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# Ranking, Allocation and Response of Risk Factors of Hybrid Annuity Model for Highway Construction Projects

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***Abstract:*** ***The government introduced the Hybrid Annuity Model (HAM) to rejuvenate PPP. By features the HAM is a mix between the existing two models – BOT Annuity and EPC. This research presents a complete framework for managing risks in HAM highway construction projects. 21 risk factors were identified through literature review and discussion with highway experts, which are associated to HAM highway projects in excess or/and similar of PPP projects. Information of risk occurrence and risk consequence in terms of linguistic variable were elicited from experts in order to determine the risk occurrence index and risk consequence index. A fuzzy-MATLAB model is proposed to calculate the risk score of each risk factor. Ranking of risk factors is done on the basis of risk score values of risks. This study also allocate the each risk either to the client or to the contractor. Four risk response strategies i.e. risk avoidance, risk mitigation, risk transfer and risk acceptance are adopted. Government structure, system & strategic intent and changes in law, concessionaire/authority are found as top three risk factors of HAM highway projects. Operating Risk, Sponsor Profile Risk and Maintenance Risk are found as lower three risk factors of HAM highway projects.***

***Keywords: Hybrid Annuity Model, risk factors, fuzzy-MATLAB, risk response.***

## I. INTRODUCTION

The unpredicted events which are likely to affect the objectives of any process, product, system, service and project are called as Risk events. Risk management is the process identifying, ranking, allocating and responding the risk events with time in the changing world (Power, 2007). A public–private partnership (PPP, 3P, or P3) is a cooperative arrangement between two or more public and private sectors, typically of a long-term nature. In other words, it involves government(s) and business (es) that work together to complete a project and/or to provide services to the population.

The government has decided to introduce Hybrid Annuity Model (HAM) to revive PPP (Public Private Partnership) in highway construction. At present, three different models –PPP Annuity, PPP Toll and EPC (Engineering, Procurement and Construction) were followed by the government while adopting private sector participation.

Launch of the new model is due to the many problems with the existing ones. Large number of stalled projects are blocking infrastructure projects and at the same time adding to NPAs of the banking system. In this context, the government has introduced Hybrid Annuity Model (HAM) to rejuvenate PPP. Scheme of HAM can be understand by figure 1.1.

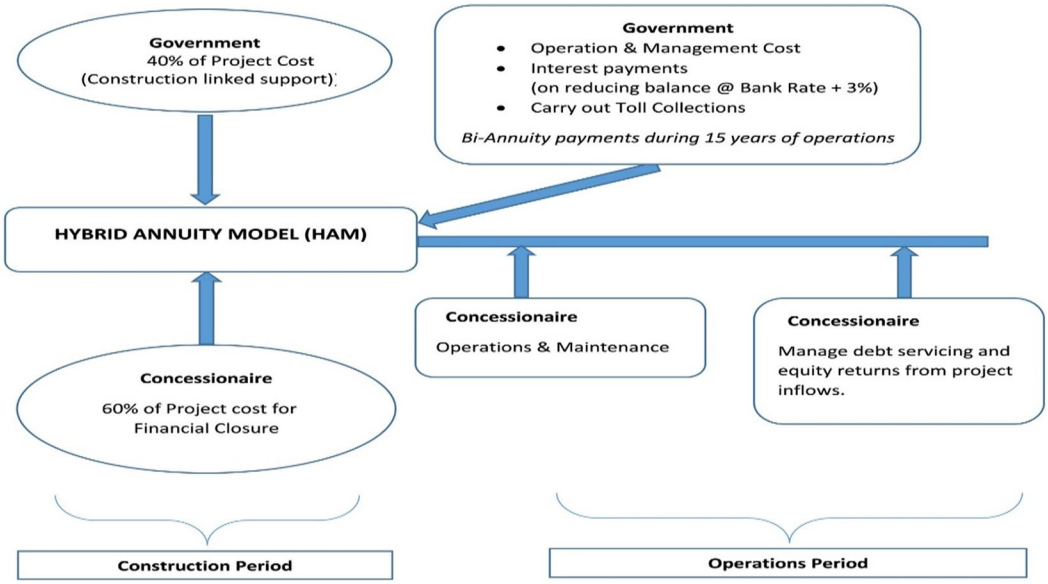


Figure 1.1. Schematic diagram of HAM projects

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## II. RESEARCH OBJECTIVES

During the research following objectives was targeted to achieve-

*A.* Identification of risk events associated to HAM projects through literature review and discussion with HAM construction experts.
*B.* Questionnaire survey to elicit information about risk occurrence and risk consequence on cost, time & quality of highway construction projects, risk allocation and risk responses.
*C.* Calculation of Risk Score (RS) of each Risk Event.
*D.* Identification of most important risk factors based on RS.
*E.* Allocation of risk to client or contractor or consultant or sharing among them.
*F.* Finally, the risk response.

## III. LITERATURE REVIEW

Fuzzy logic had however been studied since the 1920s, as infinite valued logic notably by Lukasiewicz and Tarski. After 45 years Lotfi Zadeh introduced the term fuzzy logic with 1965 proposal of fuzzy set theory. Using fuzzy logic, assessments of the problem can be elicited from experts in the form of linguistic terms such as “very low”, “low”, “medium”, “high”, “very high”. Fuzzy logic has ability to assign membership values $\mu(x)$ expressing the degree (0 for completely unfit to completely fit 1) to which a certain value of a variable fits a linguistic concept. Membership function defines how each point in the input space is mapped to degree of membership. In this research, instead of multiplying O (occurrence) & C (consequence), fuzzy logic is proposed calculate RS.
Risk is defined as the chance of an adverse event that depends on the circumstances (Mills 2001). Bowles and Pelaez (1995) noted that application of fuzzy set theory is more advantageous than tradition method of failure prioritization based on Occurrence, Consequences and Detectability. Bowles and Pelaez also noted that, if failure modes have multiple dimensions then calculated RPN might be underestimated. Mostly in past researches, Fuzzy-RFMEA is applied in specific projects as Mohammad Hayati and Mohammad Reza Abroshan (2017) applied Fuzzy-FMEA in Tehran Subway Tunneling, Cheng-Min Feng and Chi-Chun Chung (2013) applied it in assessing the risks of Airport Airside, Mohamed Abdelgawad and Aminah Robinson Fayek (2010) found the RPN and defined the corrective action categories based on RPNs value of risks, Sameh M. El-Sayegh and Mahmoud H. Mansour (2015) assess and allocate the risks using RII method risks in highway construction projects in UAE. Mahmoud Mohamed Mahmoud Sharaf and Hasan T. Abdelwahab (2015) analyzed risk factors in for Highway Construction projects in Egypt on the basis of risk score but not designed the risk response strategies. But this research focus on all risks associated to HAM highway construction in which O and C of risks are elicited from highway construction experts through questionnaire form in linguistic terms. Using questionnaire data Risk Occurrence Index (ROI) and Risk Consequence Index (RCI) are calculated through Relative Importance Index (RII) formula. Then, RS is calculated using Fuzzy-MATLAB taking inputs as ROI &RCI. Based on above mentioned discussion, several studies have been conducted for the risk analysis of PPP projects. However, no study has been found related to risk analysis in HAM projects, as it is new type of project. Therefore this study is conducted to risk analysis of HAM projects.

## IV. RESEARCH METHODOLOGY

*1) Step: 1)* Identification of Risk Factors
Total 21 risk factors were identified through literature review and discussion with highway construction experts. After identifying the risk factors a questionnaire form was prepared in following format given in Table 1.

Table 1. Identified Risks and Questionnaire Form

| Risk No. | Risk Factor | RO | RC on C/T/Q | Risk Allocation | Risk Response |
|---|---|---|---|---|---|
| R1 | Permitting Risk | | | | |
| R2 | Cost Overrun Risk | | | | |
| R3 | Time Overrun Risk | | | | |
| R4 | Equity Mobilization Risk | | | | |
| R5 | Risk in the timelines of grant during construction period | | | | |

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| | | | | | |
|---|---|---|---|---|---|
| R6 | Revenue Risk | | | | |
| R7 | Operating Risk | | | | |
| R8 | Maintenance Risk | | | | |
| R9 | Project Quality Risk | | | | |
| R10 | Force Majeure | | | | |
| R11 | Changes in Law | | | | |
| R12 | Changes in Concessionaire/Authority | | | | |
| R13 | Stability of Cash Flow | | | | |
| R14 | Interest Rate and Forex Risk | | | | |
| R15 | Inherent Profitability of the Projects | | | | |
| R16 | Leverage, liquidity and debt service coverage metric | | | | |
| R17 | Debt Maturity Profile and Refinancing Requirement | | | | |
| R18 | Accounting Quality | | | | |
| R19 | Contingent Liabilities/Off-Balance Sheet Exposure | | | | |
| R20 | Sponsor Profile Risk | | | | |
| R21 | Government Structure, Systems & Strategic Intent | | | | |

*2) Step 2)* Linguistic Definition

For each variable (RO, RC and RS), after identification of risk factors, the linguistic term for each variable are defined as “Very High”, “High”, ”Medium”, ”Low”, ”Very Low”. Meaning of each linguistic term associated to all variable are given below-

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 |

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Table 4. Linguistic Definition of RS

| RS | Score & Level of Risk |
|---|---|
| $0 \leq RS \leq 20$ | Very Low score & level of risk |
| $20 < RS \leq 40$ | Low score & level of risk |
| $40 < RS \leq 60$ | Medium score & level risk |
| $60 < RS \leq 80$ | High score & level risk |
| $80 < RS \leq 100$ | Very High score & level risk |

Table 5. 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 |

*3) Step 3)* Questionnaire survey

Crisp rating of O & C on scale 1 to 5 was elicited from highway construction experts through questionnaire survey. Experts were also asked to suggest for risk allocation and risk response strategies for each risk event. The questionnaire contained two parts P-1 & P-2. P-1 contained the respondent's details including their post, qualification, experience & their current project of working. P-2 contained groups and factors of highway construction project risks. 69 respondents were accessed for questionnaire survey.

*4) Step 4)* Risk Assessment

After performing questionnaire survey, responses from questionnaire are unified using Relative Importance Index Method which is given by,

$$\textbf{RII} = \frac{\sum W}{A \times N} \qquad \textbf{...eq.1}$$

Where $\sum W$ = Sum of response i.e. sum of crisp rating of factor given by respondents,

A = Maximum value of crisp rating which is 5

N = No. of respondents

As per RII concept, ROI of each risk factor is calculated using following formulas,

$$\text{Risk Occurrence Index (ROI)} = \frac{\sum W}{A \times N} \ldots \text{eq.2}$$

To calculate RCI average of cost consequence rating, time consequence rating & quality consequence rating is taken to calculate $\sum W$, hence again,

$$\text{Risk Consequence Index (RCI)} = \frac{\sum W}{A \times N} \ldots \text{eq.3}$$

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*5) Step 5)* Fuzzy-MATLAB model for RS calculation

RS is output variables. Triangular and Trapezoidal membership functions are used for Output Variable. Depending upon the membership function of input variables, in form of risk matrices are generated for RS calculation which depends upon two risk components ROI, RCI. Rules are shown in following tabulated-matrices.

| **RPN** | **Fuzzy computation of output RS** | | | | | |
|---|---|---|---|---|---|---|
| | | **RCI** | | | | |
| **ROI** | | **VL** | **L** | **M** | **H** | **VH** |
| | **VL** | **VL** | **M** | **L** | **L** | **M** |
| | **L** | **VL** | **L** | **L** | **M** | **M** |
| | **M** | **VL** | **L** | **M** | **M** | **H** |
| | **H** | **VL** | **L** | **M** | **H** | **VH** |
| | **VH** | **VL** | **L** | **M** | **VH** | **VH** |

Fuzzy Inference Mechanism process is used for mapping given inputs (ROI & RCI) to output (RS) using Fuzzy-MATLAB. Because of widely use and acceptance of Mamdani method, it is used in RS Fuzzy Model.

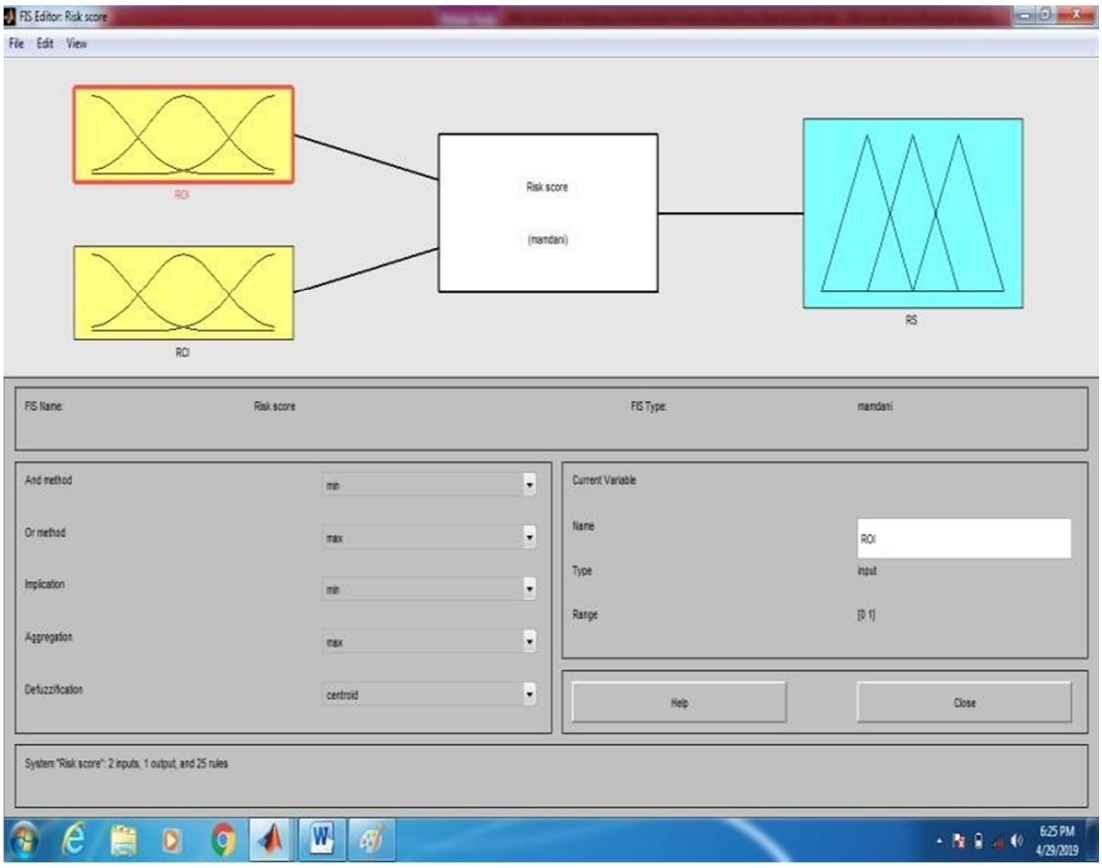


Figure. 2 Fuzzy Model for RS calculation

## V. RESULT & DISCUSSION

RS values of each risk factor are calculated by using fuzzy model. After calculation of RS values of risk factors, ranking of risk factor is done. Risk with highest RS values carry rank 1. Thus ranking of risk factors based on RS values is done in decreasing order of RS values. Ranking of risk factors is done on the basis of contractors, clients and consultants views. Spearman rank correlation coefficient can be used to show strength of relationship between two groups.

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Risk Allocation is very important when two or more parties participate in project execution. In construction projects mainly three parties come into play i.e. Clients, Contractors and Consultants.Clients are also beneficiary or owner of project. Clients hire the contractors and consultants for projects. The main work of contractors is to execute the work of construction, while consultants help the clients in decision making. Consultants mainly review the work done by contractors and quality in contractor's work done. So, in this research risks are allocated to either clients or contractors or consultants on the basis of risk allocation plan suggested by highway construction experts during questionnaire survey.

Risk response is the final and most important steps of risk analysis in highway construction. After identifying and ranking of risk factors it is required to response the risk and it is also required to decide to whom risk should be allocated. In highway construction projects it was observed that risk should be allocated to contractor or client or consultant which play important role highway construction completion. Four risk response strategies i.e. risk avoidance, risk mitigation, risk transfer and risk acceptance are adopted.

Finally in the Risk table, ROI, RCI, RS, Rank of Risk Factors, Risk Allocation Plan and Risk Response Strategies are presented.

Table 6. Risk Table

| Risk No. | Risk Factor | ROI | RCI | RS | Overall RS Rank | Risk Allocation | Risk Response |
|---|---|---|---|---|---|---|---|
| R21 | Government Structure, Systems & Strategic Intent | 0.775 | 0.375 | 94 | 1 | Client | Mitigate |
| R11 | Changes in Law | 0.750 | 0.375 | 89 | 2 | Client | Mitigate |
| R12 | Changes in Concessionaire/Authority | 0.750 | 0.375 | 87 | 3 | Client | Mitigate |
| R13 | Stability of Cash Flow | 0.625 | 0.350 | 78 | 4 | Client | Mitigate/Transfer |
| R16 | Leverage, liquidity and debt service coverage metric | 0.600 | 0.350 | 77 | 5 | Contractor | Avoid/Mitigate |
| R10 | Force Majeure | 0.575 | 0.350 | 74 | 6 | Client | Accept |
| R2 | Cost Overrun Risk | 0.550 | 0.350 | 71 | 7 | Contractor | Mitigate |
| R1 | Permitting Risk | 0.525 | 0.350 | 65 | 8 | Client | Transfer |
| R3 | Time Overrun Risk | 0.500 | 0.325 | 61 | 9 | Contractor | Mitigate |
| R6 | Revenue Risk | 0.500 | 0.325 | 55 | 10 | Client | Mitigate |
| R9 | Project Quality Risk | 0.500 | 0.325 | 54 | 11 | Contractor | Mitigate |
| R17 | Debt Maturity Profile and Refinancing Requirement | 0.475 | 0.300 | 53 | 12 | Client | Avoid |
| R19 | Contingent Liabilities/Off-Balance Sheet Exposure | 0.475 | 0.300 | 49 | 13 | Client | Avoid |
| R18 | Accounting Quality | 0.450 | 0.275 | 47 | 14 | Share | Accept |
| R5 | Risk in the timelines of grant during construction period | 0.450 | 0.275 | 45 | 15 | Client | Accept |
| R15 | Inherent Profitability of the Projects | 0.425 | 0.275 | 39 | 16 | Contractor | Mitigate |
| R14 | Interest Rate and Forex Risk | 0.425 | 0.250 | 37 | 17 | Client | Accept |
| R4 | Equity Mobilization Risk | 0.425 | 0.250 | 33 | 18 | Client | Accept |
| R7 | Operating Risk | 0.400 | 0.225 | 32 | 19 | Contractor | Accept |
| R20 | Sponsor Profile Risk | 0.400 | 0.225 | 29 | 20 | Client | Avoid |
| R8 | Maintenance Risk | 0.400 | 0.200 | 26 | 21 | Contractor | Mitigate |

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## VI. CONCLUSION

This study has been provide a framework to rank, allocation and response the risk events, which are quite possible in Hybrid Annuity Model (HAM) type highway construction projects.

In order to rank the risk events in the HAM highway projects, Risk Score is calculated using fuzzy logic while taking the risk occurrence and risk consequence as input.

Government structure, system & strategic intent and changes in law, concessionaire/authority are found as top three risk factors of HAM highway projects.

Operating Risk, Sponsor Profile Risk and Maintenance Risk are found as lower three risk factors of HAM highway projects.

Risks are allocated to either to client or contractor or consultant based on the experts' poll majority.

Four methods of risk response i.e. risk avoidance, risk mitigation, risk transfer and risk acceptance are suggested in the study.

Several insurance policies were seen and analyzed during the study, which are also incorporated in this thesis.

Using proposed methodology of this research, further risk analysis in other specific projects like as railway, airport, and buildings can be done.

Future researchers can apply Artificial Neural Network theory, Evaluation Algorithms to analyse risks in highway construction to compare results of this research.

Future researcher may also analyse the influences of Risk Allocation Plan and Risk Response Strategies on construction of highway projects.

This research has potential to play important role in risk management in highway construction projects.

This research can be used in cost and time contingencies allocation for highway projects. This research is semi quantitative which gives results in index and RS form.

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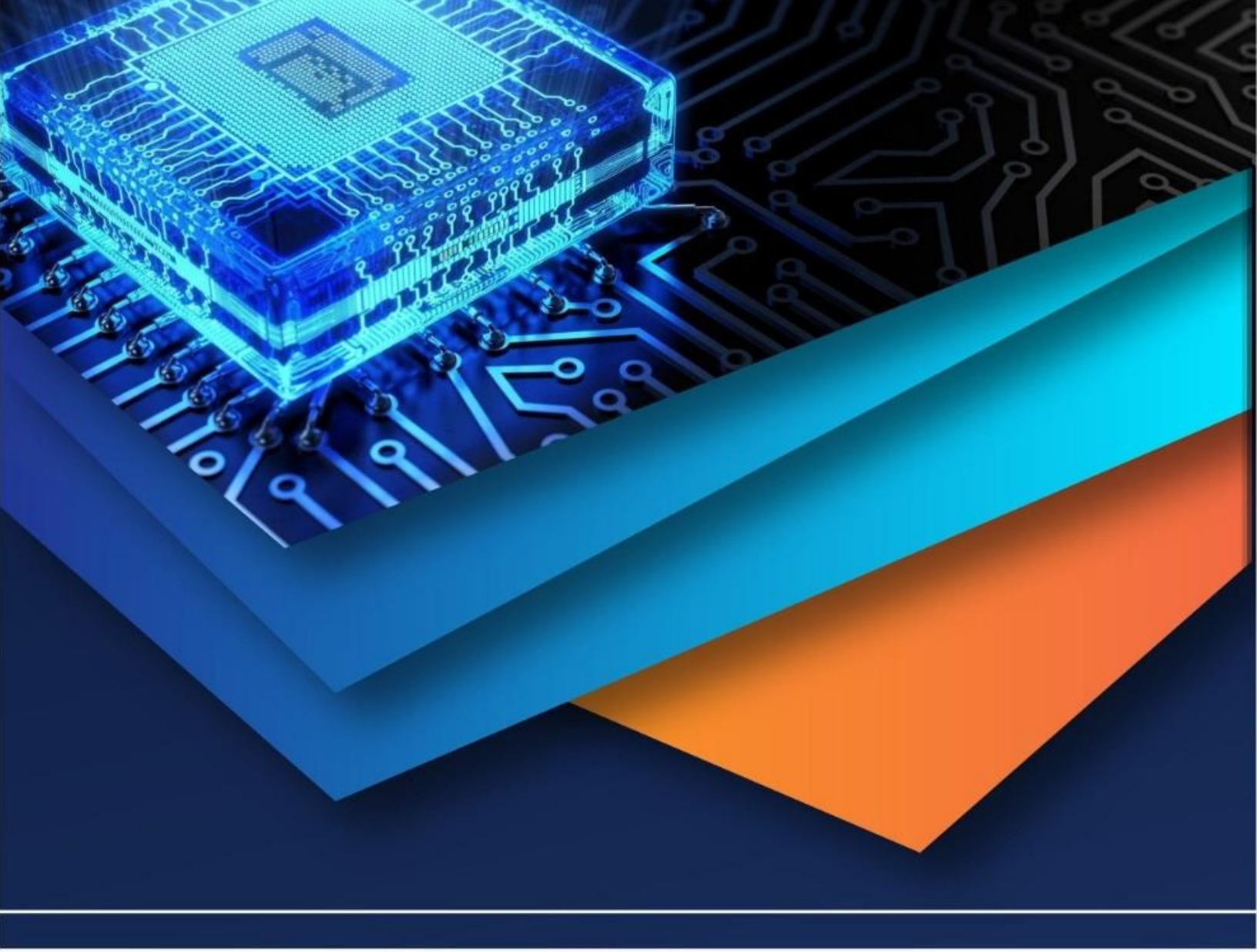

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