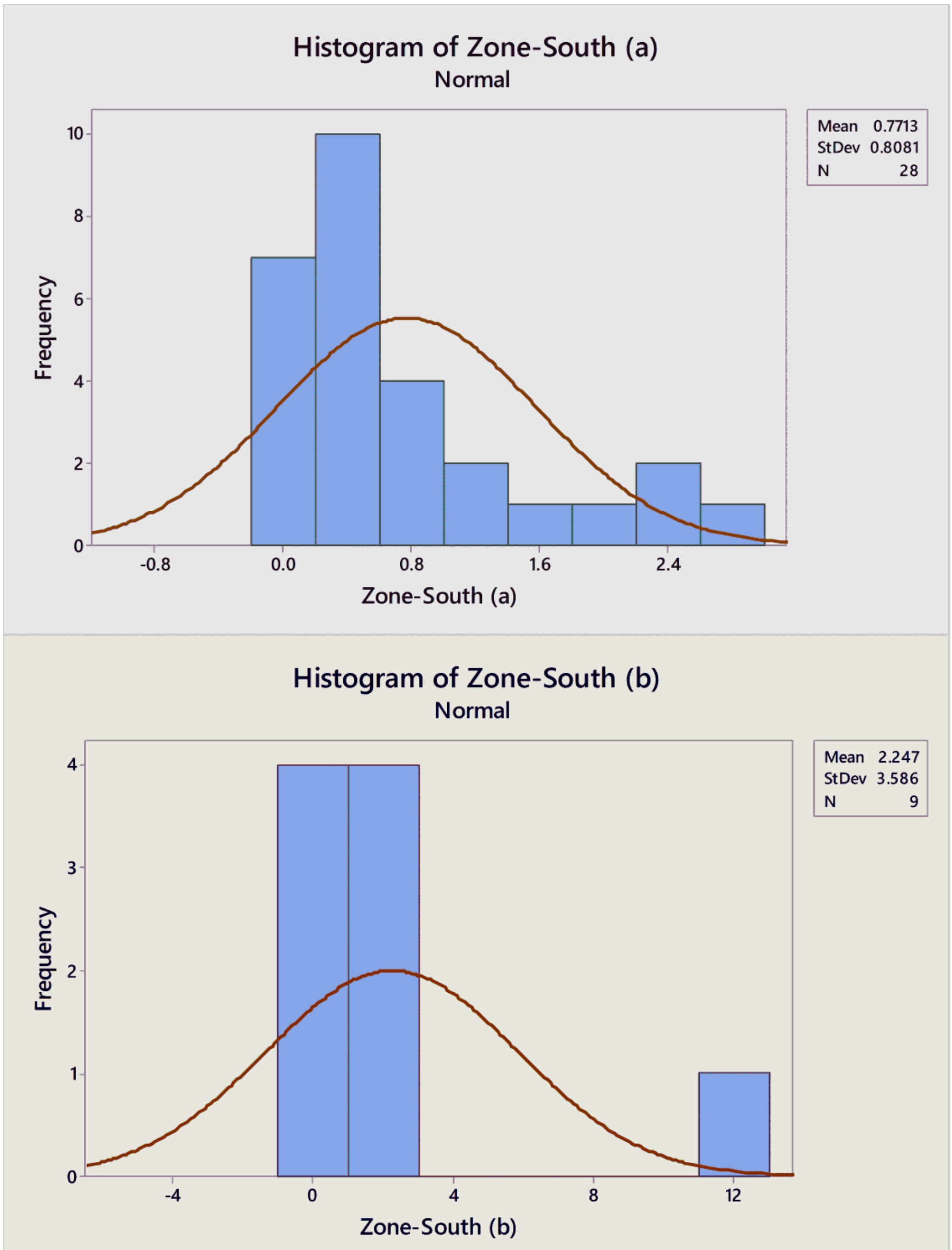

Figure 2: Histogram plots for South (a) & (b) category IRIs

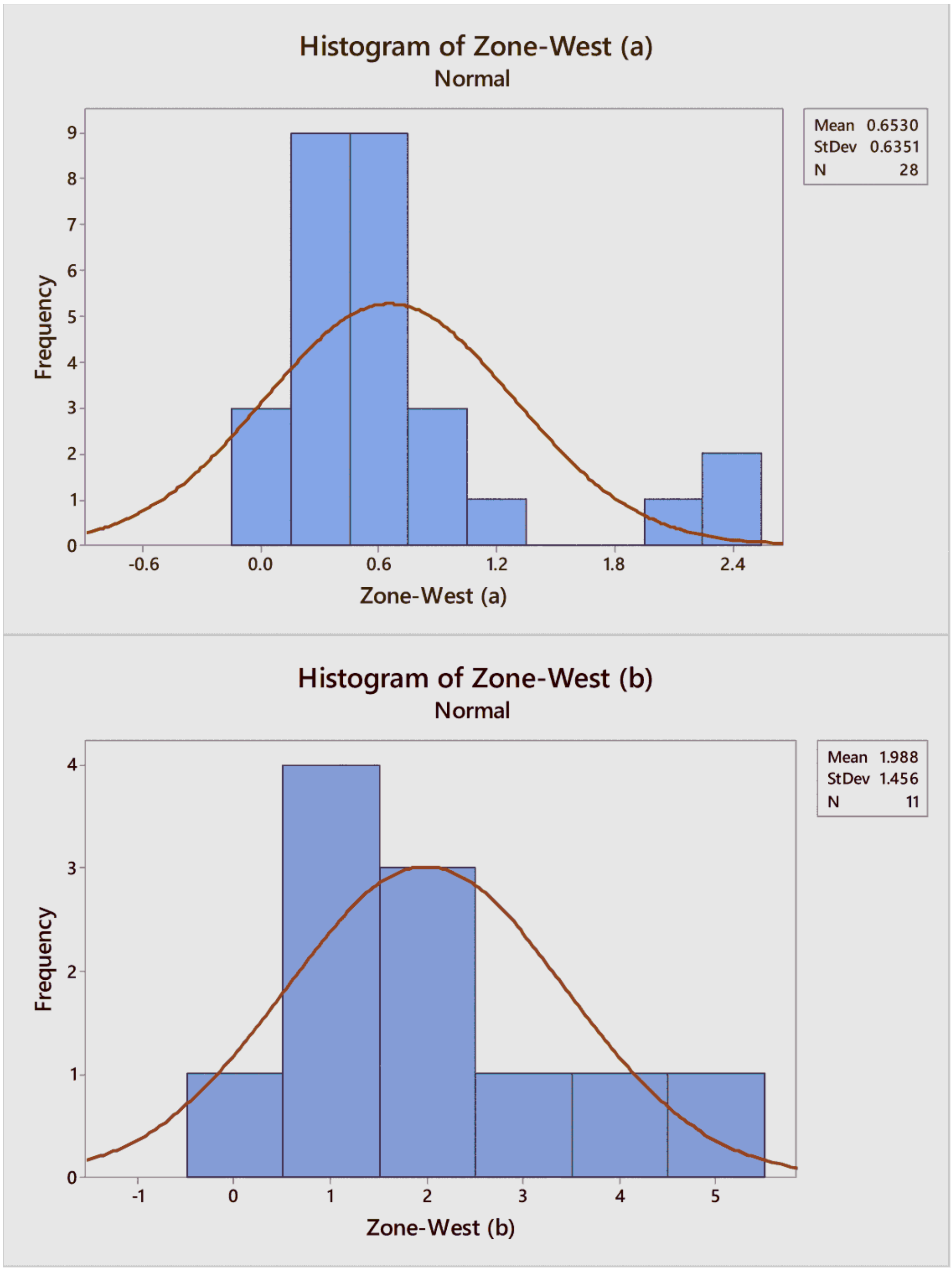

Figure 3: Histogram plots for West (a) & (b) category IRIs

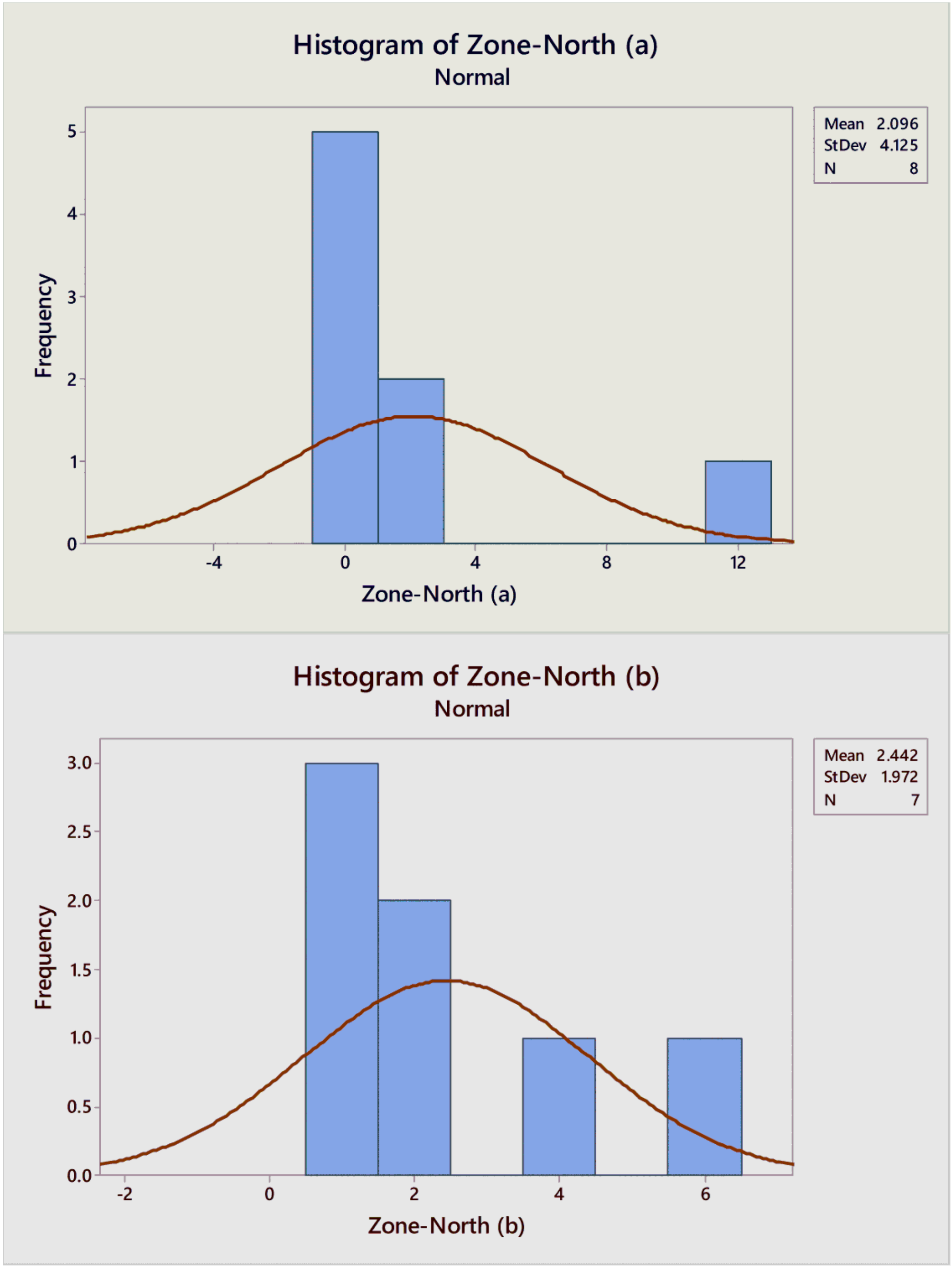

Figure 4: Histogram plots for North (a) & (b) category IRIs

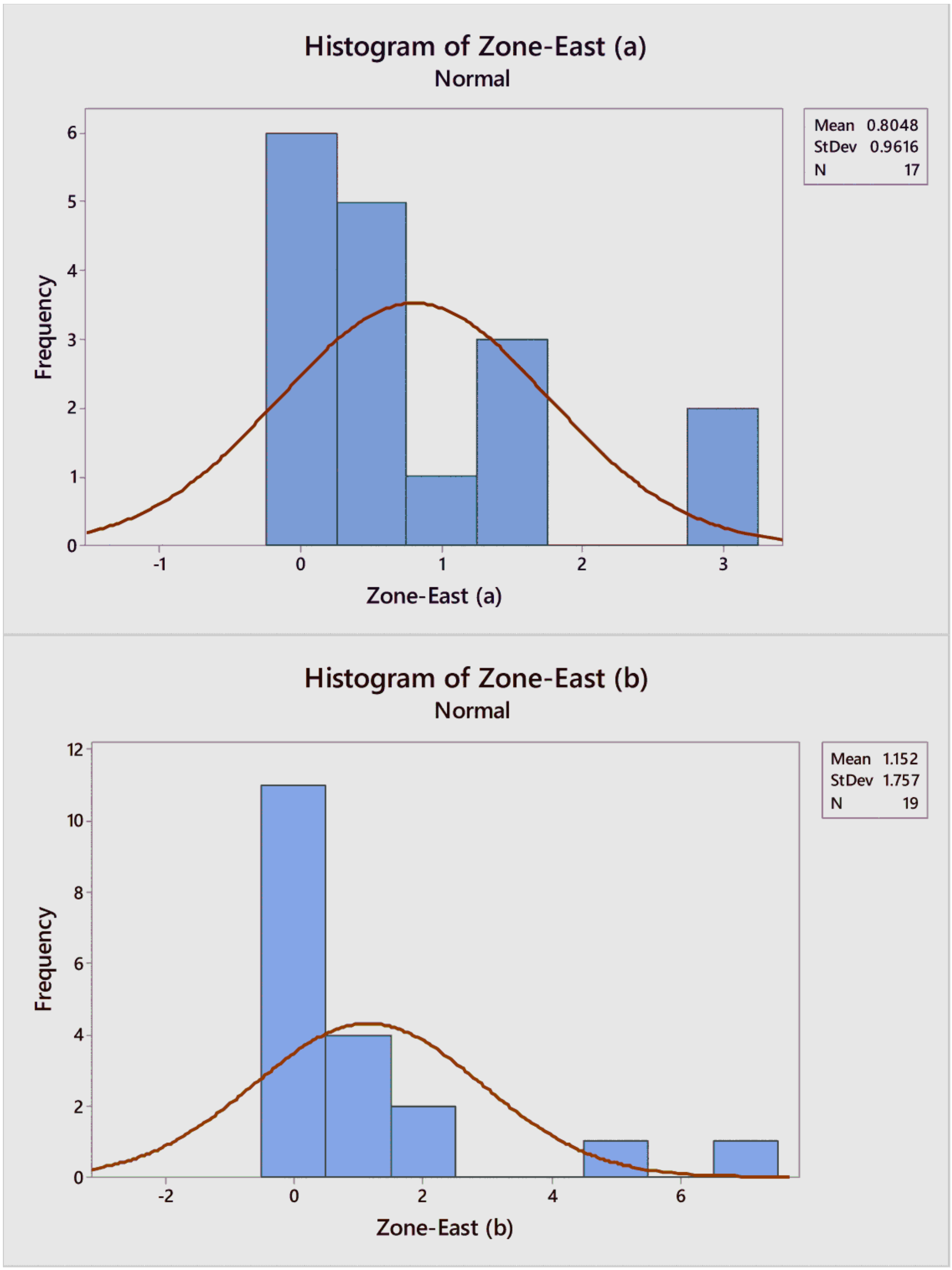

Figure 5: Histogram plots for Zone East (a) & (b) IRIs

In the next step, probability plots are obtained for the zone-wise IRIs for different categories of magnitudes. The distribution of data across reference lines of different models is visually inspected and the Anderson-Darling co-efficient is obtained. The values of Anderson-Darling co-efficient thus obtained are least for Weibull or Lognormal Distributions, thus confirming them to be the best choices for recurrence interval modeling for data fitting.

d) Weibull Distribution Model

Many stochastic function represents data distribution of natural processes like the occurrence of earthquakes. These functions help in formulating an empirical model for the given process. Choosing the best function among many necessitates understanding the properties of different functions suitable for modeling the data. More than one functions can adequately represent the given seismic data, but then comparison and robustness of one over another is judged based on evaluated model parameters for different distribution functions. Earthquake IRIs data for various zones are fitted on four major probability distribution models, including Weibull, Lognormal, Exponential, and Normal, and it is found that the data fitted best either in case of Weibull or Lognormal with the least values of Anderson Darling in only these cases (Figure 6 to 9). Based on these results and also recent work in this area where Weibull distribution is concluded to be the best option to model inter-event pattern, it is decided to do the modeling and analysis using the Weibull distribution function. The Weibull distributions are used as a generalized exponential distributions with additional model parameters to accommodate data variability and range.

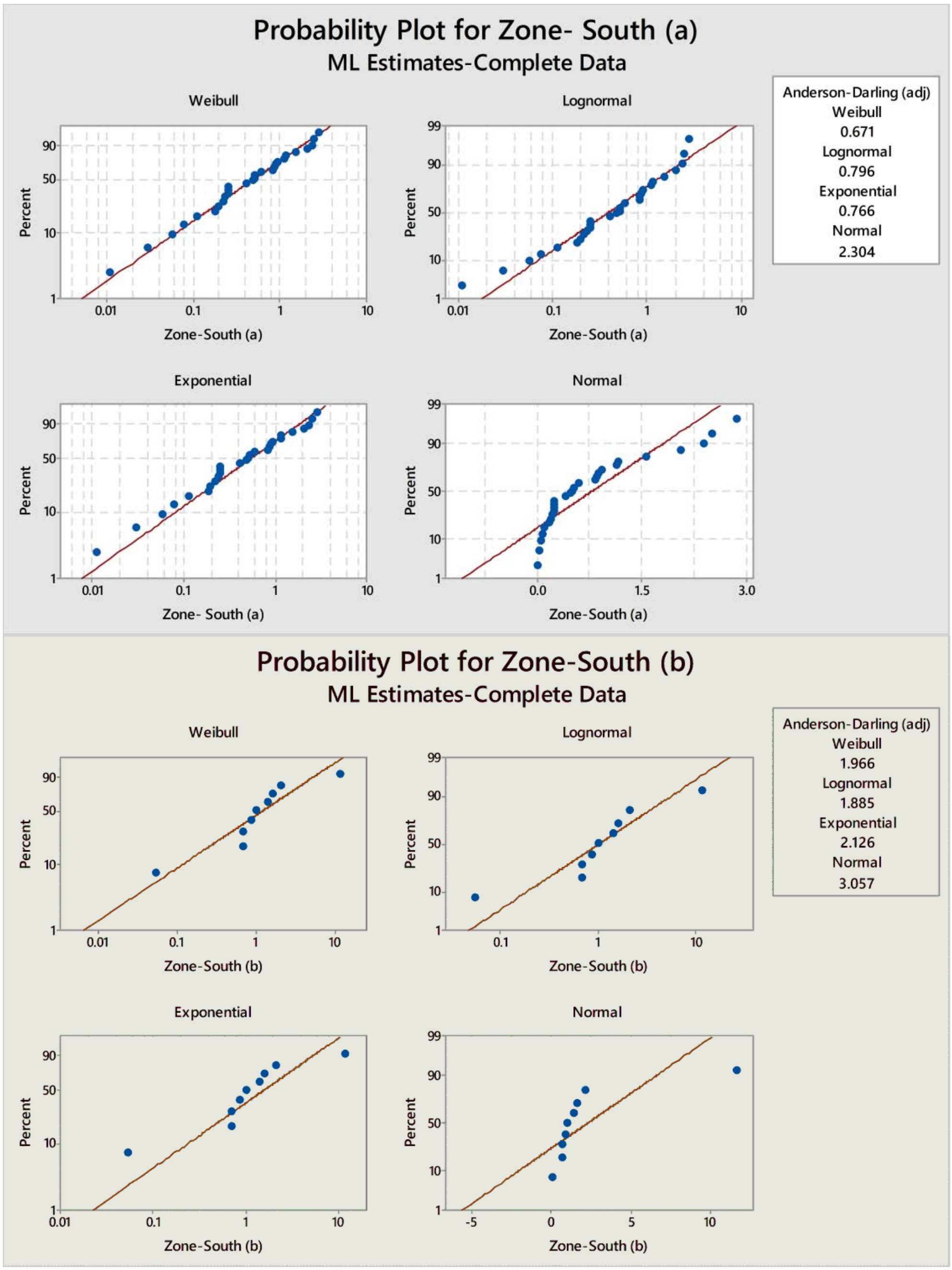

Figure 6: Probability plot of IRI for South (a) & (b) category. This plot shows IRI data falls near the Weibull reference line

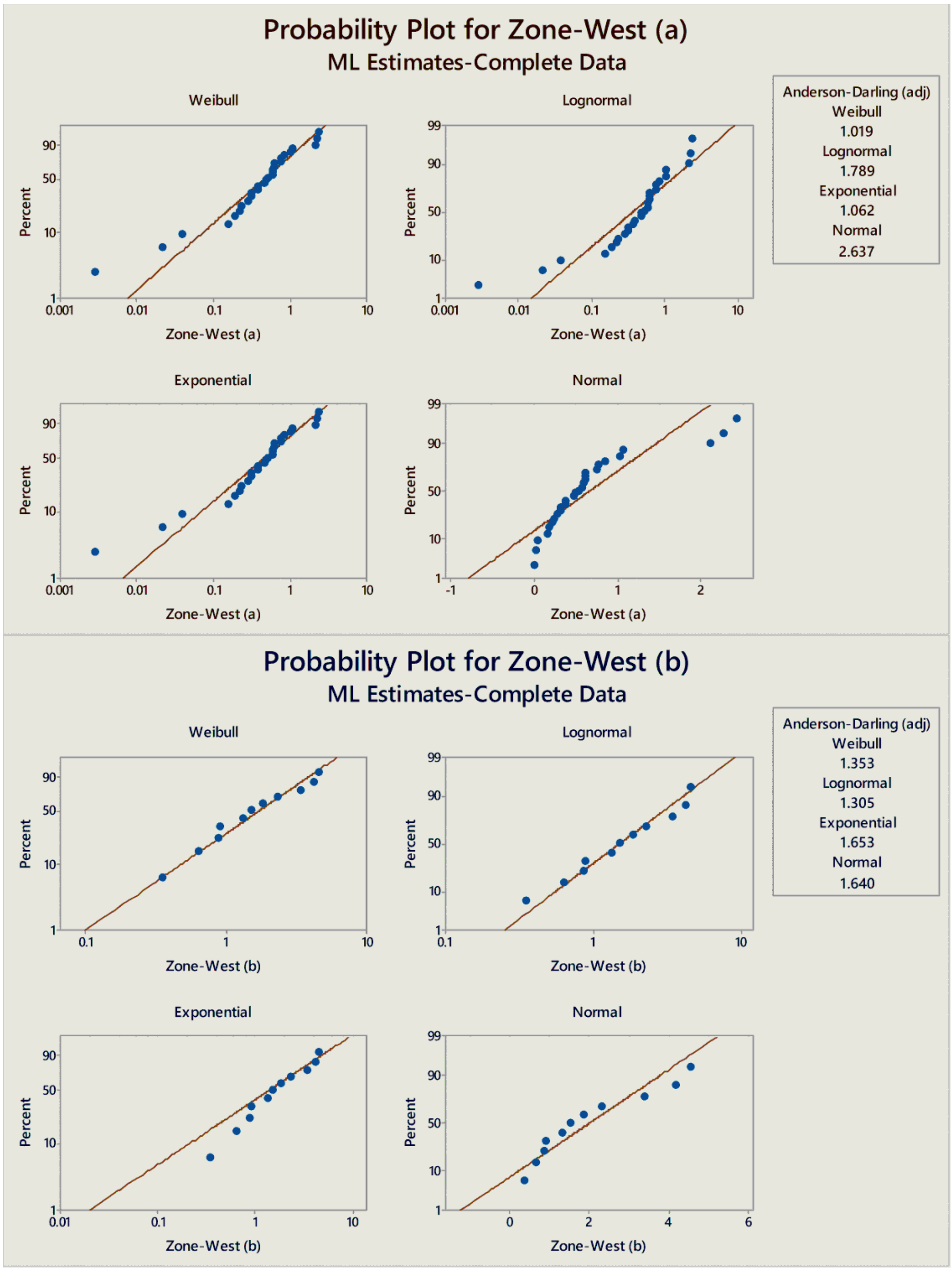

Figure 7: Probability plot of IRI for West (a) & (b) category. This plot shows IRI data falls near the Weibull reference line

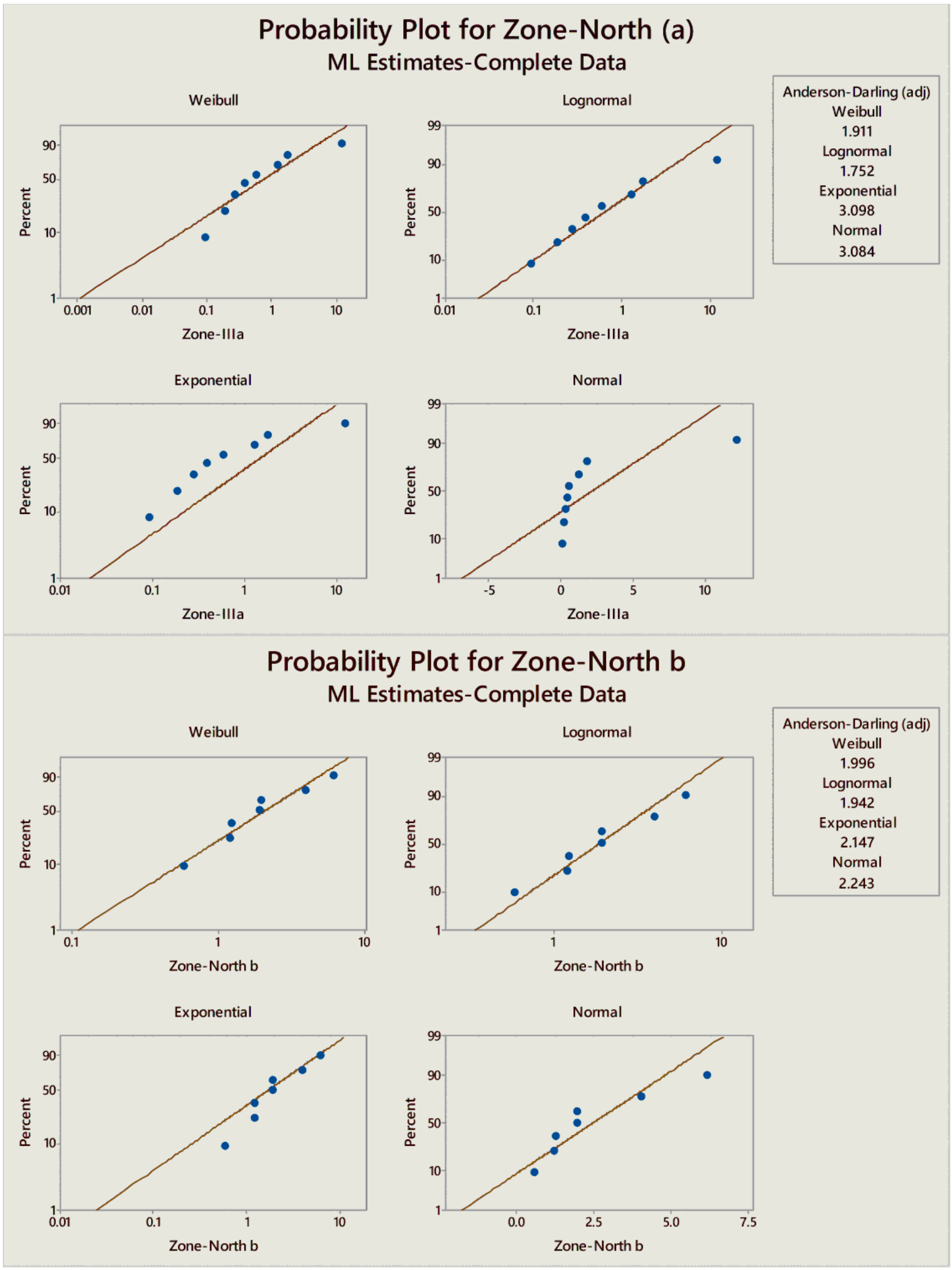

Figure 8: Probability plot of IRI for North (a) & (b) category. This plot shows IRI data falls near the Weibull reference line

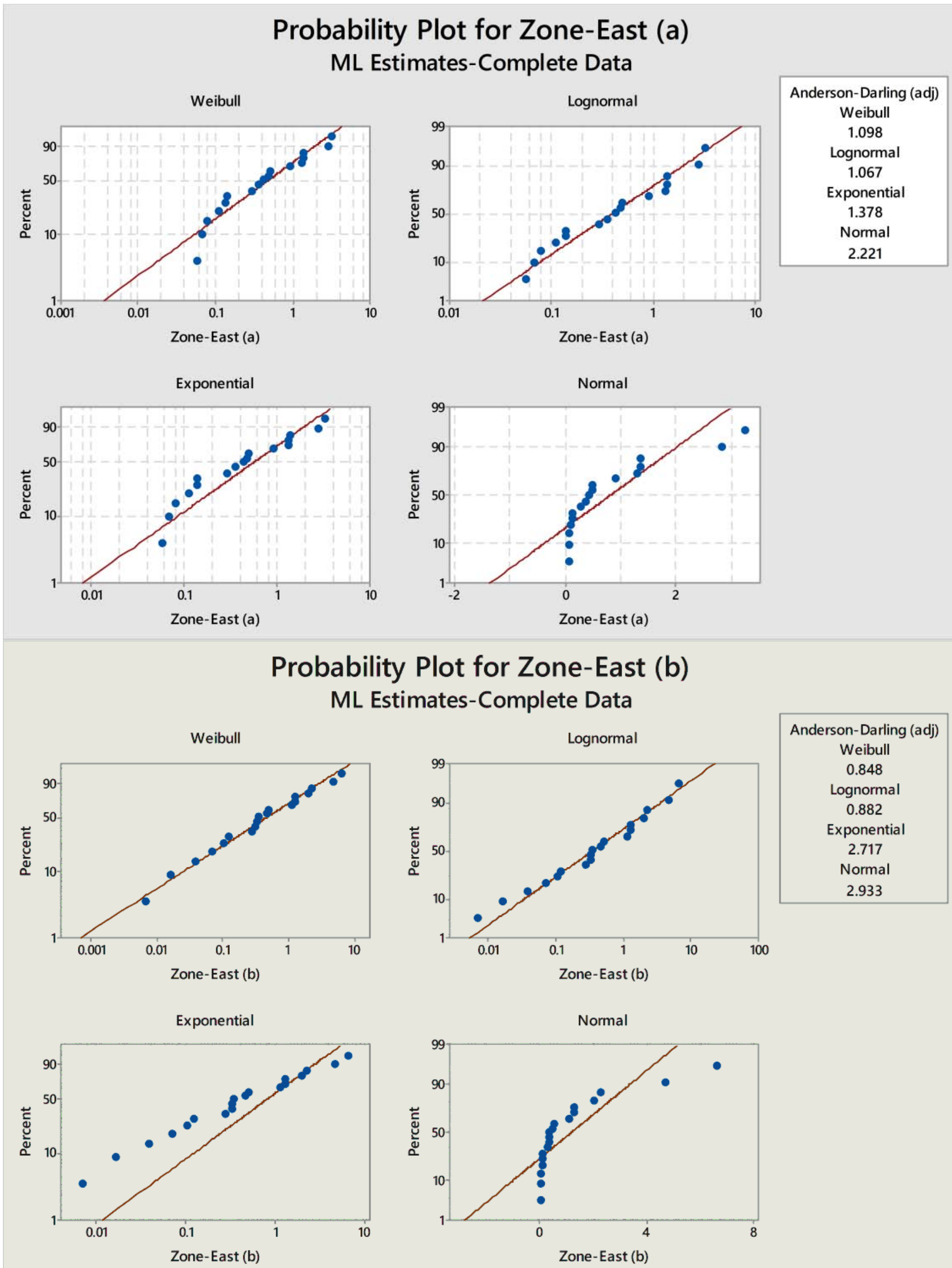

Figure 9: Probability plot of IRI for East (a) & (b) category. This plot shows IRI data falls near the Weibull reference line

If t is the time interval in years between successive events, α and β are the scale and shape parameters respectively for the Weibull distribution then,

Probability Distribution Function (PDF): f (t) = $\alpha\beta t^{\beta-1}e^{-\alpha t^{\beta}}$

Where, α > 0; β > 0

Cumulative Distribution Function (CDF): $\varphi\ (t) = e^{-\alpha t^{\beta}}$

Where φ (t) is the cumulative probability of the next earthquake that will occur at a time later than t, and t is the time measured in years from the time of the last earthquake.

If (τ/t) is the conditional probability that the next earthquake will occur during the time interval between t and τ, then it is given as

Weibull Conditional Probability: $p(\tau/t) = (1 - e^{-[\beta*[(t+\tau)^{\alpha}-t^{\alpha}]}$

τ for Maximum Conditional Probability as proposed by Sergio G Ferraes (2003):

$$\tau = \frac{1}{\alpha\beta t^{\beta-1}}$$

III. Probabilistic Analysis Method

a) Parameters Estimation for earthquake IRIs

Variability in data and extremities in values are the significant reasons for selecting Weibull as a suitable model for analyzing earthquake recurrence intervals. The two-parameter Weibull distribution is the predominant distribution in reliability and lifetime data analysis used to model extreme value data. The two-parameter Weibull distribution has shown effective results for assessing earthquake recurrence intervals and is commonly used in modeling such data(Ram Bichar Singh Yadav et al. (2008), Şeyda Yilmaz et al. (2016), Sumanta Pasari et al. (2018), Sumanta Pasari et al. (2015)). The classical approach for estimating the scale and shape parameters employs the maximum likelihood estimation (MLE) method. The hazard function of Weibull is time-dependent with hazard increasing with time when the shape factor is greater than one and decreasing when it is less than one. When the shape factor equals one, the Weibull hazard function becomes constant or equivalent to the exponential function. The estimated parameters are tested to fit the distribution using the Anderson-Darling test.

b) Zone-wise probability calculation

i. *Zone South*

Zone South has 48 earthquakes recorded from the year 1995 to 20017 with maximum magnitude 2.9 and minimum magnitude 5.3, minimum depth as 0, and maximum as 45.7. Declustering is done by using the declustering function of ZMAP software which evaluated total five clusters in the zone with a total of 10 events as aftershocks, foreshocks, or dependent events out of total 48 events. The zone is further grouped into two categories based on earthquake magnitudes.

For South (a) category, the maximum recorded earthquake is of magnitude 3.9 (1996), whereas the minimum recorded earthquake is of magnitude 3 (2017). The last earthquake for this zoning category is recorded in 2017.

Similarly, for South (b) category, the maximum recorded earthquake is of magnitude 5.3 (2001), whereas the minimum recorded earthquake is of magnitude 4 (2015). The last earthquake for this zoning category is recorded in 2015. The estimated model parameters (scale, shape) are listed in Table 5.The conditional probabilities as per the Weibull model are as given in Table 6.

ii. *Zone West*

Zone West has 55 earthquakes recorded from the year 1996 to 20017 with maximum magnitude 4.9 and minimum magnitude 2.8, minimum depth as 0 (not recorded) and maximum as 40.6. Declustering is done by using the declustering function of ZMAP software which evaluated total three clusters in the zone is a total of 7 events as aftershocks, foreshocks, or dependent events out of total 55 events.

For Zone West (a) category, the maximum recorded earthquake is of magnitude 3.9 (2002), whereas the minimum recorded earthquake is of magnitude 3.1 (2016). The last earthquake for this zoning category is recorded in 2016.

Similarly, for Zone West (b) category, the maximum recorded earthquake is of magnitude 4.9 (2010), whereas the minimum recorded earthquake is of magnitude 4.1 (2013). The last earthquake for this zoning category is recorded in 2017. The estimated model parameters (scale, shape) are listed in Table 5.

Table 5: Zone-wise estimated parameters for different groups of earthquake magnitudes for Weibull distribution model

	Zone South (a)	Zone South (b)	Zone West (a)	Zone West (b)	Zone North (a)	Zone North (b)	Zone East (a)	Zone East (b)
Shape Factor	0.924	0.809	1.03	1.482	0.642	1.436	0.863	0.647
Scale Factor	0.743	1.955	0.66	2.209	1.381	2.711	0.742	0.832
Log-Likelihood	-20.583	-15.529	-16.047	-17.397	-11.952	-12.58	-12.975	-17.97
Mean	0.771	2.25	0.653	1.988	2.1	2.442	0.805	1.152

Std. Deviation	0.808	3.59	0.635	1.456	4.12	1.972	0.962	1.757
Range	2.849	11.62	2.429	4.198	12.11	5.593	3.191	6.615

iii. *Zone North*

Zone North has 25 earthquakes recorded from the year 1999 to 2017 with maximum magnitude 2.2 and minimum magnitude 4.6, minimum depth as 1.2, and maximum as 35. Declustering is done by using the declustering function of ZMAP software which evaluated total four clusters in the zone with a total of 8 events as aftershocks, foreshocks or dependent events out of total 25 events.

For Zone North (a) category, the maximum recorded earthquake is of magnitude 3.8 (2016), whereas the minimum recorded earthquake is of magnitude 3.0 (1999). The last earthquake for this zoning category is recorded in 2016. Similarly, for Zone North (b) category, the maximum recorded earthquake is of magnitude 4.5 (2013), whereas minimum recorded earthquake is of magnitude 4.0 (2013). The last earthquake for this zoning category is recorded in 2016. The estimated model parameters (scale, shape) are listed in Table 5.

iv. *Zone East*

Zone East has 59 earthquakes recorded from the year 1995 to 20017 with maximum magnitude 2.8 and minimum magnitude 6.1, minimum depth as 0 and maximum as 82.9. Declustering is done by using declustering function of ZMAP software which evaluated total ten clusters in the zone with a total of 24 events as aftershocks, foreshocks, or dependent events out of total 59 events.

For Zone East (a) category, the maximum recorded earthquake is of magnitude 3.9 (2002), whereas minimum recorded earthquake is of magnitude 3.1 (2003). The last earthquake for this zoning category is recorded in 2016.

Similarly, for Zone East (b) category, the maximum recorded earthquake is of magnitude 6.1 (1997), whereas minimum recorded earthquake is of magnitude 4.0 (2016). The last earthquake for this zoning category is recorded in 2017. The estimated model parameters (scale, shape) are listed in Table 5.

IV. Results & Discussion

The stochastic methodology is applied to the earthquake inter-event recurrence intervals for earthquakes recorded in the past 100 years by classifying the whole region into four zones based on the clusters of seismogenic faults and historical seismicity. Similar studies have been done for other regions in India and around the world with many promising results in terms of conditional probabilities for assessing future hazard scenarios. The generalized exponential behavior, memory-less-ness, best fitting in terms of data, and promising results in other similar studies became reasons for the use of Weibull probability distribution as a modeling function for the earthquake IRIs in this study. Zone-wise conditional probability for different groups of earthquake magnitudes are calculated using respective model parameters. The results cover all possible combinations of elapsed time (t) and remaining time (τ) with an incremental value of 3 years. The following results are observed in this study:

1. The mean Weibull IRI (τ_{mean}) for the next event in for category (a) of magnitudes (3<= Mw < 4) came out to be 1.68 years whereas for category (b) of magnitudes (4<= Mw <= 6) it came out to be 0.98 years.
2. The average remaining time for category (b) earthquakes is found to be less than that of category (a) earthquakes.
3. The estimated elapsed time (t) since the last earthquake as per catalog is added to the Weibull occurrence year as estimated from the equation for the maximum suggested by Sergio G. Ferraes (2003), and the results are presented in Table 11.
4. Results show that the probability of occurrence of 4 to 5 magnitude earthquakes is higher for zone South in 2022, zone West, and North in 2021 and zone East in 2022.
5. Similarly, the probability of occurrence of 3 to 5 magnitude earthquakes is higher for all the zones in 2022.
6. The average IRI with maximum probability is found to be 3.25 years for earthquakes ranging from magnitude 3 to 6.
7. For category (a) magnitudes in all the zones, the average IRI with maximum probability is found to 4.17 years
8. For category (b) magnitudes in all the zones, it is found to be 1.59 years.
9. The standard deviation category (a) earthquakes IRI is found to be maximum as 5.08, whereas it is found to be least for category (b) earthquakes IRI as 0.83.
10. It is observed the probability of recurrence for category (a) earthquakes is higher as compared to that of category (b) earthquakes with exception in Zone North, where the probability of recurrence of category (b) earthquakesis found to be higher than category (a) earthquakes.

11. The log-likelihood is found to be least for zone North (a) & (b) categories, justifying the data pertaining to this zone to be the best-fit for the Weibull distribution model.

V. Conclusions

The following conclusions are drawn from this study:

1. For all zones, category (a) magnitude have a longer time duration between next earthquakes while category (b) magnitudes have a shorter duration for the earthquake to happen.
2. Years 2021 to 2023 are critical for the entire region as significant seismological activity is predicted. This time must be suitably utilized at least for projects under construction to assure sufficient detailing measures are undertaken.
3. As for existing structures that are of critical importance, their state of strength must be reassessed in case of a seismic event.
4. The results published in this study are going to be instrumental in future site-specific hazard studies and for the development of site-specific hazard curves for various regions across the state of Madhya Pradesh.
5. It is also recommended to use results of this study to perform PSHA as a non-Poissonian model and compare results with the ones obtained by PSHA done with a Poissonian recurrence model for the study region.

Acknowledgment

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Table 6: Conditional Probabilities using Weibull Method for Zone South (a) & (b) categories

Conditional Probabilities using Weibull Method for ZONE South (a) category											
	Elapsed Time										
Remaining Time (t)	0	3	6	9	12	15	18	21	24	27	30
3	0.871	0.841	0.829	0.821	0.816	0.811	0.807	0.803	0.8	0.797	0.795
6	0.98	0.973	0.97	0.967	0.965	0.963	0.962	0.961	0.96	0.958	0.958
9	0.997	0.995	0.994	0.994	0.993	0.993	0.992	0.992	0.992	0.991	0.991
12	0.999	0.999	0.999	0.999	0.999	0.999	0.998	0.998	0.998	0.998	0.998
15	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1	1
Conditional Probabilities using Weibull Method for ZONE South (b) category											
3	0.991	0.972	0.961	0.952	0.944	0.938	0.932	0.927	0.922	0.918	0.914
6	1	0.999	0.998	0.997	0.997	0.996	0.995	0.994	0.994	0.993	0.992
9	1	1	1	1	1	1	1	1	0.999	0.999	0.999
12	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1

Table 7: Conditional Probabilities using Weibull Method for ZONE West (a) & (b) categories

Conditional Probabilities using Weibull Method for ZONE West (a) category											
Remaining Time	Elapsed Time										
3	0.871	0.881	0.885	0.888	0.89	0.891	0.892	0.893	0.894	0.895	0.896
6	0.985	0.986	0.987	0.988	0.988	0.988	0.989	0.989	0.989	0.989	0.989
9	0.998	0.998	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
12	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1	1
Conditional Probabilities using Weibull Method for ZONE West (b) category											

3	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1	1

Table 8: Conditional Probabilities using Weibull Method for ZONE North (a) & (b) categories

Conditional Probabilities using Weibull Method for ZONE North (a) category											
Remaining Time (Years)	0	3	6	9	12	15	18	21	24	27	30
3	0.939	0.791	0.727	0.683	0.65	0.623	0.601	0.582	0.566	0.552	0.539
6	0.987	0.943	0.913	0.889	0.868	0.85	0.833	0.819	0.805	0.793	0.782
9	0.997	0.982	0.97	0.958	0.947	0.937	0.928	0.919	0.91	0.902	0.895
12	0.999	0.994	0.989	0.983	0.978	0.973	0.968	0.962	0.958	0.953	0.948
15	1	0.998	0.995	0.993	0.99	0.988	0.985	0.982	0.979	0.977	0.974
18	1	0.999	0.998	0.997	0.996	0.994	0.993	0.991	0.99	0.988	0.987
21	1	1	0.999	0.999	0.998	0.997	0.997	0.996	0.995	0.994	0.993
24	1	1	1	0.999	0.999	0.999	0.998	0.998	0.997	0.997	0.996
27	1	1	1	1	1	0.999	0.999	0.999	0.999	0.998	0.998
30	1	1	1	1	1	1	1	0.999	0.999	0.999	0.999
Conditional Probabilities using Weibull Method for ZONE North (b) category											
3	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986
6	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1	1

Table 9: Conditional Probabilities using Weibull Method for ZONE East (a) & (b) categories

Conditional Probabilities using Weibull Method for ZONE East (a) category											
Remaining Time (Year)	0	3	6	9	12	15	18	21	24	27	30
3	0.853	0.792	0.768	0.752	0.74	0.73	0.722	0.715	0.709	0.703	0.698
6	0.969	0.952	0.942	0.935	0.93	0.925	0.921	0.917	0.913	0.91	0.907

9	0.993	0.988	0.985	0.983	0.98	0.979	0.977	0.975	0.974	0.973	0.971
12	0.998	0.997	0.996	0.995	0.994	0.994	0.993	0.993	0.992	0.991	0.991
15	1	0.999	0.999	0.999	0.998	0.998	0.998	0.998	0.998	0.997	0.997
18	1	1	1	1	1	0.999	0.999	0.999	0.999	0.999	0.999
21	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1	1
Conditional Probabilities using Weibull Method for ZONE East (b) category											
3	0.816	0.617	0.549	0.506	0.475	0.452	0.432	0.416	0.402	0.39	0.38
6	0.929	0.827	0.777	0.741	0.712	0.689	0.669	0.651	0.636	0.622	0.61
9	0.968	0.915	0.883	0.858	0.837	0.818	0.802	0.787	0.774	0.762	0.751
12	0.984	0.955	0.936	0.919	0.905	0.891	0.879	0.868	0.858	0.848	0.839
15	0.992	0.975	0.964	0.953	0.943	0.934	0.925	0.917	0.909	0.902	0.895
18	0.995	0.986	0.979	0.972	0.965	0.959	0.953	0.947	0.941	0.936	0.931
21	0.997	0.992	0.987	0.983	0.978	0.974	0.97	0.966	0.962	0.958	0.954
24	0.999	0.995	0.992	0.989	0.986	0.984	0.981	0.978	0.975	0.972	0.969
27	0.999	0.997	0.995	0.993	0.991	0.989	0.987	0.985	0.983	0.981	0.979
30	0.999	0.998	0.997	0.996	0.994	0.993	0.992	0.99	0.989	0.987	0.986

Table 10: Zone-wise computation of year with the highest probability of occurrence of earthquakes of different categories of magnitudes (a & b) by Weibull occurrence time

ZONE	α (Scale)	β (Shape)	T	τ	$T+\tau$	Last Event Year	Probable Year for Next Event
South (a)	0.743	0.924	3	1.58	5	2017	2022
South (b)	1.955	0.809	5	0.86	6	2015	2021
West (a)	0.66	1.03	4	1.41	6	2016	2022
West (b)	2.209	1.482	3	0.18	4	2017	2021
North (a)	1.381	0.642	4	1.85	6	2016	2022
North (b)	2.711	1.436	4	0.14	5	2016	2021
East (a)	0.742	0.863	4	1.89	6	2016	2022
East (b)	0.832	0.647	3	2.74	6	2017	2023

Table 11: Table shows zone-wise statistical parameters (mean, standard deviation etc.) for Weibull occurrence time

	Mean	Standard Deviation	Minimum	Maximum	Range
All Zones	1.33	0.89	0.14	2.74	2.6
Category (a)	1.68	0.22	1.41	1.89	0.48
Category (b)	0.98	1.21	0.14	2.74	2.6

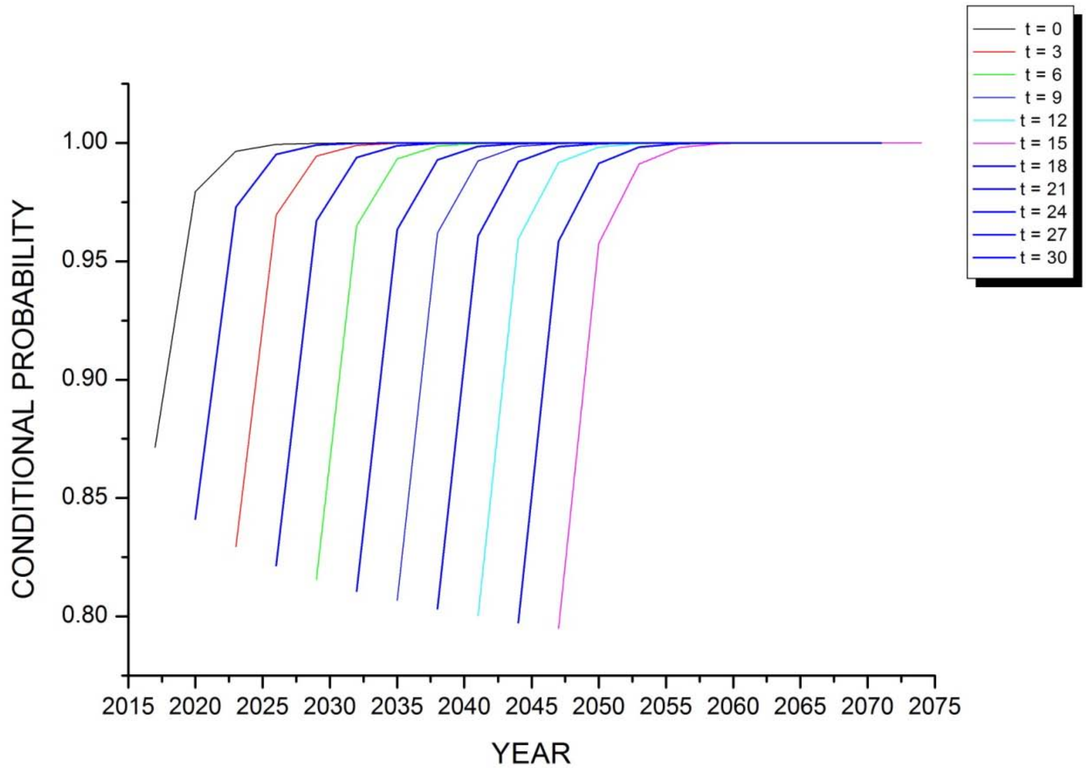

Figure 10: Conditional Probability Plot (Hazard Curve) for zone South (a) category. Elapsed time taken in an interval of 3 years up to 30 years

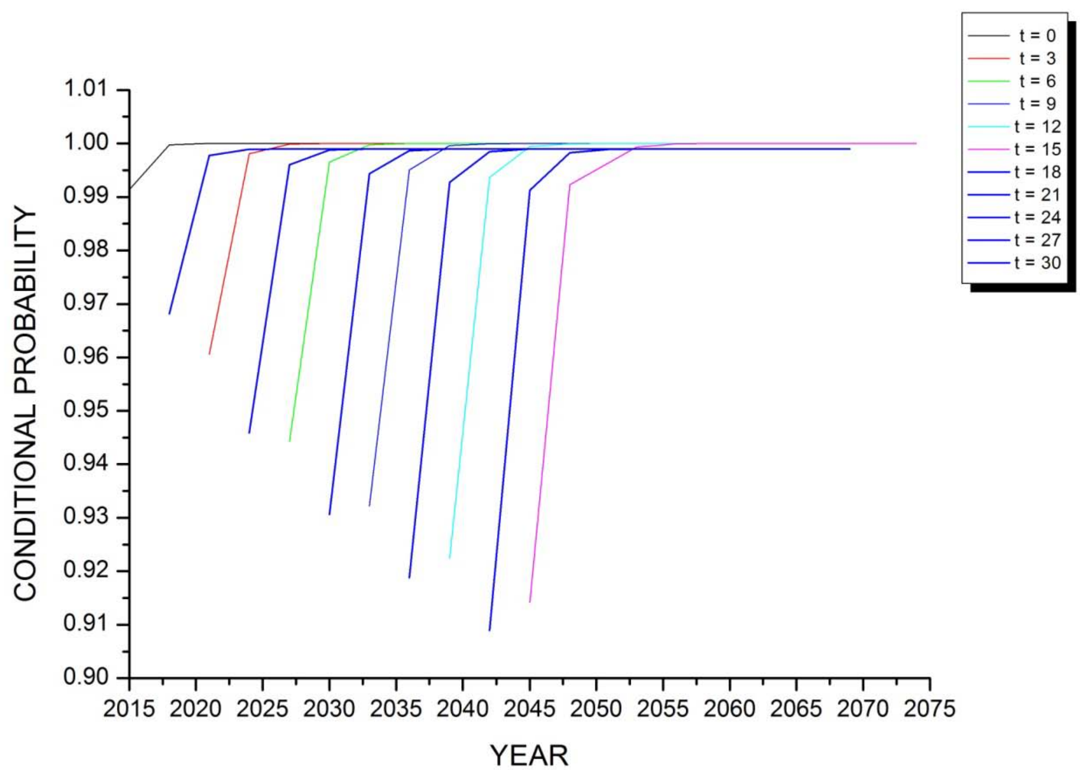

Figure 11: Conditional Probability Plot (Hazard Curve) for zone South (b) category. Elapsed time taken in an interval of 3 years up to 30 years

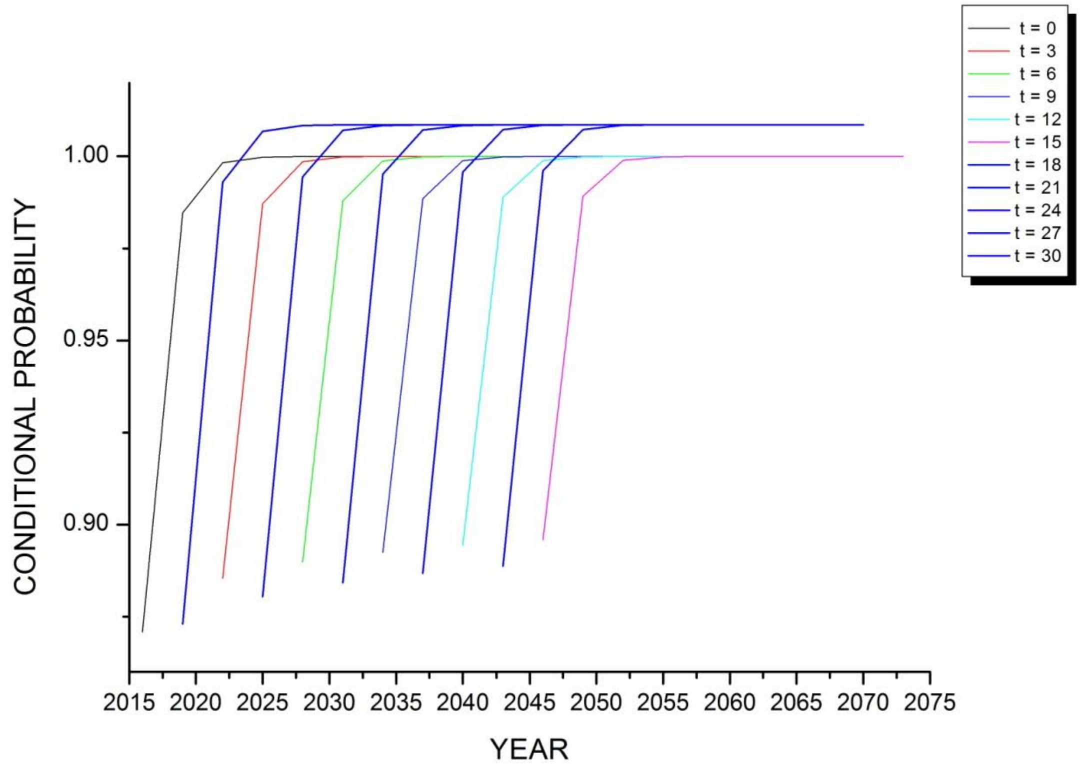

Figure 12: Conditional Probability Plot (Hazard Curve) for zone West (a) category. Elapsed time taken in an interval of 3 years up to 30 years

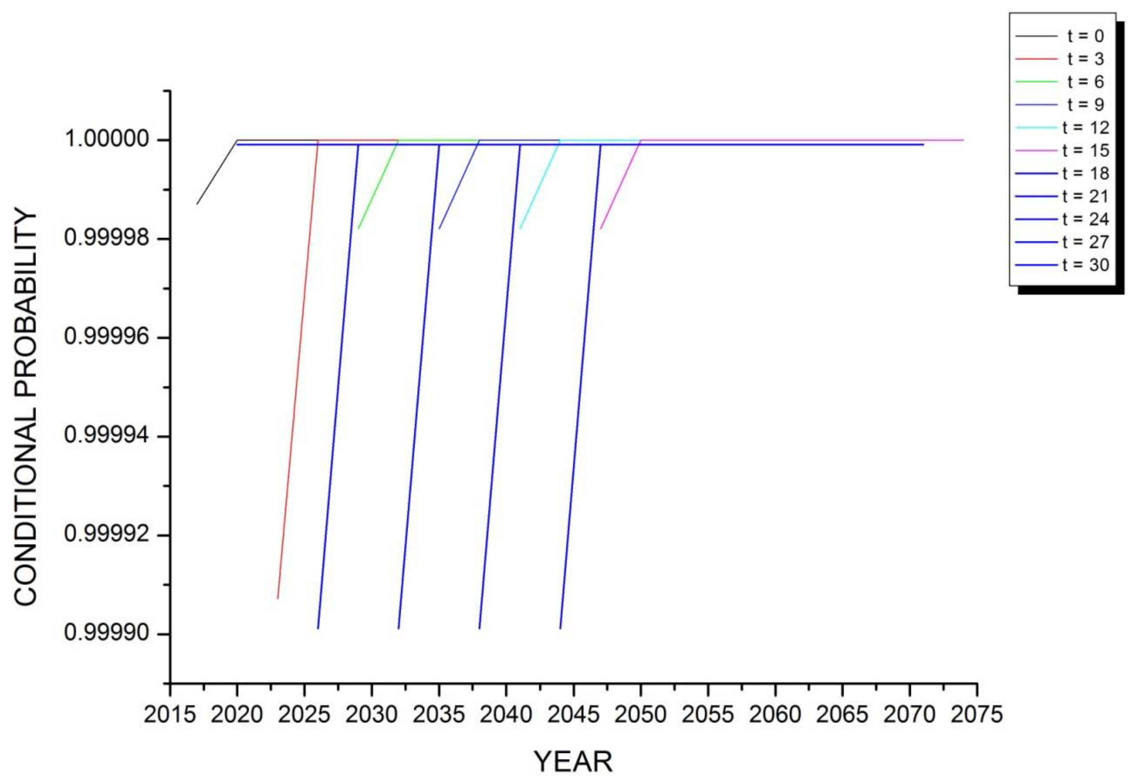

Figure 13: Conditional Probability Plot (Hazard Curve) for zone West (b) category. Elapsed time taken in an interval of 3 years up to 30 years

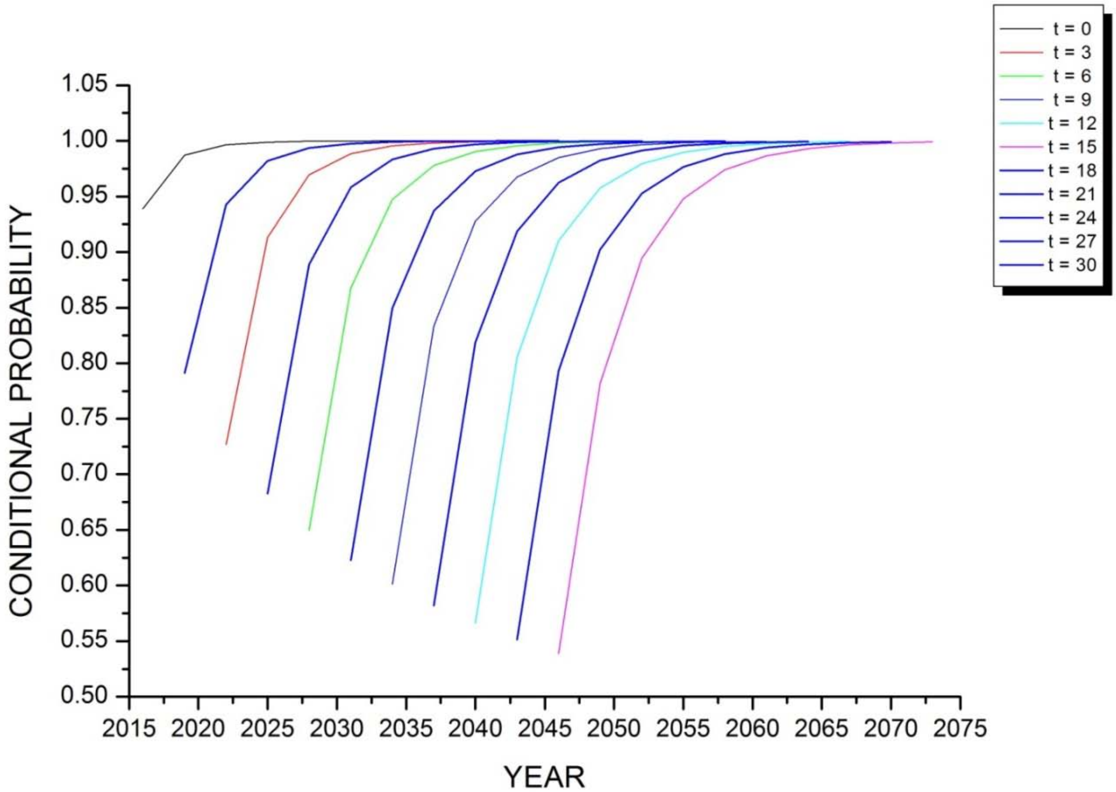

Figure 14: Conditional Probability Plot (Hazard Curve) for zone North (a) category. Elapsed time taken in an interval of 3 years up to 30 years

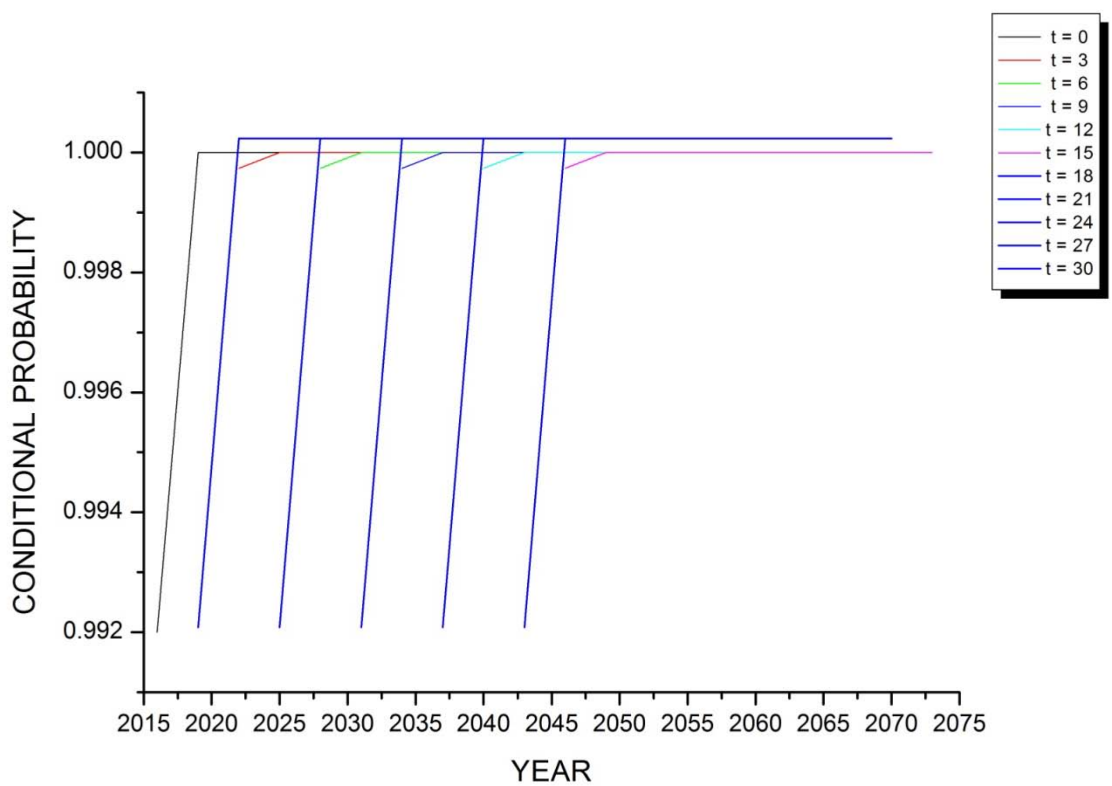

Figure 15: Conditional Probability Plot (Hazard Curve) for zone North (b) category. Elapsed time taken in an interval of 3 years up to 30 years

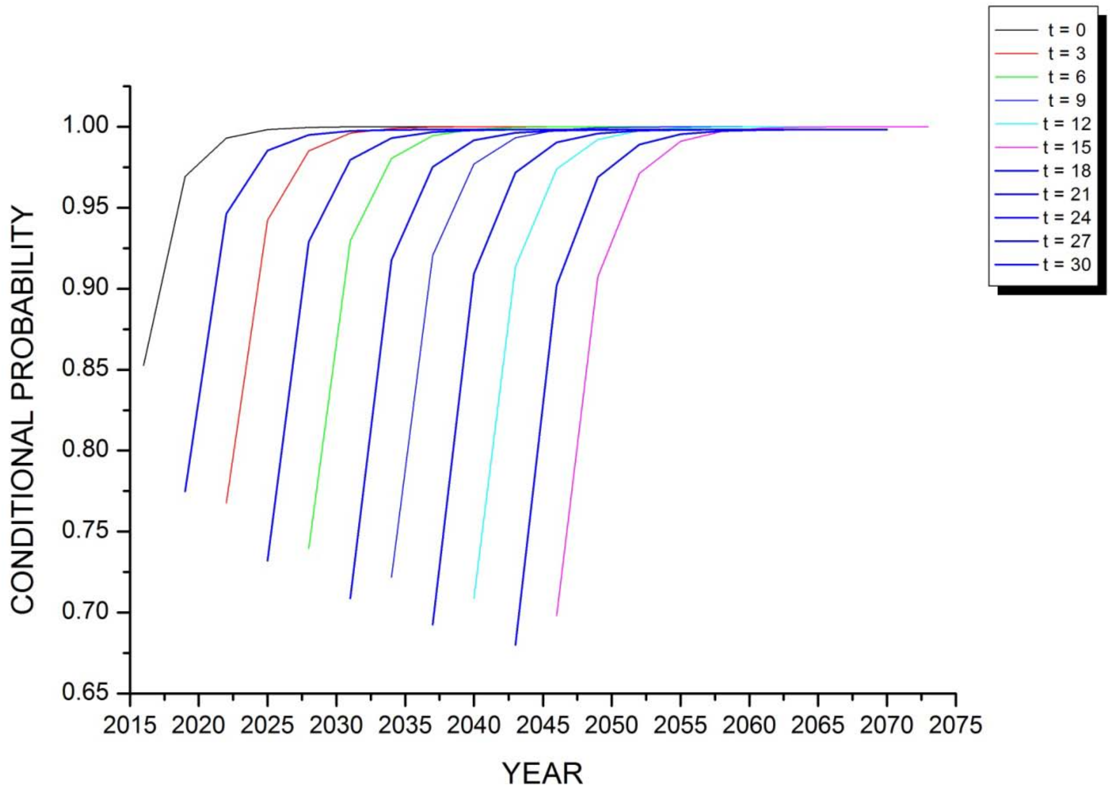

Figure 16: Conditional Probability Plot (Hazard Curve) for zone East (a) category. Elapsed time taken in an interval of 3 years up to 30 years

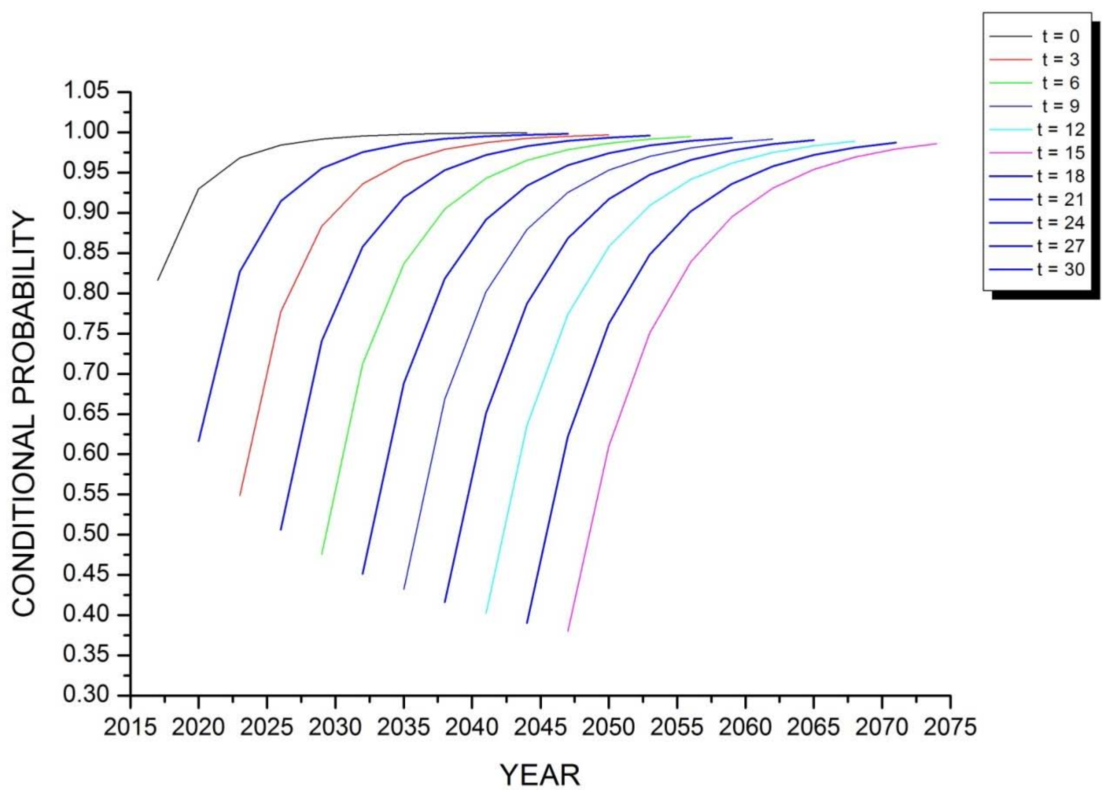

Figure 17: Conditional Probability Plot (Hazard Curve) for zone East (b) category. Elapsed time taken in an interval of 3 years up to 30 years

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Fellows get secure and fast GJ work emails with unlimited storage of emails that they may use them as their primary email. For example, john [AT] globaljournals [DOT] org.

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All members get access to 5 selected scientific museums and observatories across the globe. All researches published with Global Journals will be kept under deep archival facilities across regions for future protections and disaster recovery. They get 10 GB free secure cloud access for storing research files.

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ASSOCIATE OF ENGINEERING RESEARCH COUNCIL

ASSOCIATE OF ENGINEERING RESEARCH COUNCIL is the membership of Global Journals awarded to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

The primary objective is to recognize the leaders in research and scientific fields of the current era with a global perspective and to create a channel between them and other researchers for better exposure and knowledge sharing. Members are most eminent scientists, engineers, and technologists from all across the world. Associate membership can later be promoted to Fellow Membership. Associates are elected for life through a peer review process on the basis of excellence in the respective domain. There is no limit on the number of new nominations made in any year. Each year, the Open Association of Research Society elect up to 12 new Associate Members.

Benefit

To the Institution

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Certificate, LoR and Laser-Momento

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All the Associate members of AERC get a badge of "Leading Member of Global Journals" on the Research Community that distinguishes them from others. Additionally, the profile is also partially maintained by our team for better visibility and citation. All associates get a dedicated page on the website with their biography.

Career | Credibility | Reputation

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Associates receive discounts on the future publications with Global Journals up to 60%. Through our recommendation programs, members also receive discounts on publications made with OARS affiliated organizations.

Career | Financial

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Exclusive | Financial

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Associate	Fellow	Research Group	Basic
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Certificate, LoR and Momento 2 discounted publishing/year **Gradation** of Research 10 research contacts/day 1 **GB** Cloud Storage **GJ** Community Access	**Certificate,** LoR and Momento **Unlimited** discounted publishing/year **Gradation** of Research **Unlimited** research contacts/day 5 **GB** Cloud Storage **Online Presense** Assistance **GJ** Community Access	**Certificates,** LoRs and Momentos **Unlimited** free publishing/year **Gradation** of Research **Unlimited** research contacts/day **Unlimited** Cloud Storage **Online Presense** Assistance **GJ** Community Access	**GJ** Community Access

Preferred Author Guidelines

We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from https://globaljournals.org/Template.zip

Authors should submit their complete paper/article, including text illustrations, graphics, conclusions, artwork, and tables. Authors who are not able to submit manuscript using the form above can email the manuscript department at submit@globaljournals.org or get in touch with chiefeditor@globaljournals.org if they wish to send the abstract before submission.

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Authors must ensure the information provided during the submission of a paper is authentic. Please go through the following checklist before submitting:

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2. Authors must accept the privacy policy, terms, and conditions of Global Journals.
3. Ensure corresponding author's email address and postal address are accurate and reachable.
4. Manuscript to be submitted must include keywords, an abstract, a paper title, co-author(s') names and details (email address, name, phone number, and institution), figures and illustrations in vector format including appropriate captions, tables, including titles and footnotes, a conclusion, results, acknowledgments and references.
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6. Proper permissions must be acquired for the use of any copyrighted material.
7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

Declaration of Conflicts of Interest

It is required for authors to declare all financial, institutional, and personal relationships with other individuals and organizations that could influence (bias) their research.

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Plagiarism is not acceptable in Global Journals submissions at all.

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- Findings
- Writings
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- Illustrations
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- Printed material
- Graphic representations
- Computer programs
- Electronic material
- Any other original work

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2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

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The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

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Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

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- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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