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GIS Based Multicriteria Decision Analysis of Riverine Flooding: A Case Study of Maharashtra Deluge 2019

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Abstract: Riverine flooding is frequent catastrophic event for Indian subcontinent and prevalent in western ghat region. The south-western monsoonal precipitation escalates the situation to detrimental level in the populous regions along the rivers. The previous studies suggest that the settlements in the vicinity of seasonal rivers are mostly affected during heavy precipitation due to unpredicted event and lack of preventive infrastructure along the bank. Such devastation can be reduced with detailed analysis of river basin and flood recurrence trends. Present study focuses on the flood frequency and settlement patterns in the Krishna River basin of Maharashtra state. The region has cotton soil (clay to loamy dark grey soil) cover, which encourages the agricultural practices. The agriculture being major occupation of the state engaged more than 64% population contributing largely in cotton and cereal production of the country. The discrete pattern of rainfall causes flooding at places, which not only distresses the settlement but also adversely affects the rate of soil erosion resulting elimination of the most fertile layer of surface. The study mainly emphases on the Shirindwad, Kurundwad, Rajapur villages of Shirol taluka of Kolhapur district, where Koyna, Warna, Panchaganga, Tarli, Urmodi, Dudhganga and Hiranyakeshi rivers of Krishna River basin overflowed decade's water level in August 2019 flooding event. The event put an eternal scar to the inhabitants with pile of flood water over their cotton soil. The devastation of the event would be predicted if spatio-temporal analyses of rainfall and settlement pattern have been done. So, the present study aims to evaluate the impacts of future flooding by the analysis of rainfall pattern and demarcation of settlement clusters under threat. This can be done by scrutinizing ancillary data in GIS (geographical information system) environment with the help of temporal satellite data. The GIS-based multicriteria decision analysis can provide result as demarcation of potential flood risk zones and this can be resourceful for disaster management and town planning practices.
Keywords: Riverine flooding, Hydrometrological hazard, Demarcation, GIS (Geographical Information System), Flood risk zones, Multicriteria decision analysis.

I. INTRODUCTION

The natural disaster impact vigorously on territory as well as human life cycle. Such types of natural disaster are unpredictable. The flood is one of the natural disasters which heavily effects on the surrounding life. In a present day we, humans have a science, a technology, by using these we can able to create the solution for manmade disasters. But in such kind of natural calamities we can predict the disaster with certain accuracy. We are still in searching for a solution which gives us exact prediction and real time condition to tackle such types of disaster very wisely. Can we fetch the real time data very precisely? Do we have any sources for data? Can we detect a flood prone area?

Every year in India, one third of the area is affected due to overflowing of rivers and canals. According to the Working Group of Planning Commission on Flood Control Programme, the total flood affected area of India is nearby 4.56 lakhs Sq. Km. Due to the rapid growth of the urbanisation and industrialization near to the banks of the river reduces the width of the river cross-section as well as due to effluents generated from the industries and household sewage are reducing depth of the river.

Due to this phonomenan the flood condition may arises in the nearly area. India is an agricultural country. Almost 75% population of the country is depending upon the occupation of agriculture. water is the breath of any agricultural activity but the disaster like flood greatly causes agricultural loss, loss of livestock and human lives. In India, for the farming the main biggest source is rain water and river water. Rivers are perennial and non-perennial, which can help to supply water for the agricultural as well as other purposes. The non-perennial rivers are having no longer water supply; they are also called as seasonal rivers.

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The discrete pattern of rainfall in different region may have the cause of drought and flood condition. As the 75% population is depending upon the agricultural occupation, the revenue which can be generated by the farmers is being reduced. It may become a serious issue for Revenue Department and also the growth of GDP will decreases. Due to the discrete pattern of rainfall can cause flood and drought condition also unbalance the human life cycle as well.

India is ranked as the high-risk class for humanitarian crises and disasters. The Indian topography, climatic condition as well as the prevalence of socioeconomic versatility among the marginalized and poor section of population make the county, most disaster country in the prone. Every year of about 40 million hectares of land mass affected due to the flood events.

Remote sensing and GIS are extremely useful and powerful tools in hazard management. Satellite data can provide hazardous footprints with greater accuracy, which are useful for assessing or monitoring the impact of hazard and mitigate flood activities. Remotely sensed data (optical and microwave) can be used effectively for quickly assessing severity and impact of damage due to flooding. In the past two decades, various studies have been carried out using remote sensing data to assess and detect flood inundation areas and to assess the dynamics behaviours of floods. (Ref.1)

The present study aims to evaluate the impacts of future flooding by the analysis of rainfall pattern and demarcation of settlement clusters under threat. This can be done by scrutinizing ancillary data in GIS (geographical information system) environment with the help of temporal satellite data. The GIS-based multicriteria decision analysis can provide result as demarcation of potential flood risk zones and this can be resourceful for disaster management and town planning practices.

II. LITRATURE REVIEW

In [1] S. S. Panhalkar and Amol P. Jarag (2017) "Flood Risk Assessment of Panchaganga River (Kolhapur District, Maharashtra) Using GIS-Based Multicriteria Decision Technique" This article, the main focus of study is to analyse the flood risk zone and to identify the potential flood prone areas with the help of GIS based multicriteria decision analysis. The flood condition occurred on 5 August 2005 across Panchaganga River which is studied by using RADARSAT DATA of same year. To extracting flooded areas from non-flooded area, threshold technique used ON RADARSAT SAR DATA. Flood layer, elevation, infrastructure and land use land cover analysis, these four factors used for analysis of flood prone area. The Spatial multicriteria analysis with ranking, rating and analytical hierarchy process method used to evaluate the priority weights of each criterion.

In [2] Miss. Sneha Sanjay Bhalvankar, Mr. S. M. Bhosale (2019) "Assessment of Quality of Water Resources in Radhanagari." In this research paper, the objective of study is to analyse the quality of water in the Radhanagari town as well as to evaluate whether the present water is suitable for drinking or not. For this purpose, 15 surface and ground water samples are collected & these samples are gone through Physical, Chemical and Biological parameters as a pre and post monsoon season. The pre and post monsoon i.e. seasonal variation affect the quality of water adversely.

In [3] Ms. Kavita Joshi, Amruta Janugade, Shruti Walikar, Anuja Padwal (2020) "Flood Monitoring and Alerting System using IOT" This paper contains the solution for flood risk by developing the IoT based alerting system and flood monitoring. As Maharashtra faces the flood crises in 2019, most affected region is Sangli, Kolhapur and Satara. The flood damages surrounding nature, human livestock, and the kill peoples and destroys the human life cycle as well. The affected peoples and Government gone through the serious issue of money to spent for the affected region. Hence, by providing an immediate flood alert system and monitoring system helps for the decision making, planning and prediction.

In [4] Er. Nandakumar vadnere principal secretary, Water Resource Department (Rtd) and Chairman, Expert study committee. "Report on Krishna Sub-Basin 2019 (Vol. 1- Main Report)" Submission of study report by expert study committee, for the evolution of flood 2019 event, its analysis and finding reasons thereof, and to suggest flood mitigation majors for KRISHNA SUB-BASIN.

III.STUDY AREA

The latitude 16˚44' 9.6144" N and longitude 17˚36' 14.8248" E of Shirol Taluka, Kolhapur District, Maharashtra. While going through the various government study report and data analysis we had decided to choose the three most affected villages during 2019 flood event which are situated on the banks of Krishna River and those are Shirindwad, Kurundwad and Rjapur of Tal. Shirol, District Kolhapur.

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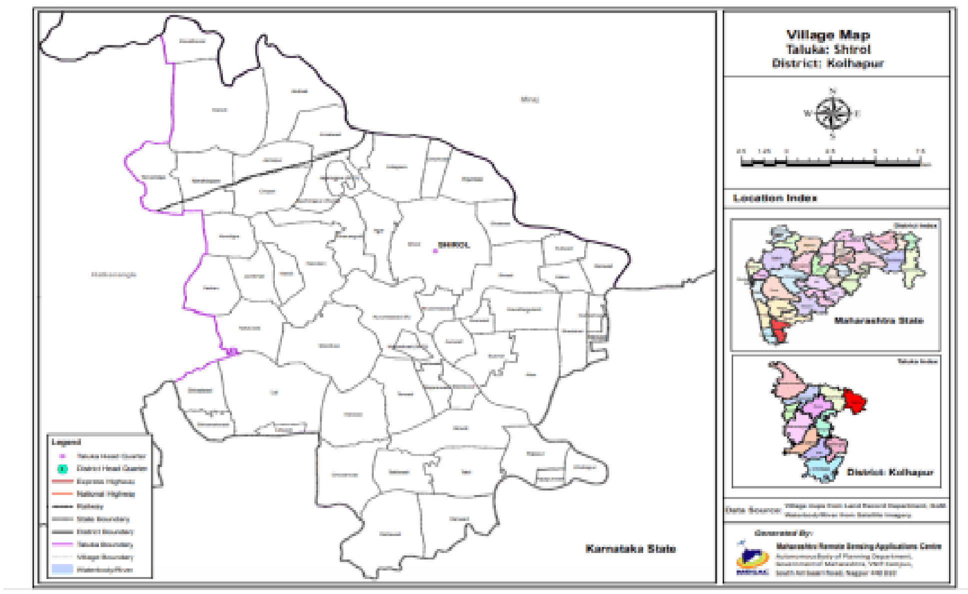


Data Source: Maharashtra Remote Sensing Application Centre Nagpur, India .
Figure.1 Study Area of Shirol Taluka.

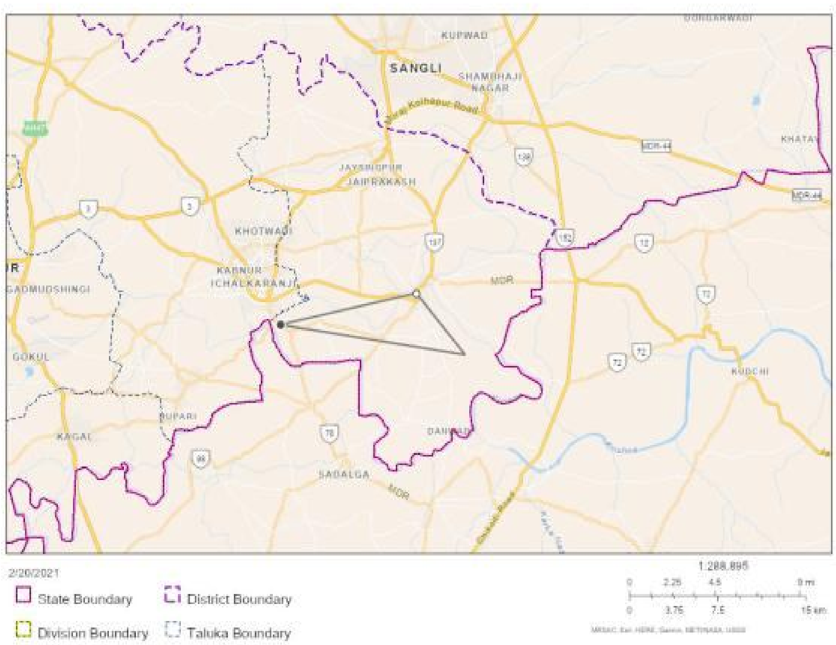


Figure.2

The above fig.2 shows the triangle with points showing the three villages Shrirndwad, Kurundwad and Rjapur.

The Krishna River arises in Western Ghats range near Mahabaleshwar. Then it flows east to Wai afterwards it flows in the direction of southeast past Sangli to the Karnataka State. In Kolhapur and Sangli district, there are three major dams which are contributing the major source of water supply and irrigation. The three major dams are Konya, Wrana and Rdhanagri. As Radhanagri Dam which situated near to the most affected villages i.e. Kurundwad, Shirindwad and Rajapur hence we had decided to study Radhanagri Dam in detail. The capacity of the Rdhanagri dam is 236.71 TMC. For the better understanding we had drawn the path in red colour of Krishna River from Rdhangari Dam to Almatti Dam covering the three most affected villages.

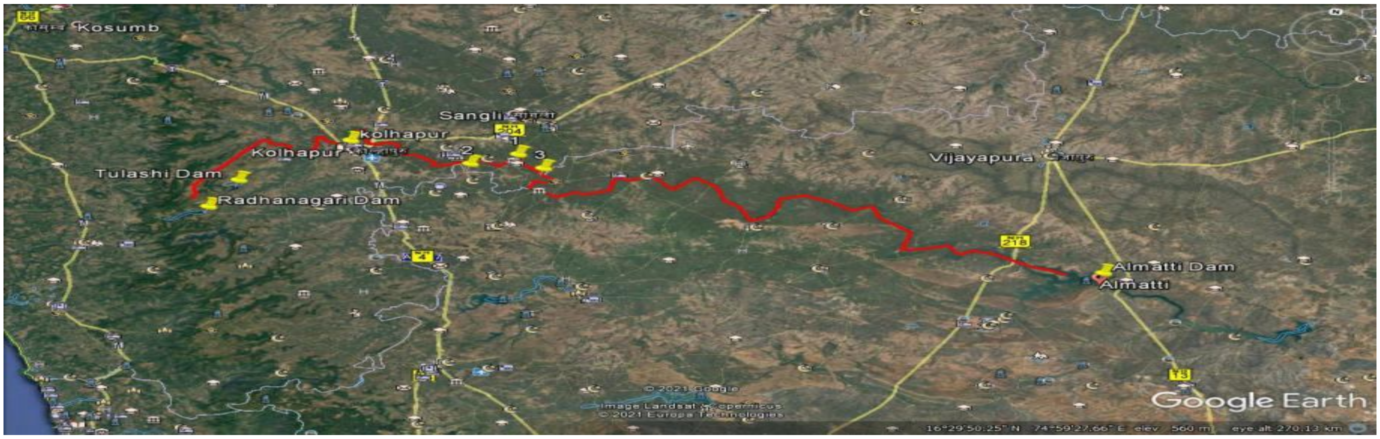


Figure.3 Google Earth Pro Image.

IV. METHODOLOGY

The procedure will be followed to achieve the objectives using different techniques and tools as per flow-chart given below:

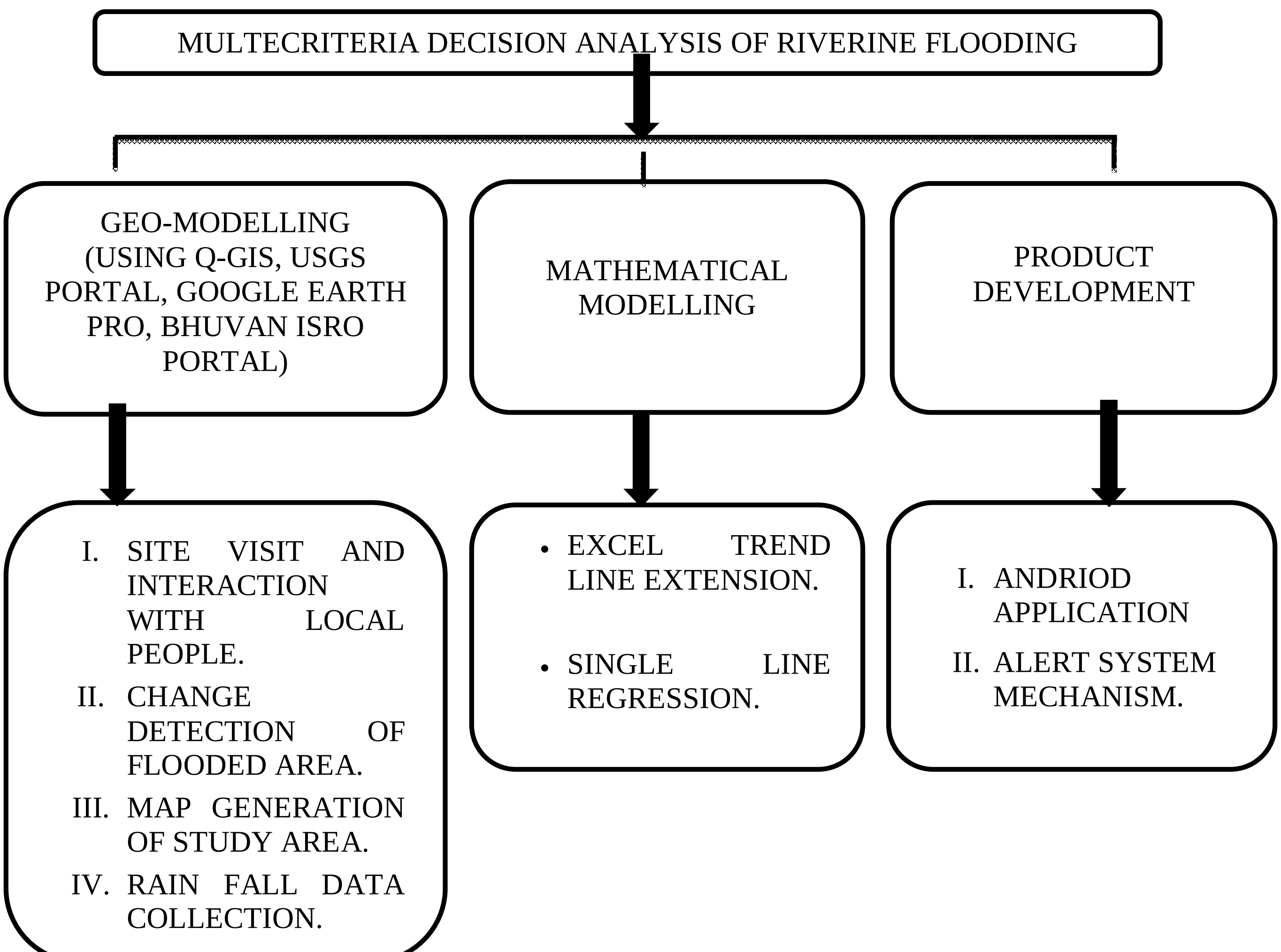
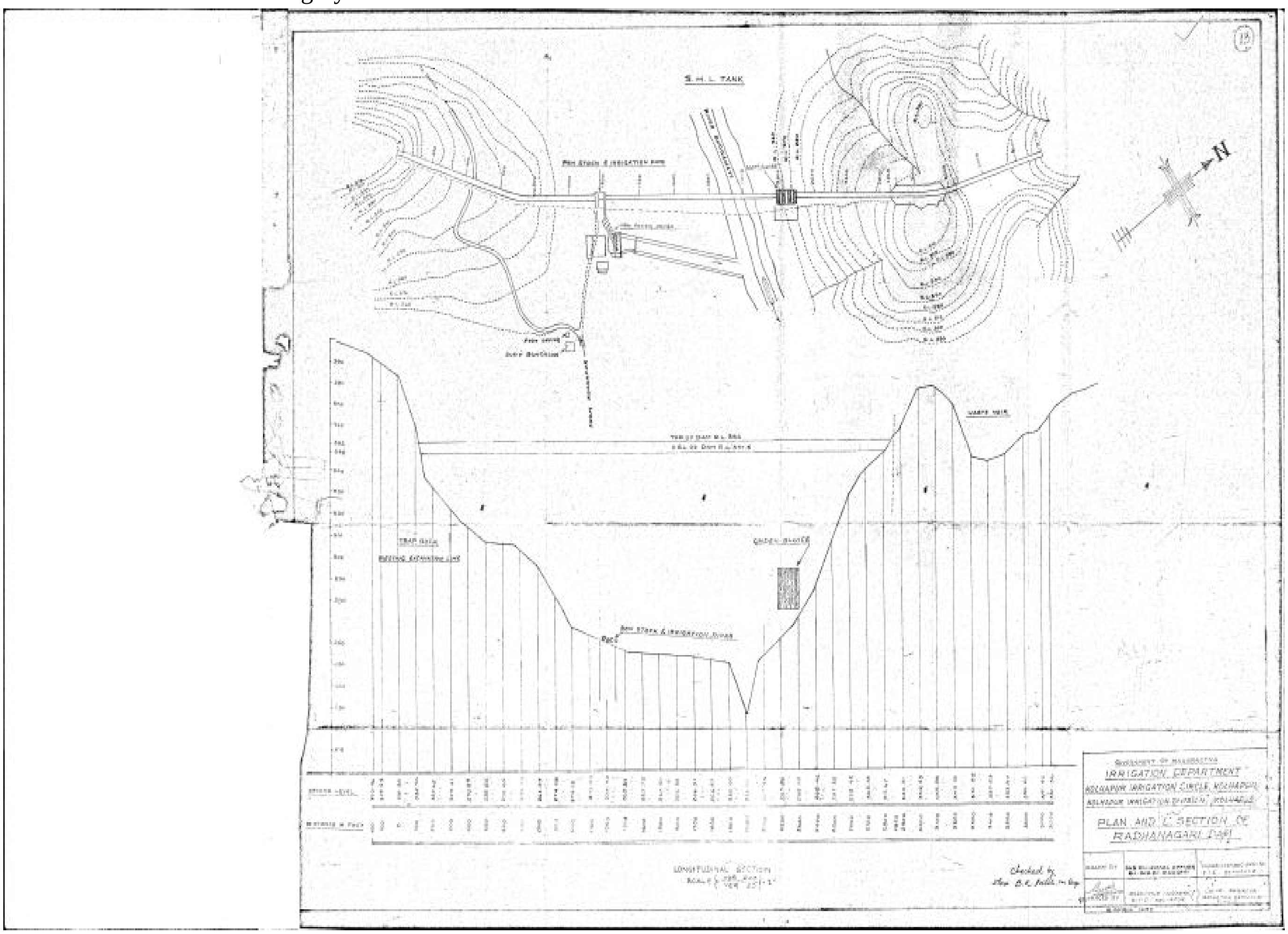


Figure.4 Methodology

Term Multicriteria Decision Analysis (MCDA) defines the technique which comes up with the final decision for the given problem by dividing the decision into different parts. Comparing and analyzing different parts which lead to justify the solution. So, we have decided to go the Multicirteia Decision Analysis of Riverine Flooding to achieve the objectives.

While going through all data which we are collected and analyzing the various reports, this Multicirteia Decision Analysis (MCDA) of Riverine Flooding further divided into the three parts i.e. Geo-modeling, Mathematical Modeling and product development. In Geo Modeling we have visited the site location and did interaction with local peoples who were affected by the flood.

We have also collected the data from the executive in charge of Rdhanagari Dam. Data such as contour map of Radhanagri basin, general information of the dam, information regarding nearby rain gaugestations and discharge pattern of dam. Along with we had discussion about Flood Alarming System for the dam.



Data Source: Water Resource Department, Kolhapur.
Figure.5 Shows the contour of Radhanagari basin.

Through the data collection, firstly we did change detection of Krishna River to know the land use land cover pattern of that area. Afterwards we did the geo-modeling for the area by generating various maps. With the help of Q-GIS 3.16 we generated Contour Map, Reservoir Map of Radhanagri Dam, Delineation Map, Watershed of Kolhapur and change detection with the reference of DATUM WGS_1984.

With the help of various sites such as Bhuvan India, Customize Rainfall Information system (CRIS), India Metrological Department (IMD), Center for Hydrometrology and Remote Sensing (CHRS) we collected rainfall precipitation data of the past 1 decade. From this we analyzed the rain fall pattern of Kolhapur.

In mathematical modeling with the rainfall data we did the Excel Trend Line Extension and Single Line Regression to predict the next 1 decade rainfall data with the help of Microsoft Excel. While going through the Geo-modeling and Mathematic Modeling we have comes up with the product development i.e. Alert System Mechanism and Android Application.

V. RESULT AND DISCUSSION

Multicriteia Decision Analysis (MCDA) of Riverine Flooding helps us to clear the picture about how we can wisely handle & manage the disaster like flood in a definite manner. Researching in dividing pattern are always gives us a better result for the proper understanding of the situation. In the geo-modelling, we performed the change detection for the Krishna river area for the year of 2009 & 2019. For the change detection of the area, we have to download the different tiles by referring perfect datum & latitude longitude of the particular area. For the tile extraction, we used United State Geological Survey Earth Explorer (USGS) access. We extracted the tiles for the year 2009 & 2019 i.e. LANDSAT 2009 & LANDSAT 2019. These tiles are the footprint of the Landsat which are in black & white coding. The tile should be cloud free, so we can easily observed and identify ground details. Afterwards, we put tiles in Q-GIS software for the proper banding & scaling of tiles to detect the changes occurred over the period of time.

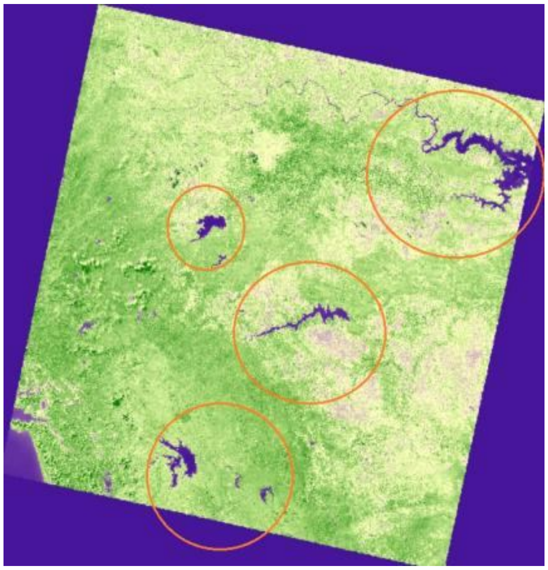


Figure.6 Shows the LANDSAT (Year 2009).

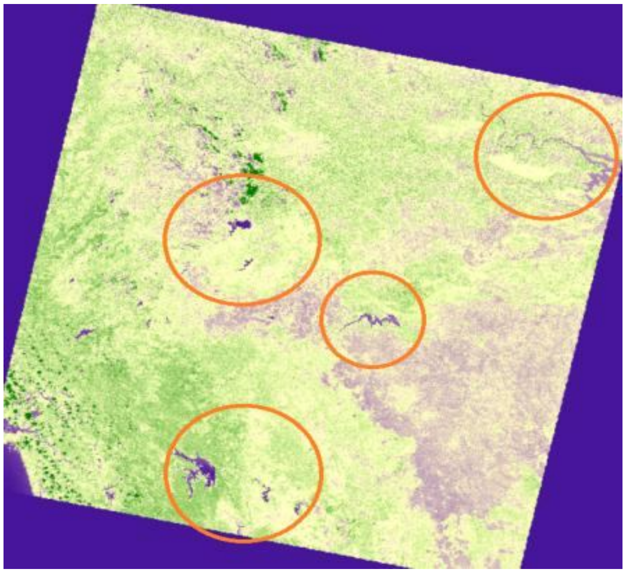


Figure.7 Shows the LANDSAT (Year 2019).

The above satellite images shows the changes occurred in Krishna river region. In 2009 Landsat image, we are seeing that the width of Krishna river is comparatively more large than the width of river of Landsat image 2019. This occurred due to growth of vegetation and meandering of the river which reduced width and depth of the river over the years. This condition may create flood situation in the nearby area. The circles in satellite images are showing water bodies which are decreasing over the period of time.

For the next stage of geo-modelling, we generated the various for the Kolhapur district & Radhanagari Reservoir. For the detail analysis of study area, we generated Contour map of Kolhapur, Delineation map of Kolhapur, watershed of Radhanagari Dam & LU/LC map of Kolhapur. For this map generation, we used Q-GIS 3.16 software.

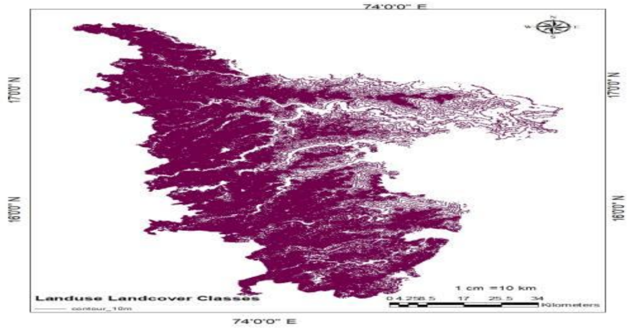


Figure.8 Shows the Contour map, Kolhapur (10m contour).

For understanding the ground pattern and undulations, we have to generate contour map of the Kolhapur. The above map shows (Fig.8) the contours of 10m with dark purple shading. The closely spaced contours show the evenness of ground while the contour which is not closely spaced shows the undulations of the ground. Our study area comes under the not closely spaced contour zone.

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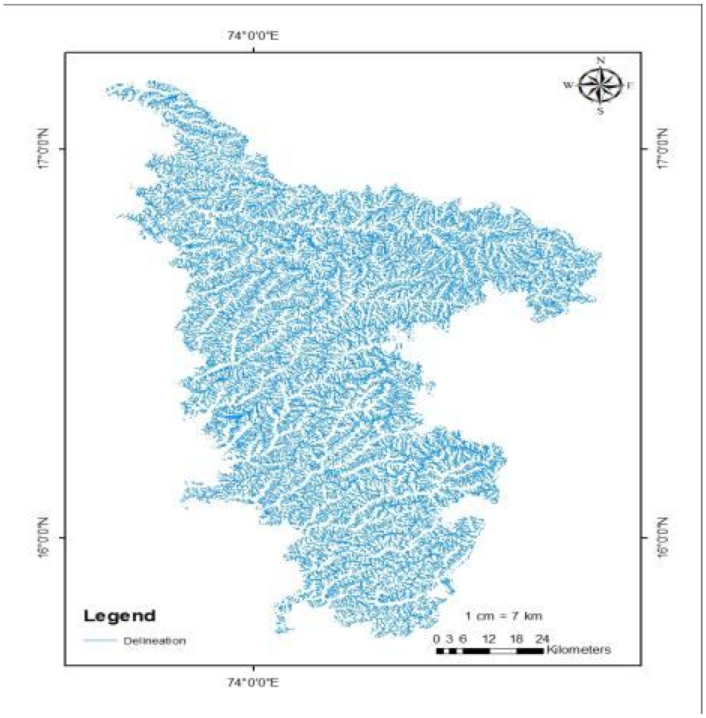

Figure.9 Shows the Delineation map, Kolhapur.

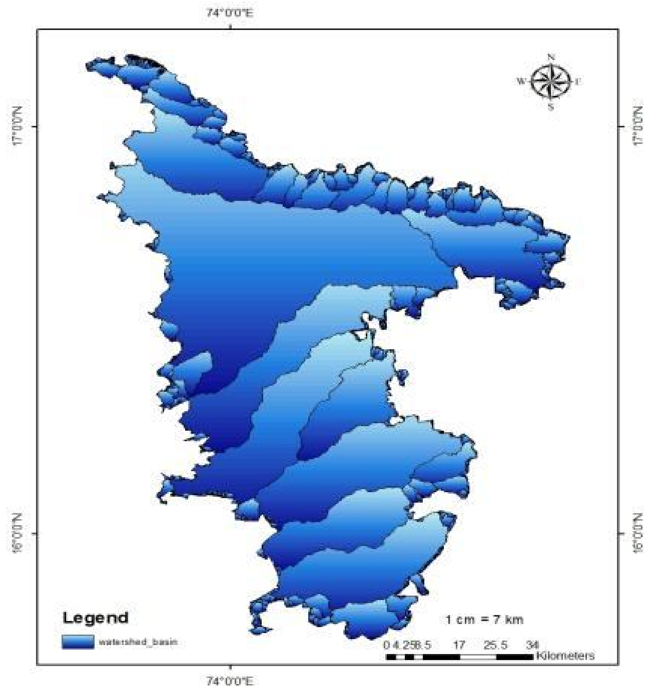

Figure.10 Shows the Watershed map, Kolhapur.

Delineation map is the delineating watershed boundaries. The blue lines on a map identify the watershed boundaries of the areas. It also shows the flowing pattern of water bodies. These are drawn on topographic maps by using contour lines.Contour lines are the lines which are joining the same elevation points on the ground.

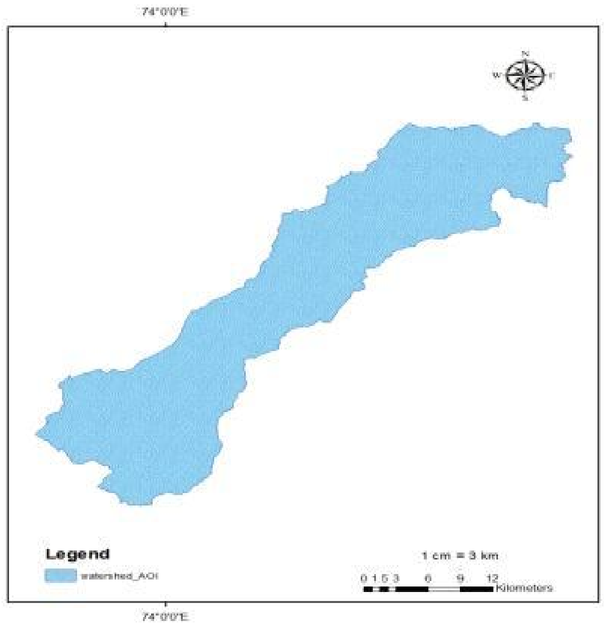

Figure.11 Shows the Watershed map, Reservoir of Radhanagari Dam.

This watershed Map shows the (Fig.11) reservoir of Radhanagari Dam.

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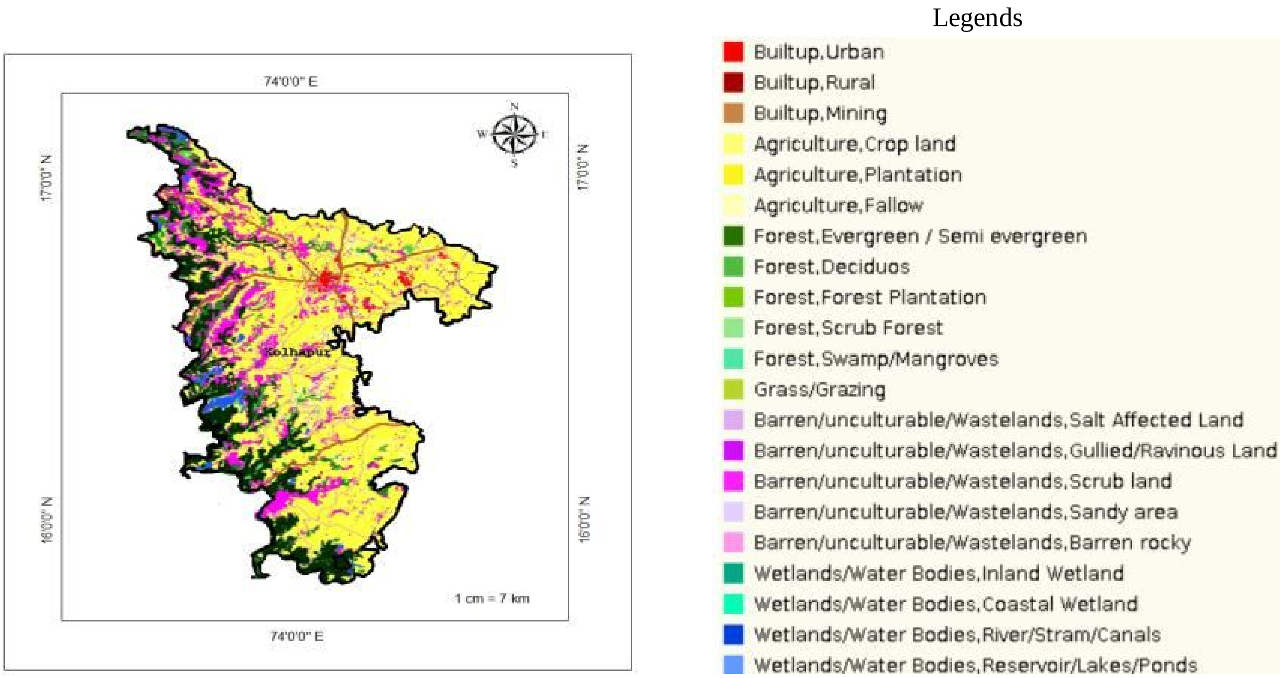
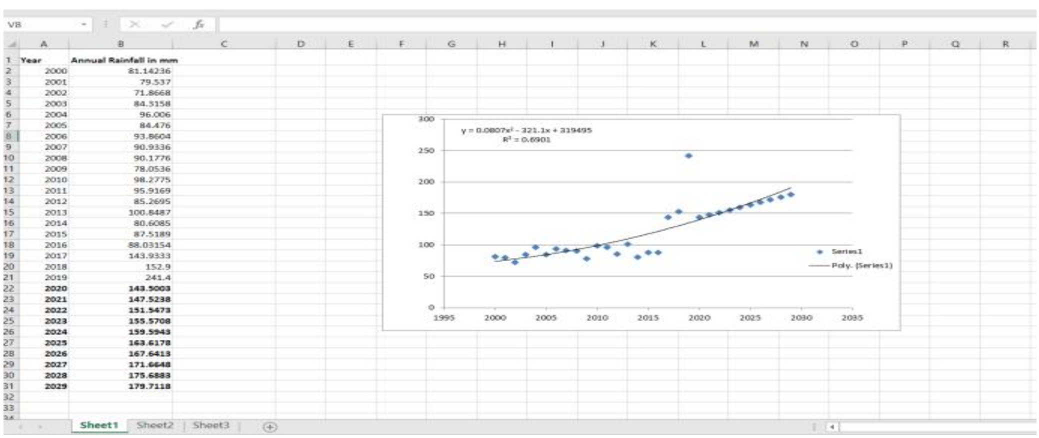


Data Courtesy: Maharashtra Remote Sensing Application Centre, Nagpur.
Figure.12 Shows the Land Use Land Cover Map, Kolhapur.

This map shows growth of urbanisation, industrialization and residential zones in the Kolhapur district. Also it shows forest, semi-forest, agriculture, plantation, waste lands, barren lands, uncultivable, water bodies, river, reservoir, lake, ponds over the period of time in Kolhapur district. By analysing the study area with geo-modelling perspective, with the rainfall data we did a mathematical modelling using Microsoft Excel. For prediction of rainfall we performed two methods in a Microsoft Excel i.e. Excel Trend Line Extension and Single Line Regression.

In the Excel Trend Line Extension, we collected the rainfall data for the past 2 decade i.e. from 2000 to 2019. The trend line shows the future prediction of rainfall data for the next 1 decade.



Year	Annual Rainfall in mm
2000	81.14236
2001	79.537
2002	71.8668
2003	84.3158
2004	96.006
2005	84.476
2006	93.8604
2007	90.9336
2008	90.1776
2009	78.0536
2010	98.2775
2011	95.9169
2012	85.2695
2013	100.8487
2014	80.6085
2015	87.5189
2016	88.03154
2017	143.9333
2018	152.9
2019	241.4
2020	**143.5003**
2021	**147.5238**
2022	**151.5473**
2023	**155.5708**
2024	**159.5943**
2025	**163.6178**
2026	**167.6413**
2027	**171.6648**
2028	**175.6883**
2029	**179.7118**

Figure.13 Shows the Excel Trend Line Extension.

Single line regression is done with two component variables i.e. one is dependent and other independent. The dependant variable is calculated with the help of independent variable i.e. dependant variable is function value of independent variable.

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SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.604242622							
R Square	0.365109147							
Adjusted R Square	0.329837433							
Standard Error	85.47033981							
Observations	20							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	75618.31	75618.31	10.35132	0.004776729			
Residual	18	131493.2	7305.178					
Total	19	207111.5						
	Coefficients	*andard Er*	*t Stat*	*P-value*	*Lower 95%*	*Jpper 95%*	*ower 95.0*	*pper 95.0%*
Intercept	-21227.3152	6660.309	-3.18713	0.005104	-35220.10616	-7234.52	-35220.1	-7234.52
YEAR	10.66357143	3.314397	3.217348	0.004776	3.700280426	17.62686	3.700280	17.62686
	334.4261429							

RAINFALL=INTERCEPT +/- YEAR *COFFICIENT

Example for 2021

= -211227.31 + 2021*10.6635

= 323.6235

Figure.14 Shows the Single Line Regression

The Fig. 14 shows the calculation of Rainfall for the intercept years.

rainfall{mm}	YEAR
147.65	2000
102.7	2001
95.07	2002
103.175	2003
142.55	2004
256.6	2005
205.3	2006
231.65	2007
161.27	2008
188.87	2009
231.25	2010
192.15	2011
114.725	2012
177.85	2013
163.77	2014
96.825	2015
162.325	2016
373.1	2017
432.8	2018
443	2019

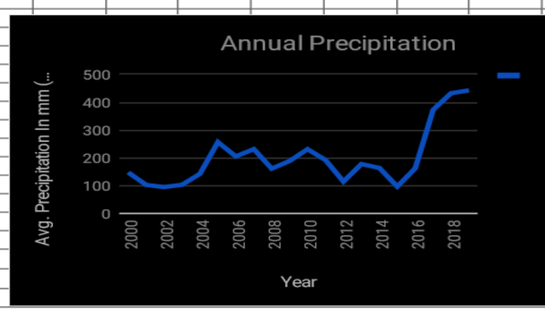

Figure.15 Shows the Single Line Regression

By discussing geo modelling and mathematical modelling we have come up with the decision that flood prone area requires an IoT based application which will gives alarm to the farmers, villagers and local citizen and it also help to the disaster management department for better assessment of flood conditions.

We are proposing a solution for the flood like Kolhapur disaster in the form of IoT based technology named as "KABANDHAM APPLICATION." In holy language Sanskrit, word KABANDHAM means Water. This application is useful for the local people as well as the various local bodies to manage flood like condition on the local level. This application is under the progress while there are more chances of development in this application; hence still we are working on it.

Figure.16

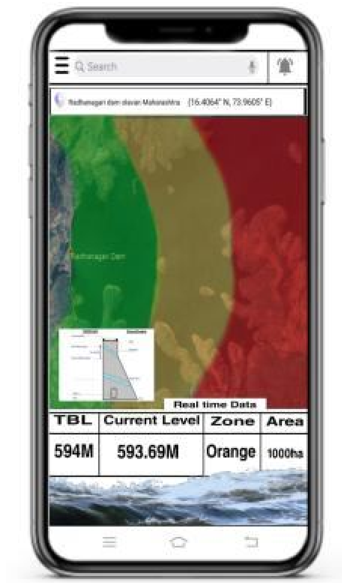

Figure.17

Figure.18

Figure 16 shows the application user will be able to fetch daily precipitation information, identification and location of dam and its features. The bell icon provided on the top right corner, on activating will notify the user with alert pop-up notification.
Figure 17 shows the UI will show different zones of flood prone area, also he/she will be able to identify under which zone his/her current location is falling. The user will be able to identify nearby dam with real time data.

1) *Red Zone:* High Alert
2) *Orange Zone:* Medium Alert
3) Green Zone: Safe

Figure 17 shows the menu tab which is provided on top left corner includes navigational features with which user will able to use the application with ease. Along with the IoT based application, we are proposing Alert System Mechanism which can be installed at dam. This mechanism is useful for those people who cannot be able to use the smartphones. This mechanism is installed on the upstream side of dam with having physical installed at various levels of the dam wall. As water level rises up to the sensor, it sends signal to control room and thereby to the villages respectively. Thus the control room creates the siren alarm to alerting the people.

VI. CONCLUSION

The study on GIS Based Multicriteria Decision Analysis of Riverine Flooding: A Case Study of Maharashtra Deluge 2019 by collecting appropriate data, Geo modeling, Data analysis and App development; following conclusions may achieve:

A. Farmers and Villagers will get aware by app alarm before flood in future. Accordingly erosion of soils can be minimized by providing protection bunds etc.
B. Through the alarm system and by use of app, residents in flood zone can minimize damages in future due to floods.
C. Due to the mass use of app by villagers, farmers, revenue department and local authorities can manage disaster more effectively.

VII. ACKNOWLEDGMENT

On the very outset of this report, I would like to extent any sincere and heartfelt obligation towards all the personages who have helped me in this endeavor, without their active guidance, help, cooperation and encouragement. I would have made headway in the project.

We are thankful to the JSPM’s Imperial College of Engineering and Research Wagholi, Pune. Our Principal Dr. R. S. Deshpande, our HOD of Civil Engineering Dr. N. V. Khadke, our guide prof. P. G. Bongale, co-guide prof. S. J. Mohite, prof. D. N. Mandlik and other teaching staff.

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B. WRD (Water Recourse Department), Radhangari Dam, Kolhapur.

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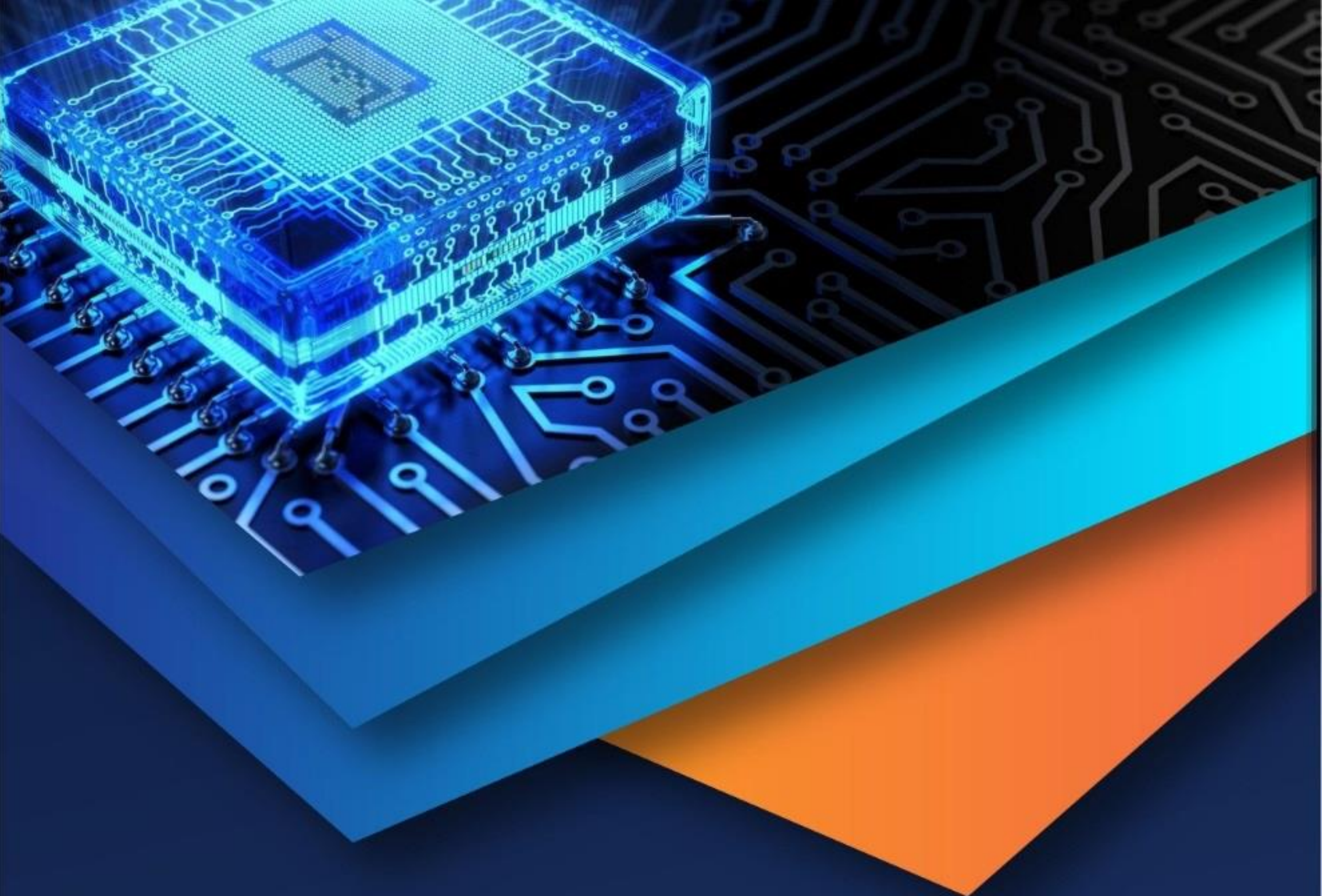

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