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Estimation of Location (μ) and Scale (λ) for Two-Parameter Half Logistic Pareto Distribution (HLPD) by Least Square Regression Method

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Abstract: ***In this paper, we propose the estimation of Location (μ) and Scale (λ) parameters using two step least square estimation method. We also computed Average Estimate (AE), Variance (VAR), Standard Deviation (STD), Mean Absolute Deviation (MAD), Mean Square Error (MSE), Simulated Error (SE) and Relative Absolute Bias (RAB) for both the parameters under complete sample based on 1000 simulations to assess the performance of the estimators. In this paper, finally we shows that the best performance of Least Square Regression Estimation Method.***
Keywords: Two parameter HLP distribution, median ranks method (Benard's approximation), Least Square method, Montecarlo Simulation.

I. INTRODUCTION

Generally in many of the sciences, we face some type of situations of non monotonic failure rates for supervise the reliability analysis of the data under carefully scrutinize. In order to model such data, Aarset, M. V. (1987). Swain, J., Venkataraman, S. & Wilson, J. R. (1988) proposed Least squares estimatimators and Weighted Least squares estimators of a Beta distribution. For an excellent review for the two distributions the readers are referred to Johnson, Kotz and Balakrishnan (1995) .Madholkaretal (1995) present an extension of the Weibull family that not only contains unimodel distribution with bath tub failure rates but also allows for a broader class of monotone hazards rates and is computationally convenient for censored data. They named their extended version as “Exponentiated Weibull Family”. On similar lines Gupta and Kundu (2001b) proposed a new model called generalized exponential distribution. A generalized (type – II) version of logistic distribution was considered and some interesting properties of the distribution were derived by Balakrishnan and Hassain (2007). Ramakrishna (2008) studied the Type I generalized half logistic distribution scale (σ) and shape (θ) parameters estimation using the least square method in two step estimation methods. Torabi and Bagheri (2010) consider different parameter estimation methods in extended generalized half logistic distribution for censored as well as complete sample. Rama Mohan, ch. and Anjaneyulu, G. V. S. R. (2011) studied how the least square method be good for estimating the parameters to Two Parameter Weibull Distribution from an optimally constructed grouped sample. Kantam et al (2013) discussed the estimation and testing in Type I generalized half logistic distribution. Rama Mohan, CH and Anjaneyulu, GVSR (2014) was studied estimation of scale and shape parameters of type I generalized half logistic distribution using Median Ranks Method. In section - 1.2, we discussed the procedure to estimate of Scale (β) and Shape (δ) parameters of HLPD by using the Least Square Regression Method. Hence it term these estimators as Least Squares method.

In section – 1.3 we presented observations and conclusions are based on simulation results with numerical example.

If Let $X_1, X_2,..., X_n$ be a random sample of size n from HLPD (β,δ) is a probability model, its probability density function (pdf), cumulative distribution function (cdf) and Hazard Function (HF) are given by

$$f(x) = f(x: \beta, \delta) = \frac{2\delta\beta^{\delta}x^{\delta-1}}{\left[x^{\delta}+\beta^{\delta}\right]^2}, \quad x \geq 0 \qquad \text{... (1.1.1)}$$

$$F(x) = F(x: \beta,\delta) = \frac{x^{\delta}-\beta^{\delta}}{x^{\delta}+\beta^{\delta}}, \quad x \geq 0 \qquad \text{... (1.1.2)}$$

$$H(x) = H(x; \beta,\delta) = \frac{\delta x^{\delta-1}}{x^{\delta}+\beta^{\delta}} \qquad \text{...(1.1.3)}$$

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II. ESTIMATION OF SCALE (β) AND SHAPE (δ) PARAMETERS OF TWO PARAMETER

A. HLPD using Least Square Regression Method

Let $x_1 < x_2 < x_3 \ldots\ldots\ldots < x_N$ be an ordered sample of size 'N' from Half Logistic Pareto Distribution with the parameters Scale (β) and Shape (δ). Then the cdf is
given as in equation (1.1.2), can be written as

$$1+F(x)=\frac{2x^{\delta}}{x^{\delta}+\beta^{\delta}} \quad \ldots (1.2.1)$$

and

$$1-F(x)=\frac{2\beta^{\delta}}{x^{\delta}+\beta^{\delta}} \quad \ldots (1.2.2)$$

$$\frac{1-F(x)}{1+F(x)}=\frac{\beta^{\delta}}{x^{\delta}} \quad \ldots (1.2.3)$$

Taking Logarithm on both side of equation (1.2.3), we get

$$\log\left(\frac{1-F(x)}{1+F(x)}\right)=\delta\log\beta-\delta\log x \quad \ldots (1.2.4)$$

From the least square parameter estimation method (also known as regression analysis), we have,

$$A=\delta\log\beta, \tilde{\beta}=\exp\left(\frac{\tilde{A}}{\tilde{\delta}}\right), B=-\delta, \tilde{B}=-\tilde{\delta}$$

and ... (1.2.5)

$$U=\log\left(\frac{1-F(x)}{1+F(x)}\right), V=\log x$$

$$\tilde{A}=\frac{\left(\sum_{i=1}^{n}v_i^2\right)\left(\sum_{i=1}^{n}u_i\right)-\left(\sum_{i=1}^{n}v_i\right)\left(\sum_{i=1}^{n}v_iu_i\right)}{\left(n\sum_{i=1}^{n}v_i^2\right)-\left(\sum_{i=1}^{n}v_i\right)^2} \quad \ldots (1.2.6)$$

$$\tilde{B}=\frac{n\left(\sum_{i=1}^{n}v_iu_i\right)-\left(\sum_{i=1}^{n}v_i\right)\left(\sum_{i=1}^{n}u_i\right)}{\left(n\sum_{i=1}^{n}v_i^2\right)-\left(\sum_{i=1}^{n}v_i\right)^2} \quad \ldots (1.2.7)$$

B. Simulation Study

In order to obtain the median ranks method estimators of Scale (β) and Shape (δ) are obtained and study the properties of their estimates through the Average Estimate (AE), Variance (VAR), Mean Square Error (MSE) and Relative Absolute Bias (RAB) and Relative Error under in order to obtain the Median Ranks Method estimators of Scale (β) and Shape (δ)and study the properties complete sample are given respectively by forgiven values of n, β and δ . If $\hat{\xi}_{lm}$ is Median Ranks Method estimate of $\hat{\xi}_m$, m=1, 2 where $\xi_m$is a general notation that can be replaced by $\xi_1 = \beta$, $\xi_2 = \delta$ based on sample l, (l=1,2,…,r) then The Average Estimate (AE), Variance (VAR), Mean Square Error (MSE) and Relative Absolute Bias (RAB) and Relative Error (RE) are given respectively by

Average Estimate $(\hat{\psi}_m) = \frac{\sum_{i=1}^{r} \hat{\psi}_{lm}}{r}$

Variance $(\hat{\psi}_m) = \frac{\sum_{i=1}^{r} (\hat{\psi}_{lm} - \overline{\hat{\psi}_{lm}})^2}{r}$

Mean Absolute Deviation $= \frac{\sum_{i=1}^{r} Med(|\hat{\psi}_{lm} - \overline{\hat{\psi}_{lm}}|)}{r}$

Mean Square Error $(\hat{\psi}_m) = \frac{\sum_{i=1}^{r} (\hat{\psi}_{lm} - \psi_m)^2}{r}$

Relative Absolute Bias $(\hat{\psi}_m) = \frac{\sum_{i=1}^{r} |(\hat{\psi}_{lm} - \psi_m)|}{r\psi_m}$

Relative Error$(\hat{\psi}_m) = \frac{1}{r}\left(\frac{\sum_{i=1}^{r} MSE\sqrt{(\hat{\psi}_{lm})}}{\psi_m}\right)^2$

III. OBSERVATIONS FROM SIMULATION RESULTS AND CONCLUSIONS.

1) The Average Estimate (AE), Variance (VAR), Standard deviation (STD), Mean Square Error (MSE) and Relative Absolute Bias (RAB) are independent of true values of the parameters of of scale (β) and Shape (δ) .
2) Average Estimate (AE) of scale parameter ($\tilde{\beta}$) were increasing when sample size (N) is increasing.
3) Variance (VAR) of scale parameter ($\tilde{\beta}$) and shape parameter ($\tilde{\delta}$) by Least Square Method were decreasing when sample size (N) is increasing.
4) Standard Deviation (STD) of scale parameter ($\tilde{\beta}$) and shape parameter ($\tilde{\delta}$) by Least Square Method were decreasing when sample size (N) is increasing.
5) Mean Absolute Deviation (MAD) of scale ($\tilde{\beta}$) and shape parameter ($\tilde{\delta}$) by Least Squares Method were decreasing when sample size (N) is increasing.
6) Mean Square Error (MSE) of scale parameter ($\tilde{\beta}$) and shape parameter ($\tilde{\delta}$) by Least Square Method were decreasing when sample size (N) is increasing.
7) Simulated Error(SE) in Average Estimate (AE), Variance (VAR), Standard Deviation (STD), Mean Square Error (MSE) and Relative Absolute Bias (RAB) of scale parameter ($\tilde{\beta}$) and shape parameter ($\tilde{\delta}$) by Least Square Method were decreasing when sample size (N) is increasing.
8) Relative Absolute Bias (RAB) of scale parameter ($\tilde{\beta}$)) and shape parameter ($\tilde{\delta}$) by Least Square Method were decreasing when sample size (N) is increasing.
9) Scale parameter ($\tilde{\beta}$) by Least Square Method is having less variance(VAR).
10) Scale parameter ($\tilde{\beta}$) and shape parameter ($\tilde{\delta}$) by Least Square Method having less Standard deviation.

A. Numerical Example

We generate a random sample of size 10 with scale (β) = 0.5 and shape (δ) = 3 of HLPD and the order sample is given by 0.37, 2.46, 2.89, 3.28, 3.59, 3.98, 4.56, 5.47, 8.25, 9.23. Solving equations (3.3.6) and (3.3.7) for this simple data and the resulting estimators of the scale (β) and shape (δ) of HLPD as follows:

Scale Parameter Medians Rank method $\hat{\delta}$ = 0.25672

Shape Parameter Medians Rank method $\hat{\beta}$ = 2.3.4567

The above example it may demonstrated that Least Square Regression Method of estimation gives best result.

1) *Simulated Data:* The Average Estimate(AE), Variance(VAR), Mean Square Error(MSE) and Relative Absolute Bias(RAB), Relative Error(RE) of Least Square method estimators of scale and shape parameters under complete sample of 1000 simulations. Population parameters Scale=0.5 and Shape = 3 in Table-1.1.

Table 1.1

Sample size	Para meters	Average Estimation	Variance	MAD	MSE	RAB	RE
50		0.145892	0.00427	0.08371	0.12539	0.35411	0.17705
	$\hat{\delta}$	1.271366	0.30723	0.690501	2.98818	0.28811	0.86432
100	$\hat{\beta}$	0.144203	0.00306	0.079635	0.12659	0.71159	0.1779
	$\hat{\delta}$	1.479711	0.60649	0.921707	2.31128	0.50676	0.76014
150		0.190193	0.01079	0.128935	0.09598	0.1549	0.1549
	$\hat{\delta}$	0.980956	0.29872	0.721972	4.07654	1.00952	1.00952
200		0.241152	0.02022	0.186359	0.067	1.03539	0.12942
	$\hat{\delta}$	1.44426	0.37095	0.818894	2.42033	1.03716	0.77787
250		0.252815	0.0163	0.168259	0.0611	1.23593	0.12359
	$\hat{\delta}$	1.509687	0.36595	0.765655	2.22103	1.24193	0.74516
300		0.247445	0.0169	0.178204	0.06378	1.51533	0.12628
	$\hat{\delta}$	2.529393	0.32663	0.757875	0.22147	0.47061	0.2353
350		0.258414	0.01538	0.155983	0.05836	1.6911	0.12079
	$\hat{\delta}$	2.508062	0.26704	0.646877	0.242	0.57393	0.24597
400		0.317106	0.02112	0.17595	0.03345	1.46315	0.09145
	$\hat{\delta}$	2.486837	0.23908	0.600144	0.26334	0.68422	0.25658
450		0.295101	0.02371	0.191071	0.04198	1.84409	0.10245
	$\hat{\delta}$	2.446952	0.21625	0.626062	0.30586	0.82957	0.27652
500		0.301234	0.02071	0.184539	0.03951	1.98766	0.09938
	$\hat{\delta}$	2.757186	0.02158	0.194464	0.05896	0.40469	0.12141

2) *Simulated Data:* The Average Estimate(AE), Variance(VAR), Mean Square Error(MSE) and Relative Absolute Bias(RAB), Relative Error(RE) of Least Square method estimators of scale and shape parameters under complete sample of 1000 simulations. Population parameters Scale=1.5 and Shape =2 in Table-1.2.

Table 1.2

n	Para meters	Average Estimation	Variance	MAD	MSE	RAB	RE
50		0.8236966	0.452514	0.21839	0.457386	0.323697	0.004509
	$\hat{\delta}$	1.217976	0.571732	0.67458	0.611562	0.195506	0.00391
100	$\hat{\beta}$	0.9431828	0.231694	0.2841	0.310045	0.886366	0.003712
	$\hat{\delta}$	1.257106	0.556472	0.5357	0.551892	0.371447	0.003714
150		1.0495562	0.220089	0.3744	0.2029	0.274778	0.003003
	$\hat{\delta}$	1.428822	0.436436	0.72573	0.326244	0.428383	0.003138
200		0.957831	0.21332	0.56579	0.293947	0.831324	0.003614
	$\hat{\delta}$	1.372304	0.412985	0.60652	0.394002	0.627696	0.002977
250		1.0695903	0.20432	0.54866	0.149178	0.068822	0.002575
	$\hat{\delta}$	1.538986	0.352885	0.75995	0.212534	0.576267	0.002856
300		1.1137644	0.19558	0.59524	0.185252	0.417542	0.002869
	$\hat{\delta}$	1.40451	0.315787	0.68634	0.354608	0.893235	0.002305
350		1.2247195	0.190634	0.5875	0.075779	0.073037	0.001835
	$\hat{\delta}$	1.659454	0.300334	0.92333	0.115972	0.595956	0.001703
400		1.2355012	0.086303	0.5883	0.06996	0.88401	0.001763
	$\hat{\delta}$	1.722293	0.272567	0.80607	0.077121	0.471498	0.001389
450		1.2588825	0.051789	0.57599	0.058138	0.829943	0.001607
	$\hat{\delta}$	1.764251	0.256586	0.9512	0.055578	0.624841	0.001179
500		1.5962211	0.046737	0.84595	0.009259	0.962211	0.000641
	$\hat{\delta}$	1.962912	0.200593	1.0077	0.001376	0.092719	0.000185

The Average Estimate(AE), Variance(VAR), Mean Square Error(MSE) and Relative Absolute Bias(RAB), Relative Error(RE) of Least Square method estimators of scale and shape parameters under complete sample of 1000 simulations. Population parameters Scale=2.5 and Shape = 2 in Table-1.3.

Table-1.3

Sample size	Para meters	AE	VAR	MAD	MSE	RAB	RE
50		1.7336	0.11489	0.45829	0.58736	0.15328	0.00307
	$\hat{\delta}$	0.85451	0.13969	0.51295	1.31215	0.28637	0.00573
100	$\hat{\beta}$	1.88912	0.05577	0.32686	0.37318	0.24435	0.00244
	$\hat{\delta}$	0.904	0.14156	0.48079	1.20121	0.548	0.00548
150		2.17969	0.01053	0.1227	0.1026	0.19219	0.00128
	$\hat{\delta}$	1.04962	0.24076	0.65183	0.90323	0.71279	0.00475
200		2.22343	0.01668	0.16089	0.07649	0.22125	0.00111
	$\hat{\delta}$	1.01199	0.10563	0.42288	0.97617	0.98801	0.00494
250		2.23374	0.01589	0.15934	0.0709	0.26626	0.00107
	$\hat{\delta}$	0.95239	0.09707	0.42114	1.09748	1.30951	0.00524
300		2.35243	0.00426	0.08334	0.02178	0.17708	0.00059
	$\hat{\delta}$	1.33484	0.0218	0.17223	0.44244	0.99774	0.00333
350		2.37316	0.00513	0.09246	0.01609	0.17758	0.00051
	$\hat{\delta}$	1.68042	0.00419	0.08195	0.10213	0.55926	0.0016
400		2.39503	0.0069	0.10189	0.01102	0.16795	0.00042
	$\hat{\delta}$	1.82357	0.01172	0.13821	0.03113	0.35286	0.00088
450		2.42725	0.00483	0.08326	0.00529	0.13095	0.00029
	$\hat{\delta}$	1.82404	0.01465	0.16056	0.03096	0.39591	0.00088
500		2.47469	0.0002	0.01767	0.00064	0.05062	0.0001
	$\hat{\delta}$	2.0948	0.01335	0.1449	0.00899	0.23699	0.00047

The Average Estimate(AE), Variance(VAR), Mean Square Error(MSE) and Relative Absolute Bias(RAB), Relative Error(RE) of Least Square method estimators of scale and shape parameters under complete sample of 1000 simulations. Population parameters Scale=3.5 and Shape = 3 in Table-1.4.

Table 1.4

Sample size	Para meters	AE	VAR	MAD	MSE	RAB	RE
50		2.76281	0.14946	0.52337	0.069069	0.05256	0.00105
	$\hat{\delta}$	1.83449	0.15445	0.47002	0.027394	0.04138	0.00083
100	$\hat{\beta}$	2.85768	0.0431	0.24859	0.127936	0.14307	0.00143
	$\hat{\delta}$	1.84271	0.14594	0.47134	0.024742	0.07865	0.00079
150		3.1891	0.01096	0.1087	0.474859	0.41346	0.00276
	$\hat{\delta}$	2.12153	0.22421	0.59686	0.014770	0.09115	0.00061
200		2.80416	0.1675	0.50875	0.092513	0.24333	0.00122
	$\hat{\delta}$	2.00114	0.10585	0.3828	0.000001	0.00114	0.00001
250		3.24995	0.01443	0.14298	0.562417	0.74994	0.003
	$\hat{\delta}$	1.97314	0.09224	0.36713	0.000722	0.03358	0.00013
300		3.34328	0.00431	0.07446	0.711122	1.01194	0.00337
	$\hat{\delta}$	2.31846	0.02524	0.20054	0.101416	0.47769	0.00159
350		3.36409	0.00492	0.08878	0.746656	1.20973	0.00346
	$\hat{\delta}$	2.68707	0.00466	0.08804	0.472065	1.20237	0.00344
400		3.3905	0.00809	0.11715	0.792998	1.42481	0.00356
	$\hat{\delta}$	2.66799	0.00038	0.02627	0.446213	1.33598	0.00334
450		3.42326	0.005	0.08841	0.852409	1.66187	0.00369
	$\hat{\delta}$	2.81983	0.014	0.15231	0.672127	1.84463	0.00410
500		3.47603	0.0002	0.01827	0.952639	1.95206	0.0039
	$\hat{\delta}$	3.11576	0.01306	0.14073	1.244909	2.78939	0.00558

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Table 1.5

Sample size	Para meters	AE	VAR	MAD	MSE	RAB	RE
50		0.17192	0.00541	0.07389	0.10874	0.32975	0.0066
	$\hat{\delta}$	0.57075	0.06398	0.2779	0.27151	0.26053	0.00521
100	$\hat{\beta}$	0.14683	0.00278	0.0729	0.13393	0.73192	0.00732
	$\hat{\delta}$	0.50665	0.1012	0.33759	0.21322	0.46176	0.00462
150		0.23062	0.00525	0.07564	0.06695	0.77621	0.00517
	$\hat{\delta}$	0.65201	0.07125	0.31304	0.11426	0.50704	0.00338
200		0.25646	0.01843	0.17941	0.06429	1.01425	0.00507
	$\hat{\delta}$	0.76824	0.02982	0.23072	0.06586	0.51326	0.00257
250		0.25389	0.01744	0.15848	0.06363	1.26126	0.00505
	$\hat{\delta}$	0.7504	0.02946	0.2193	0.05908	0.60767	0.00243
300		0.23866	0.01512	0.17289	0.06667	1.5492	0.00516
	$\hat{\delta}$	0.80965	0.02005	0.17354	0.03564	0.56633	0.00189
350		0.30794	0.01079	0.13196	0.03606	1.32927	0.0038
	$\hat{\delta}$	0.81477	0.01983	0.19523	0.03211	0.62715	0.00179
400		0.39312	0.00816	0.11427	0.01176	0.86751	0.00217
	$\hat{\delta}$	0.85889	0.01916	0.16564	0.01684	0.51913	0.0013
450		0.42085	0.00564	0.10043	0.00575	0.68223	0.00152
	$\hat{\delta}$	0.82569	0.01336	0.14943	0.03397	0.82943	0.00184
500		0.47442	0.00022	0.0176	0.00059	0.24363	0.00049
	$\hat{\delta}$	0.96475	0.0014	0.04654	0.00111	0.16621	0.00033

The Average Estimate (AE), Variance(VAR), Mean Square Error(MSE) and Relative Absolute Bias(RAB), Relative Error(RE) of Least Square method estimators of scale and shape parameters under complete sample of 1000 simulations. Population parameters Scale=1.5 and Shape = 3 in Table-1.6.

Table 1.6

Sample size	Para meters	AE	VAR	MAD	MSE	RAB	RE
50		1.17531	0.00489	0.09012	0.10542	0.10823	0.00216
	$\hat{\delta}$	2.44372	0.09077	0.2976	0.30944	0.09271	0.00185
100	$\hat{\beta}$	1.14391	0.0027	0.05959	0.1268	0.23739	0.00237
	$\hat{\delta}$	2.49467	0.09937	0.42249	0.25536	0.16844	0.00168
150		1.24251	0.0056	0.09259	0.0663	0.25749	0.00172
	$\hat{\delta}$	2.63544	0.05812	0.29203	0.1329	0.18228	0.00122
200		1.25176	0.01729	0.1632	0.06162	0.33098	0.00165
	$\hat{\delta}$	2.72722	0.03004	0.23285	0.07441	0.18185	0.00091
250		1.23038	0.01657	0.1576	0.07269	0.44936	0.0018
	$\hat{\delta}$	2.75367	0.0288	0.22873	0.06068	0.20527	0.00082
300		1.2426	0.01811	0.17798	0.06626	0.5148	0.00172
	$\hat{\delta}$	2.82288	0.02015	0.19377	0.03137	0.17712	0.00059
350		1.30292	0.00996	0.12808	0.03884	0.45986	0.00131
	$\hat{\delta}$	2.81254	0.02507	0.21484	0.03514	0.2187	0.00062
400		1.40003	0.00788	0.11261	0.00999	0.26658	0.00067
	$\hat{\delta}$	2.86893	0.0168	0.16351	0.01718	0.17476	0.00044
450		1.42764	0.00489	0.08811	0.00524	0.21709	0.00048
	$\hat{\delta}$	2.82585	0.01385	0.15351	0.03033	0.26122	0.00058
500		1.47515	0.00021	0.01787	0.00062	0.08282	0.00017
	$\hat{\delta}$	2.96573	0.00141	0.04652	0.00117	0.05712	0.00011

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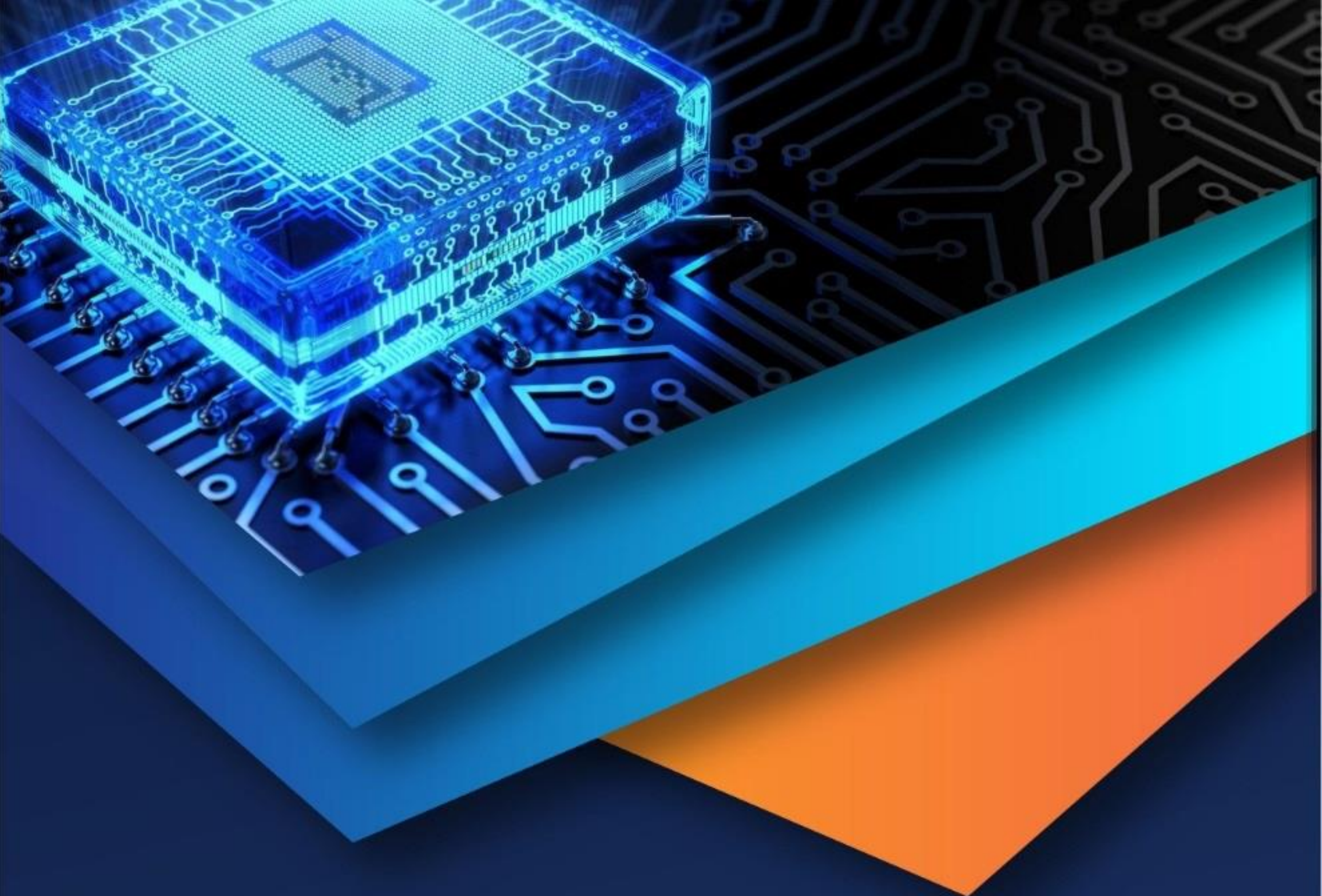

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