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An Analysis of Seasonal Trend Variation in Rainfall and Temperature Pattern in Ahmedabad Region of Gujarat, India

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Abstract: ***The annual maximum and minimum temperatures, as well as precipitation data in the Ahmedabad region of Gujarat State, were analyzed in this study using data obtained from the official NASA website. The objective was to identify the variations in maximum and minimum temperatures and rainfall from the year 1981 to 2022. Statistical methods, including linear regression, were employed to demonstrate the trends in maximum and minimum temperature changes and rainfall over time. As a result, the study suggests promoting preventive measures, such as providing accurate weather and climate data for planning, to mitigate these impacts, particularly for communities reliant on temperature-sensitive agriculture.***
Keywords: Climate changes, Linear regression, Trend analysis.

I. INTRODUCTION

One of the defining issues of the modern era is climate change. Long-term weather patterns have changed as a result of climate change on a local and global level. Global climate change is occurring at an alarming rate, and there is currently no indication that this trend will slow down (Ahrens, 2006). This change in climate is an indication of a significantly high fluctuation in mean condition of climate or its variability with continuous trend for decades or more (Vijayavenkata, Raman, Iniyan & Goic, 2011). The impacts of this change in climate is already experienced the world over such as melting of ice cap and even changes in weather patterns (IPCC, 2007). All these events have provided strong evidence of rapid change in climate of the world. As a result of this change in climate, there has been increase in global temperature resulting in warming of the earth. This warming which has occurred largely since the 1970s is due to increase in industrial activities all over the world. Also, in recent decades there has been a diminishing arctic sea ice; both in sizes and in depths. In the past 100 years, global sea levels have increased to about17cm. This magnitude of increase in the past decade is almost twice compared to the century before now (IPCC, 2007). Based on available evidence, it is now more certain than ever, that humans are changing Earth's climate due to several activities embarked upon by man in the search to satisfy its needs (Diagi, 2017). This change has resulted in the warming of the atmosphere and ocean, accompanied by sea-level rise, a strong decline in Arctic sea ice and other climate related changes. One of the most significant evidence available of man-induced changes in climate is the continual rise in carbon dioxide (CO2) as measured at the Mauna Loa Observatory in Hawaii, where the observation of CO2 has been going on since 1958. In December 2008, the concentration of CO2 in earth's atmosphere was about 386 parts per million (ppm), with a steady new increase rate of about 2 ppm per year. However, of recent the atmospheric concentration of CO2 is about 30% higher than what it was about 150 years ago before the industrialization period. In other words, the level of CO2 present in the atmosphere is more than they have been in the last 400 millennia. This situation has become many topics of debate both at national, regional and world level. Nearly a quarter of the emission of carbon dioxide that comes from man's activities is absorbed by land areas; another quarter is absorbed by the ocean. However, one way to understand these changes in climate is to carry out a study on global warming which is the main cause of these changes. Temperature is not a static phenomenon as has been observed over time. On a global scale, the surface temperature of the earth has increased by 0.74 ± 0.18oC during the last 100 years ending in 2005 (IPCC, 2007); although this figure has been discovered to vary from one place to another depending on how its manifest in a particular place. Numerous studies have shown that there has been a steady increase in temperature across Nigeria. Audu et al. (2004) observed that there is a general rise in mean minimum temperature of 3℃ per decade based on 40 years data from Nigeria. Bello (2010) observed temperature increases of about 0.2℃-0.3℃per decade at various locations in the rainforest of Nigeria. Adakayi (2009) also asserted that there is a general rise in annual minimum temperature in Katsina from 1971-2006.

Several other studies conducted on regional basis have also found a positive trend in temperature, even though the changes slightly vary from region to region (Karaburun et al., 2012; Karaburun et al., 2011; Abudaya, 2013; Ustaoglu, 2012). To be able to measure the degree of warming arising from these changes in climate, changes in global temperature has to be studied which is a fundamental factor according to Ikenna et al. (2017). Amadi et al. (2014) asserted that one of the most commonly used parameters that indicate climate change is temperature. Temperature is a climatic variable that informs us the degree of hotness or coldness of a place. Therefore, in order to ascertain the impact of climate change over Ebonyi, the study of changes in the degree of hotness or coldness of the state is necessary. Audu (2012) also pointed out that one of the climatic variables mostly affected by global warming, climate change and variability is temperature. Notable researches carried out to investigate changes in temperature include that of Mohiuddin et al., (2014) who understudied the pattern of change of temperature of Dhaka, in this study maximum temperature was observed to be having a decreasing trend. Also, Jain and Kumar (2012) on investigation of Indian cities discovered that most cities had rising trends although there were records of cities with falling trends in the maximum temperature. Other studies include Amadi et al. (2014); Ogolo and Adeyemi (2009) and Jackson et al. (2012). This study has become necessary bearing in mind the importance that temperature changes plays in almost every aspects of man's life ranging from energy supply, water supply, flood and drought, thermal comfort, work output and especially agriculture, through rainfall (Arora et al., 2005). Ebonyi State being an agricultural state is a very important state in Nigeria in terms of food production and since temperature variation plays a crucial role in crop productivity it is therefore necessary to undertake a study to ascertain its impact in the state especially because farming in this State is majorly based on rain-fed agriculture which can be impacted upon by these changes in temperature.

II. STUDY AREA

Ahmedabad is the largest city in the state of Gujarat located between latitude 23.02oN, longitude 72.35oE and latitude 23.03o N, longitude 72.58o E in western India at an elevation of 54.9 meters asl (180 ft.) on the banks of the River Sabarmati. It spans an area of 475 km2. The city is almost flat except for the small hills of Thaltej- Jodpur Tekra. The climate of Ahmedabad is extremely dry except for the monsoon months. The weather is hot and extremely dry during the month of March to June. The average summer maximum is 39˚C and average minimum is 24˚C. Average maximum temperature from November to February is 30˚ C and average minimum is 15˚C Highest average rainfall was during the month of July followed by August, September, June and October.

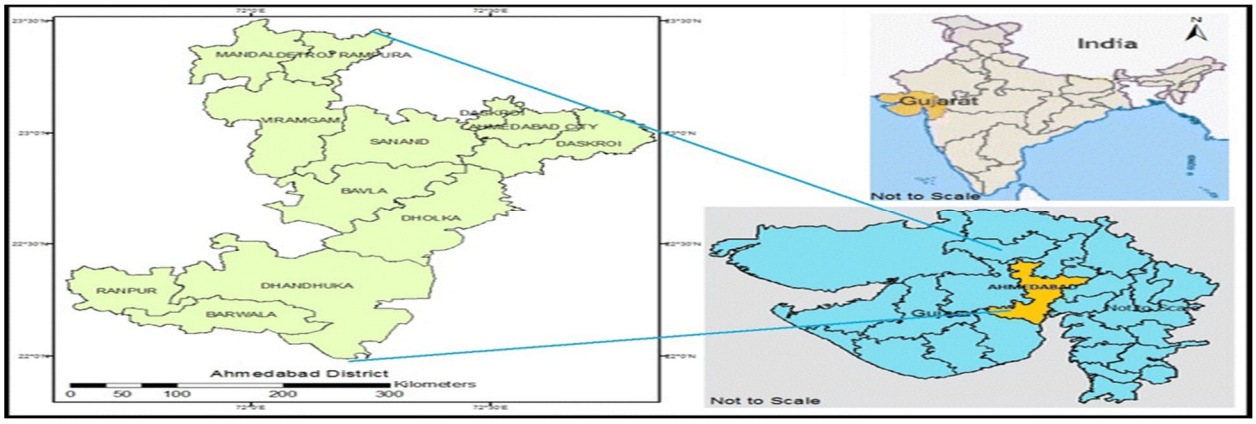

Figure 1: Location map of Ahmedabad region

III. DATA COLLECTION AND RETRIEVAL

Datasets used in this research were sourced from the publicly accessible records of the NASA (gov) from the year 1981 to 2022. The structure of data was in CSV format and included parameters like average maximum temperature, average minimum temperature & average precipitation and this parameter have a numeric value.

Attributes	Types	Descriptions
Years	Numeric	Considered Years
Months	Numeric	Considered Months
Maximum Temperature	Numeric	Total Monthly Average Maximum Temperature
Minimum Temperature	Numeric	Total Monthly Average Minimum Temperature
Precipitation	Numeric	Total Monthly Average Precipitation

Table 1 Numeric Data Values Analysis

IV. TREND ANALYSIS

The linear regression is used in the study to model the trends in temperature and precipitation data over the 42 years' period. The result helps to determine the overall average rates of change in trends of annual temperature and rainfall in the study area. Trend analysis is a tool used to fit a general trend model to time series data and provide forecast. The trend analysis for a time series data can take different forms such as linear quadratic or cubic but in this analysis linear trend model was used. In this case, a standard regression model is used to describe the relation between temperature, rainfall and time. The keyword "Trends", in this study is a term that is commonly used in climatic studies to describe a general increase or decrease in climatic phenomena over time. However, in order to determine the degree of significance of the observed trend, the coefficient of correlation R2 was used to test for significance. The correlation coefficient is a statistical measure that calculates the strength of the relationship between the relative movements of two variables. R-square shows how much of the change in the dependent variable can be explained by the independent variable. The values range between -1.0 and 1.0 therefore, any variable with R2less than 0.5 shows that the trend is statistically not significant but if the value of R2is greater than or equal to 0.5, the trend could be said to be statistically significant.

V. ANALYSIS RESULT

Trend analysis in several study shows Linear regression method used by various researchers. Simple summary of the rainfall data from year 1982-2012 is given in Table 2. Which discuss descriptive statistics such as the mean, standard deviation (SD), coefficient of variation(CV), kurtosis and skewness. It has been found from the computed table that monthly coefficient of variation (CV) value is between 48.13% to 437.84%. Maximum value of kurtosis is 34.71 in March month and highest value of skewness is also found in March, which is 5.61.

	Minimum	Maximum	Mean	SD	CV(%)	Kurtosis	Skewness
January	0	5.27	0.67	1.71	255.64	3.59	2.26
February	0	15.82	0.753333	2.95	391.59	17.99	4.11
March	0	63.28	2.262857	9.90	437.84	34.71	5.61
April	0	89.65	4.774524	14.36	300.82	31.73	4.97
May	0	126.56	8.712857	23.28	267.24	15.71	3.68
June	0	511.52	81.8619	91.49	111.76	10.64	2.70
July	31.64	548.44	249.415	120.00	48.13	-0.37	0.16
August	10.55	506.25	204.4443	122.15	59.75	-0.21	0.62
September	0	358.59	98.57786	88.29	89.57	1.09	1.20
October	0	131.84	14.35119	25.68	178.97	10.78	2.77
November	0	47.46	3.095476	9.1069	294.20	18.93	3.64
December	0	15.82	1.336429	3.34	250.39	8.21	2.75

Table 2: Statistical summary of Rainfall of Ahmedabad region

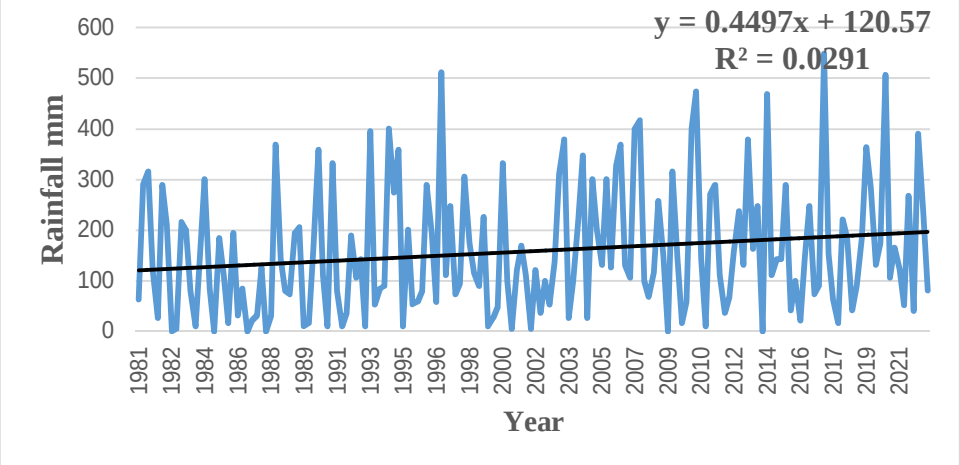

Figure 2: Seasonal rainfall trend from 1981 -2022 (from June to September)

The maximum rainfall occurs in monsoon season that is from June to September. Figure 2 is showing the general increasing trend of seasonal rainfall in the Ahmedabad region, where the linear regression equation is showing positive slope value (a = 0.44) and the R2 value comes about 0.02. R2 which is coefficient of determination value explains that 0.2% of variability in the seasonal rainfall is explained by this linear regression model.

The descriptive statistics like mean, Standard Deviation (SD), coefficient of variation (CV), kurtosis and skewness are given in Table 3 and 4 for maximum and minimum temperature, respectively.

Although the CV for both maximum and minimum temperature is found to be low as compared to rainfall but on the other hand the kurtosis and skewness values show extreme variation than rainfall. The observed data were analyzed for the period of 1981–2012 and explained through the figures 3 and 4. From both of these figures, it become clear that the maximum and minimum temperature are low during monsoon seasons and are relatively high during pre-monsoon months. Regarding temperature, trends found for both maximum and minimum temperature data on seasonal basis from 1981 to 2022 are not very significant. The maximum and minimum temperature trend analysis are presented in figures 6 and 7, respectively.

	Minimum	Maximum	Mean	SD	CV(%)	Kurtosis	Skewness
January	30.08	37.21	33.57	1.74	5.21	-0.64	-0.24
February	34.17	40.12	37.34	1.40	3.74	-0.61	-0.08
March	39.57	45.24	42.06	1.49	3.54	-0.83	0.06
April	42.83	46.55	45.02	0.84	1.87	-0.11	-0.42
May	42.4	48.58	46.25	1.23	2.66	0.94	-0.65
June	39.54	48.78	44.59	1.76	3.96	1.33	-0.65
July	33.63	43.37	38.78	2.32	5.98	-0.21	-0.28
August	31.49	41.36	34.81	2.10	6.05	0.55	0.75
September	31.77	42.1	36.27	3.03	8.35	-1.04	0.34
October	32.42	42.4	36.77	2.89	7.86	-1.04	0.37
November	30.76	39.9	35.18	2.32	6.61	-0.50	-0.18
December	29.27	35.82	33.43	1.58	4.75	0.32	-0.85

Table 3: Statistical summary of maximum temperature of Ahmedabad region

	Minimum	Maximum	Mean	SD	CV(%)	Kurtosis	Skewness
January	3.54	10.93	7.86	1.41	18.06	1.06	-0.12
February	4.82	14.58	9.60	2.12	22.13	-0.03	-0.09
March	8.71	18.05	14.42	2.09	14.48	-0.07	-0.29
April	15.58	21.8	19.37	1.64	8.49	-0.45	-0.44
May	20.96	26.18	23.57	1.27	5.41	-0.45	-0.24
June	23.3	28.19	26.07	1.09	4.184	-0.14	-0.27
July	22.82	26.54	24.57	0.63	2.60	2.36	0.55
August	21.87	24.93	23.29	0.72	3.11	-0.57	0.09
September	18.33	25.17	21.76	1.35	6.23	0.51	-0.01
October	13.15	19.85	16.80	1.36	8.11	0.13	-0.15
November	10.35	15.68	13.01	1.40	10.78	-0.97	-0.001
December	4.21	12.29	9.11	2.09	22.93	-0.26	-0.64

Table 4: Statistical summary of minimum temperature of Ahmedabad region

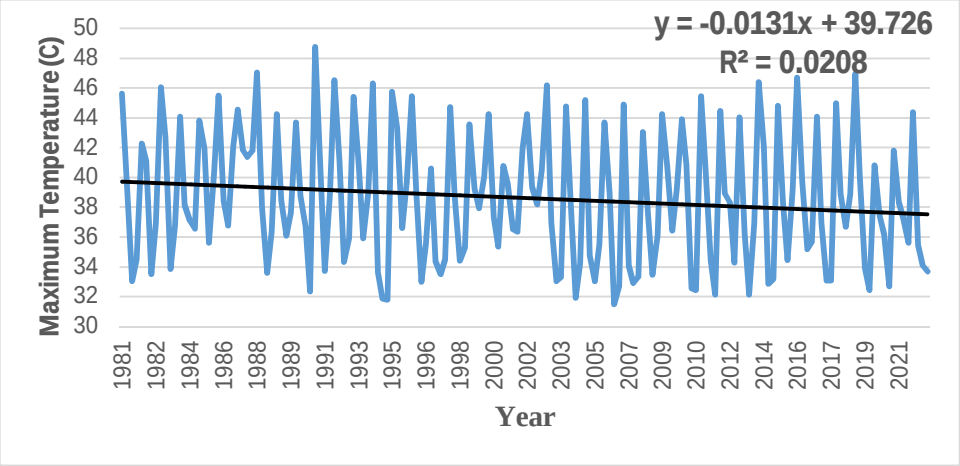

Figure 3.: Seasonal trend of maximum temperature from 1981-2022.

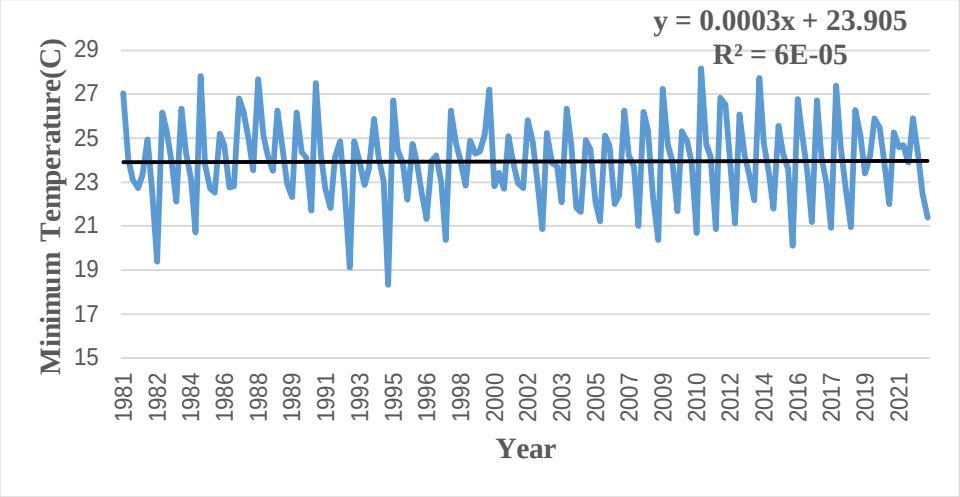

Figure 4: Seasonal trend of minimum temperature from 1981-2022.

VI. DISCUSSION

A variability analysis of climatological factors is of great importance for policy makers and researchers in their decision making as rainfall plays leading role in deciding the use of the water obtainability in the areas. Hence, it is clearly visible that the dataset is not normally distributed and most of the data fall in upper whisker that is, in the 4th quartile. According to literature, CV is used to classify the degree of variability as less (CV < 20%), moderate (20 < CV < 30%), high (CV > 30%), very high (CV > 40%) and CV > 70% indicate exceptionally high inter-annual variability of rainfall. Based on this, from the observed data considered that all the months had above 30% of CV highlighting the high variability of precipitation over the area. The outcome showed that the amount of rainfall in the region is extremely variable. Then, if the kurtosis values are analyzed, then it can be understood that during monsoon (June, July, August, September) the kurtosis values are less and also the skewness value which explains that the dataset are light tailed during monsoon months and follows a symmetric pattern. In other words, we can say that rainfall in the study area follows a symmetric pattern during monsoon months. In contradiction to it, during no seasonal months, the dataset shows high kurtosis value, so it can be termed that rainfall during post and pre-monsoon months follows a heavy tailed nature means the presence of outliers or extreme values are there.

In the simplest form, it can be said that rainfall in the study area before and after monsoon months is uneven in nature. Surface air temperature is one of the most important elements in weather and climate forecasting, so investigation of its behaviour is vital for understanding of climate variability which can differ spatially and temporally at different local, regional and global scales (Ghasemi, 2015).

In spite of the overwhelming indication of increasing temperatures all over the world, precise approximation of the time trends is still an open issue (Gil-Alana, 2018). In a similar way as the air temperature has vital influence on the water cycle in the study area, the deep understanding of the nature of its happening must be carried on. Unlike rainfall, the seasonal (June, July, August and September) maximum and minimum temperature show decreasing nature as the rainfall is at its peak during these months in the study area. And before and after monsoon months the temperature shows increasing pattern.

Figure. 3 represents the seasonal mean maximum temperature and its trend in the period of under examination. Using a linear regression model, the rate of change is defined by the slope of regression line which in this case is about -.0131 °C for maximum temperature and .00037 °C in case of minimum temperature during the period of 1981–2022. Also, it is observed that the average monthly maximum temperature for the studied period, the coefficient of variation (CV) varies from 1.87% to 8.35%, that means more or less the maximum temperature show stability over time and less variability is observed.

The trends of seasonal minimum temperature over diverse years are also obtained using linear regression best fit lines. The linear regression trends with their linear regression equations and coefficient of determination are represented in Figure 4. The coefficient of variation for mean (Lewis and King, 2016) monthly minimum temperature shows a variation ranging from 2.60 to 22.93%. From the study, it is proved that minimum temperature shows more variation than the maximum.

VII. CONCLUSION

Gujarat with its longest coastline in India (~1,663 km) is even more susceptible to Climate Change impacts. Ahmedabad region also experience the same. Deviations and oscillations in climatic parameters is a recurring phenomenon in this region. Rainfall and temperature are the most determinant climatic parameters in the area, as more than 80% of the agriculture is dependent on rain. The metrological data for the Ahmedabad region in Gujarat has been analysed in this study. The analysis of the time series was carried out using linear regression, which are widely used tests for conducting trend analysis. The variability analysis for the monthly rainfall, maximum temperature and minimum temperature is presented. To propose that a region like Ahmedabad is highly susceptible to the significant influences of climate variability mainly the rainfall variability and as rainfall is the main driver of agricultural growth in the studied region hence its extreme occurrence during monsoon and also during post and pre-monsoon months is very much crucial to the development. From the analysis, it is visibly understood that both maximum and minimum temperature all over a year do not show much variability in the study area and hence agricultural yield cannot be hampered much by temperature Rainfall and temperature pattern trend analysis of Ahmedabad region of Gujarat, India variability. Therefore, the concerned investors should take into consideration the rainfall variability in particular and temperature variability in general of the area into their climate change adaptation strategy.

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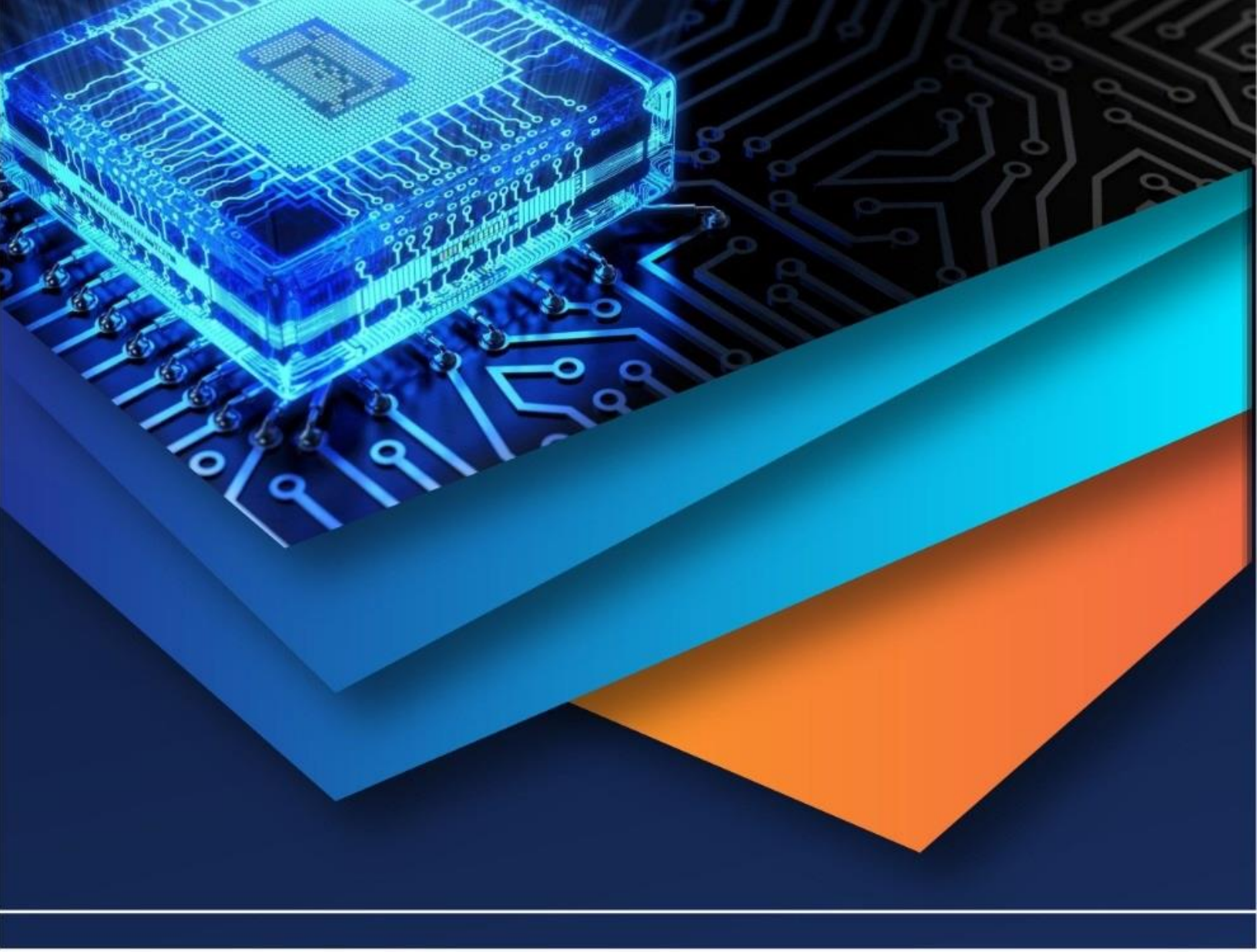

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