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Risk Management in Road Construction Projects using Fuzzy Logic

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Abstract: This research presents a complete framework for managing risks in road construction projects using Fuzzy-Risk Failure mode & Effect Analysis (F-RFMEA) system. In this research risk management is done through undergoing five major steps: 1. Identification of risk factors through literature review and discussion with highway construction expert's result in 61 risk factors are identified, which are categorized in 12 groups 2. Assessment of risk factors in terms of its occurrence, consequences on cost, time & quality and detectability through questionnaire survey. 3. Ranking of risk factors based on Risk Priority Number (RPN, function of occurrence, consequence and detectability of risk) using Fuzzy-MATLAB 4. Risk Allocation i.e. to whom risk should be allocated 5.Treating the risks by designing risk response strategies.
Keywords: Fuzzy Logic, Road Construction Projects, Risk Management, MATLAB.

I. INTRODUCTION

Qualitative and Quantitative are the two strategies which can give critical learning about risks. Most development organizations consolidate the two strategies so as to recognize, dissect and portray the risks, which they may need to confront (Baker et al., 1998). Evaluation of risk variables is important for contrasting risks and one another and, whenever estimated in money related terms (Collier, 2009). Qualitative techniques, similar to Root Cause Analysis, are appropriate for identifying reasons for risks. The need of strategy to think about risks relies on the explicitness of the circumstance. Road construction projects play very important role in social, economic and cultural development of any country. These projects undergo many risks during construction process, so it is required to analyze these risks before starting any road construction. road construction requires large amount of cost, time and quality investment, but in road construction several risks may come into play as threat which affect the cost, time and quality of road construction, so it is required to analyze the risks in road construction to take suitable response against risks before starting of road construction. Thompson and Perry (1992) concluded that project may fail due to ineffective risk analysis and risk response. So to complete any project successfully it is necessary manage the risks associated to respective project. It is well known fact that road construction requires already large amount of money and time investment. But these projects may face several types of risks which affect also the quality beside the cost and time of completion of construction of road projects. Each risk has some probability of occurrence and consequence on time, cost and quality of road construction projects. Thus risk management is needed to response the risk after identifying the risks and measuring the impact of risk mainly on cost, time and quality of construction of road projects.

Risk Management in construction of road projects has following benefits-

1) Make the business more realistic and help in planning of project.
2) Allow to take various effective actions in favor of project.
3) Make the way easy to achieve business goals and objectives of projects.
4) Control the loss might be faced by clients or contractors.
5) Control the cost, time and quality of work.

II. RESEARCH OBJECTIVES

During the research following objectives was targeted to achieve-

1) Identification of risk events associated to construction of road projects through literature review and discussion with road construction experts.
2) Questionnaire survey to elicit information about risk occurrence, risk consequence on cost, time & quality of road construction projects, risk detectability, risk allocation and risk responses.
3) To propose a fuzzy model using computer software MATLAB for Risk Priority Number (RPN) calculation.
4) Identification of most important risk factors based on RPN.
5) Allocation of risk to client or contractor or consultant or sharing among them.
6) To propose a RFMEA table which shows the ROI, RCI, RDI, RPN & rank of each risk, risk response and risk allocation plan.

III. RELATED WORKS

Risk is characterized as the opportunity of an unfriendly occasion that relies upon the conditions (Mills 2001). Hazard Management keeps the undertaking execution moving in sheltered and successful way (Dandage et al. 2018). Ineffectually evaluated and oversaw risks influence venture execution and the development company's long haul advertise maintainability (Ahsan and Gunawan).

Prathamesh Brid and Raju Narwade (2017) found that fuzzy logic approach simplize the tough job of project manager to analyze the unclear and vague data and information. They also found that fuzzy logic is useful and satisfactory approach for decision making in construction industry.

Hesham Abd El Khalek, Remon Fayek Aziz, Hamada Mohamed Kamel (2016) utilized the fuzzy logic approach to liklihood and impact of risks folllowing the vagueness in the liklihood and impact of risk. They evaluate the risk in construction projects through calculating the R-index of each risk which is function of liklihood and impact of risk.

John B. Bowles & C. Enrique Pelaez (1995) have concluded that FMEA & FMECA are the more effective methods than traditional methods to analyze the failures in a product or system. Bowles and Pelaez also found that involvement of fuzzy logic in FMEA technique can give more precise and accurate information about failure status of product or system. To apply fuzzy logic in FMEA, it is required to define linguistic terms, fuzzy numbers and and membership functions of risk occurrence, risk consequences, risk detectability and risk priority number. Bowles and Pelaez also conclude that fuzzy logic with FMEA is also most useful when there is lack of availability of information. Bowles and Pelaez also noted that, if failure modes have multiple dimensions then calculated RPN might be underestimated.

Mohamed Abdelgawad and Aminah Robinson Fayek (2010) found the RPN values of identified risk factors in construction industry using Fuzzy-MATLAB. They used Impact of risk, probability of occurrence of risk and current control on risk as input and RPN as output in Fuzzy-MATLAB. They applied Fuzzy-AHP to count weight of impact of risk on cost, time and quality of construction project. They also concluded that responses should be given to risk events based on RPN values prioritization not on the rules of thumb. Fuzzy and FMEA was concluded as appropriate and satisfactory to calculate RPN values of risk factors.

Cheng-Min Feng and Chi-Chun Chung (2013) assessed the the risks in airport airside using fuzzy logic and FMECA. They identified 14 risk factors from the aviation accident database of International Civil Aviation Organization (ICAO). Each risk factor was considered as failure mode. They conduct a case study using questionnaire on Taiwan Taoyuan International Airport. They elicit the information from experts about probability, severity and detectability of risk factors in airport airside. RPN of each risk factor was calculated by making a fuzzy model on MATLAB software. They gave more attention to higher RPN value risk than lower RPN value risks

Mohsen Ahmadi, KouroushBehzadian, AbdollahArdeshir and ZoranKapelan (2015) managed the risks in construction of highway projects. They used fuzzy logic in FMEA & MCDA to assess and prioritize the risk factors. Combined fuzzy-AHP was used to compute the impact of risk factors on cost, time and quality of work. They identified 30 risk factors and calculated the RPN values of risks. Risk were prioritized on the basis on RPN value. Higher RPN risk was responded firstly. Lack of fund and time was identified most significant factors. They also conclude that suggested response strategies are sufficient, useful and appropriate to handle the risks in construction of highway projects.

Sameh M. El-Sayegh and Mahmoud H. Mansour (2015) assessed and allocated risks in highway construction projects in UAE. They identified 33 risk factors and designed a questionnaire to elicit information from experts about probability of occurrence and impact of risk and risk allocation on highway construction projects. They found Risk occurrence index and Risk Impact index using Relative Importance Index (RII) method to find significant risk factors. They also differentiate the risk factors on the basis of contractors, consultants and owners views. They found strong correlation between all three groups of respondents using spearman rank correlation coefficient. They also analyzed the risk allocation suggested by owner and contractors and recommended the final risk allocation plan.

Mahmoud Mohamed Mahmoud Sharaf and Hassan T. Abdelwahab (2015) analyzed the risk factors in Highway Construction Projects in Egyp using risk score. They identified the 73 risk factors and categorized them into 12 risk groups. To elicit the information for occurrence and impact of risk questionnaire method was used. They calculated the Risk Score by multiplying Average Impact and Average Probability of Occurrence, while average probability of occurrence and average impact was calculated by Relative Importance Index (RII) method. Delay in Decision making and land acquisition was found most significant risk factors based on Risk Score value. They also concluded that risk factors having high frequency of occurrence in the life cycle of project and having high impact on project's cost and time are most risky factors in construction of highway projects of Egypt.

Mohammad Hayati and Mohammad Reza Abroshan (2017) assessed the risk factors of operating process of Tehran Subway Tunnel using Fuzzy-FMEA and concluded that FMEA is one of the best technique to identify, evaluate and powerful management of risk

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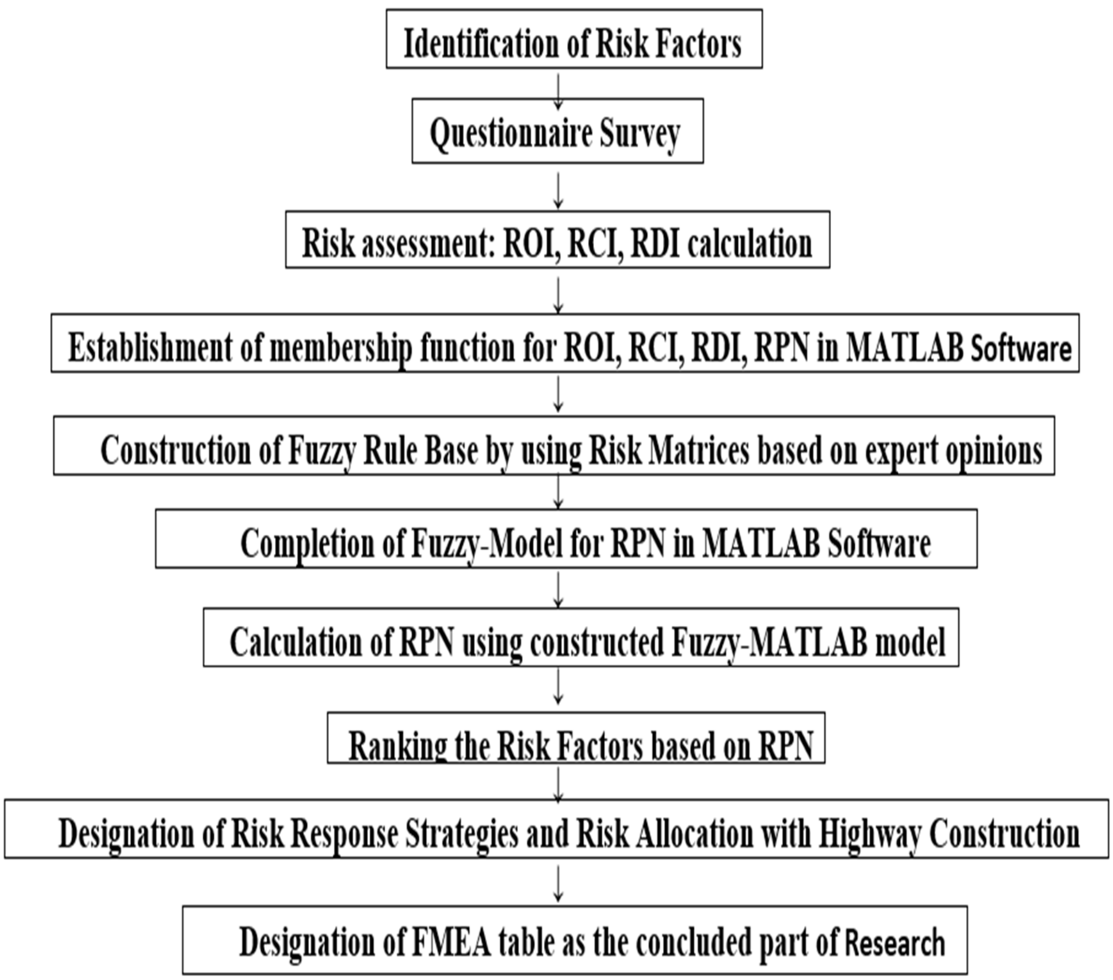
factors. They used triangular membership function for occurrence, severity and detectability to calculate RPN values of each risk factor. To elicit the information about risk parameters they conduct a questionnaire on Tehran Subway Tunnel. They found Fuzzy-FMEA as a more flexible and realistic tool and technique for risk analysis than other traditional tool and techniques.

Subya. R and Manjusha Manoj (2017) assessed the risk factors in construction of highway projects. They used fuzzy logic and multiple regression analysis in risk assessment. They identified 53 risk factors and categorized them into 12 groups. They elicit the information about risk parameters through questionnaire survey. They found safety regulation and land acquisition as the most significant risk factors in construction of highway projects. They found the fuzzy set theory as reliable mathematical tool to handle and deal with vague, imprecise and uncertain data.

Maryam Gallab, Hafida Bouloiz, Youssef Lamrani Alaoiu, and Mohamed Tkiouat (2018) assessed the risks in mantinance activities. They used Fuzzy logic in FMEA to assessed risk factors in maintenance activities of LPG supply chain. They concluded that, to operate and insufficient and imprecise data fuzzy logic is advantageous.

IV. RESEARCH METHODOLOGY

A. Methodology Flow



Total 61 risk factors were identified through literature review and discussion with highway construction experts. These risk factors are categorized into 12 groups. After identifying the risk factors a questionnaire form was prepared in following format given in Table 1. It was decided to elicit information about Occurrence, Consequences, detectability of risk factors from road construction experts. Notes were also prepared with each road construction experts to elicit information about risk allocation and risk response strategies.

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B. *Questionnaire Form*

Table: 1 Identified Risks and Questionnaire Form

Sr. No.	Risk Category	Risk No.	Risk Factor	R O	RC on C/T/Q	R D	Risk Alloc-ation
1.	Construction Risks	R1	Lack of experience of consultant, contractors or sub-contractors				
		R2	Contractor Productivity Issues				
		R3	Insufficient availability of time to complete project				
		R4	Change in construction scope				
		R5	Change of owner of project				
		R6	Rework due to errors				
		R7	Incomplete or complexity in project team				
		R8	Non-reliability in construction work quality				
2.	Design Risks	R9	Incomplete design of highways				
		R10	Design Errors and Omissions				
		R11	Uncertainty in horizontal and vertical alignment				
		R12	Uncertainty in access requirement				
3.	Political Risks	R13	Issues related to obtaining railway and government Permit				
		R14	Change in rules, regulations and policies of government				
		R15	Bribe				
		R16	Expropriations				
		R17	Embargoes				
		R18	Encroachment Risk				
4.	Technical Risks	R19	Obsolete technology				
		R20	Inappropriate construction methods				
		R21	Delay in preparation of submittals				
		R22	Delay in approval of submittals				
5.	Topographical Risks	R23	Insufficient availability of lands				
		R24	Uncertainty in Land acquisition cost and schedule				
		R25	Natural Obstructions i.e. hill, river, trees etc.				
		R26	Uncertainty in landscaping activities				
6.	Utilities Risks (gas, fuel, electricity)	R27	Utilities not allocated on times				
		R28	Lack of availability of utilities				
		R29	Uncertainty in price of utilities				
7.	Organizati-onal Risks	R30	Unskilled members in organization				
		R31	Labour dispute and strike				
		R32	Conflict between project related parties				
		R33	Reputations of organization in market				
		R34	Labour productivity issues				
		R35	Poor communication and coordination between project team				
		R36	Bankruptcy risk				
8.	Resources(manpower,	R37	Lack of resources				
		R38	Fluctuation in prices of material and equipments				

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	materials and machineries) Risks	R39	Labour wages issues				
		R40	Quality issues of materials and equipments				
9.	Physical Risks	R41	Unanticipated damage during construction				
		R42	Failure, damage, fire or theft of material and equipment				
		R43	Safety issues i.e. labour injuries				
10.	Site Risks	R44	Poor soil conditions				
		R45	Chance of rise in G.W.T				
		R46	Unforeseen climate conditions on site location				
		R47	Poor drainage facilities on site location				
		R48	Existing traffic				
		R49	Force Majeure				
		R50	Poor site management				
		R51	Heritage Issues				
		R52	Mineral mining issues				
11.	Financial &Commercial Risks	R53	Insufficient availability of fund/money				
		R54	Taxes issues				
		R55	Conflict in contract document				
		R56	Third party liability				
		R57	Delay in payment				
		R58	Inflation Rate				
12.	Social and Environmental Risks	R59	Environment Impact Assessment Required				
		R60	Acts of God i.e. Flood, Earthquake etc.				
		R61	Adverse weather Conditions				

Table: 2 Linguistic Definition of Risk Occurrence

Linguistic Term	Risk Occurrence
Very High (VH)	>70% chance. Risk event will surely occur.
High (H)	50 to 70% chance. Risk event is expected to occur.
Medium (M)	30 to 50% chance. Risk event may occur.
Low (L)	10 to 30% chance. Risk event is implausible to occur.
Very Low (VL)	<10% chance. Risk event is highly implausible to occur.

Table: 3 Linguistic Definition of Risk Consequence

Linguistic term	Consequence Categories		
	Cost	Time	Quality
Very High (VH)	% increase in project cost > 10	% project delay > 10	Quality are not appropriate to fulfill the business expectations
High (H)	7 < % increase in project cost < 10	7 < % project delay < 10	Quality are unsatisfactory to project stakeholders
Medium (M)	4 < % increase in project cost <7	4 < % project delay < 7	Major parts of quality are uninfluenced
Low (L)	1 < % increase in project cost < 3	1 < % project delay < 4	Few parts of quality are influenced
Very Low (VL)	%increase in project cost < 1	% project delay < 1	Quality degradation is not observable

Table: 4 Linguistic Definition of Risk Detectability

Linguistic term	Risk Detectability
Very High (VH)	Project team is unable to identify risk event response strategy to detect risk event and controlling its consequences.
High (H)	Project team is able to identify risk event response strategy with little chance to detect risk event and controlling its consequences.
Medium (M)	Project team is able to identify risk event response strategy with medium chance to detect risk event and controlling its consequences.
Low (L)	Project team is able to identify risk event response strategy with big chance to detect risk event and controlling its consequences.
Very Low (VL)	Project team is able to identify risk event response strategy with very high chance to detect risk event and controlling its consequences effectively.

Table: 5 Linguistic Definition of RPN

RPN	Priorities & Responses Criteria
$0 \leq RPN \leq 20$	Very Low priority to take any response against risk
$20 < RPN \leq 40$	Low priority to take any response against risk
$40 < RPN \leq 60$	Medium priority to take any response against risk
$60 < RPN \leq 80$	High priority to take any response against risk
$80 < RPN \leq 100$	Very High priority to take any response against risk

Table: 6 Crisp Rating used in questionnaire

Linguistic term	Crisp Rating
Very Low (VL)	1
Low (L)	2
Medium (M)	3
High (H)	4
Very High (VH)	5

V. RESULTS AND DISCUSSION

Unforeseen Climate Condition is most important factor on the basis of RPN, because it is also known that during rainfall or snowfall road construction work progress is zero which increase the cost and time of completion of road and may decrease the quality because water resist the bond formation between binder and aggregate.

There are mainly four strategies to response the risks which are commonly accepted-

1) *Risk Avoidance* – Avoidable Risks areR11, R12, R13, R19, R20, R22, R23, R24, R25, R26, R51, R31, R32, R33, R34, R38, R39, R40, R42, R44, R48, R49, R51, R52.
2) *Risk Mitigation* –Mitigable Risks are R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R16, R17, R21, R27, R28, R31, R32, R34, R35, R37, R41, R43, R45, R47, R50, R55, R56, R57, R58, R59.
3) *Risk Transferring* – Transferrable Risks are R8, R9, R10, R40, R54, R60, and R61.
4) *Risk Acceptance* – Transferrable Risks are R4, R14, R15, R18, R29, R46, R49, R57, R58, and R61.

Note: Construction organizations commonly take following insurances policies.

a) Fire Insurance
b) Workman's Compensation Insurance in case of accident.
c) Group personal accident policy for employees who meet fatal or non-fatal injuries.
d) Cash Insurance covers loss of cash in transit or in safe.
e) Motor Insurance for covering accidental damage of vehicles.
f) Contractor's all risk insurance for plant and machineries used at project sites.
g) Burglary/theft insurance
h) Machinery Breakdown policy
i) Electronic Equipment Insurance

To examine the quality or strength of relationship among reactions of contractors, clients, and consultants speaking, the Spearman rank connection coefficient was utilized. The Spearman's rank relationship coefficient is a nonparametric proportion of connection between two arrangement utilizing ranks instead of the actual value (Kottegoda and Rosso 1997) is utilized to ascertain the relationship coefficient

$$r_s = \frac{6\sum d^2}{N^3 - N}$$

Where, r_s= Spearman's rank correlation coefficient, d = difference in ranking and N = Number of Vaiables (61 risk factors)
Value of r_S between0.7and1showsstrongcorrelationbetweentwosetsofranking. Value of r_S between 0.4 and 0.7 shows moderate correlation between two sets of ranking. Value of $r_S$between 0 and 0.4 shows weak correlation between two sets of ranking. All the required Spearman's rank Correlation coefficients are calculated using r_S formula. All the calculated value of r_S shows strong correlation between respondents

VI. CONCLUSION

This study was conducted to analyze the unforeseen situations i.e. risk analysis in road construction projects. Total 61 risk factors were identified through literature review and discussion with road construction experts which was categorized into 12 groups. It was found that there is no any method other than questionnaire survey and discussion with road construction experts to identify the risk factors and assessing occurrence, consequences & detectability of risk factors in road construction projects. Questionnaire survey data was unified by using Relative Importance Method (RII) to calculate Risk Occurrence Index (ROI), Risk Consequence Index (RCI) and Risk Detectability Index (RDI). Fuzzy model prepared in MATLAB software was used to calculate RPN of risk factors due to which improved results was obtained. Results of fuzzy model shows that unforeseen climate conditions, lack of resources, adverse weather conditions, land acquisition issues with higher RPN are the most important risk factors which require more attention before starting road construction works. After identification and ranking the risk factors based on RPN. It is necessary to design risk response strategies to identify required suitable actions against risk. RFMEA table, designed in this research can be considered as concluded part of research. RFMEA table shows the effects, occurrence, consequences, and detectability of risk factors. FMEA table also include suitable responses to risk factors and who response the risk should i.e. risk allocation. Using proposed methodology of this research, further risk analysis in other specific projects like as railway, airport, and buildings can be done. This research has potential to play important role in risk management in road construction projects. Crisp rating used in this research is on1 to 5 scale but results may be improved by using 1 to 10 scale crisp rating. 24 respondents were chosen for discussing questionnaire at 85% confidence level and 15% sampling error.

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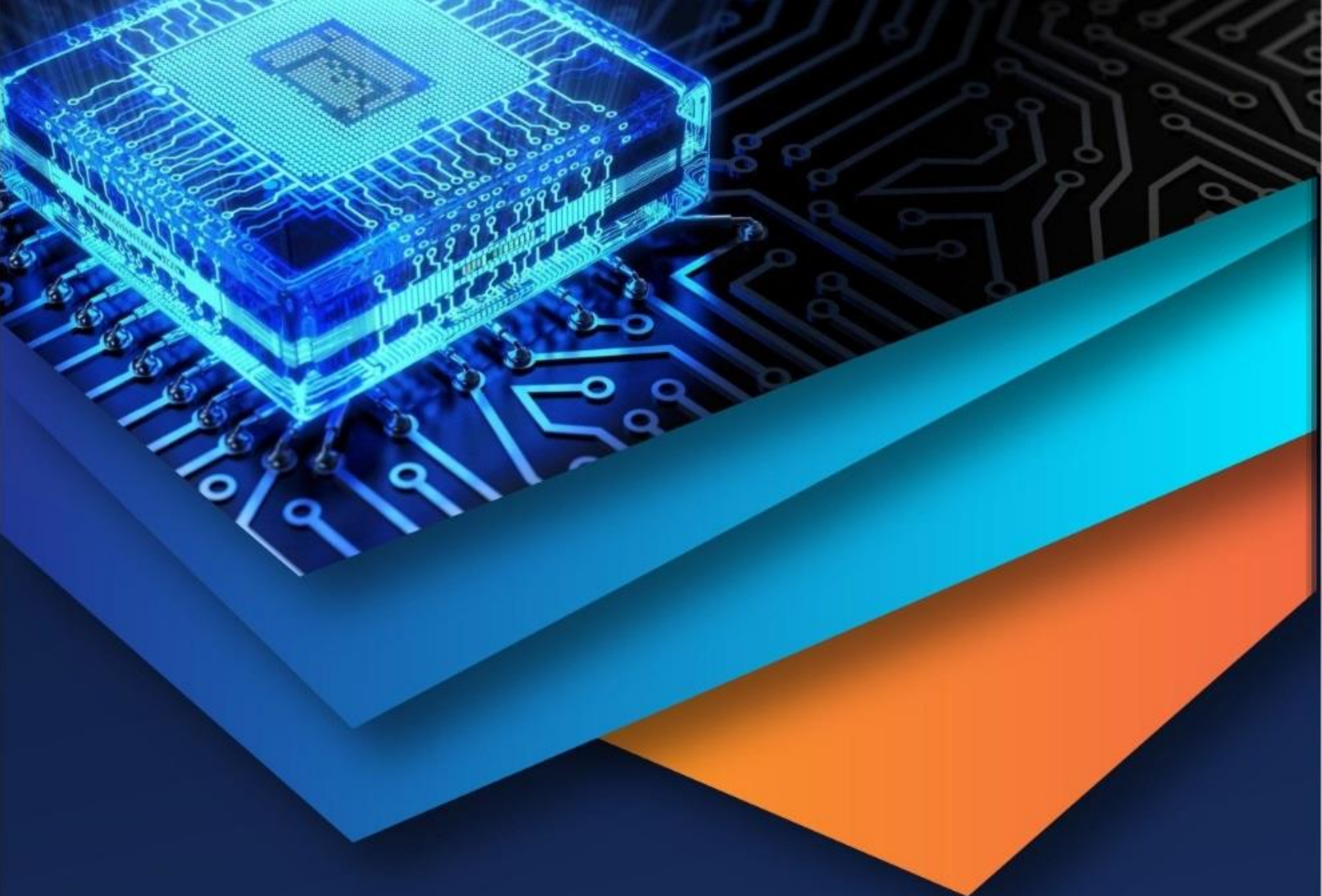

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