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Optimum Activity Overlapping Strategy for Construction Management using Analytical Approach

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Abstract: ***An effective and well-known method for the early completion of construction projects is the overlap of the project's critical activities or phases that would normally be carried out in sequence. Overlapping technique reduce the project completion time with minimum cost overrun.***
Overlapping is also called fast-tracking mechanism. It is risky because it increases the probability of rework that result in increasing the cost of the project.
The Overlapping in construction projects must be carried out effectively because each pair of activities cannot overlap, since some previous activity may not allow overlap due to maximum rework. There are various overlapping strategies that exist in a construction project which all can result in time-saving. so, the cost of these strategies varies significantly depending on the overall Rework.
A favorable overlapping strategy leads to minimal time savings costs. To find such a strategy, the question arises: "Which activities have to be overlapped and to what extent to reduce the project duration at the minimum cost?" This study addresses the question and generating an Overlapping Decision algorithm. This algorithm based on an Analytical Approach.
Keywords: Activity overlapping, Fast-tracking, Optimization, Rework, Evaluation and sensitivity, Construction management.

I. INTRODUCTION

To complete any project on the proposed duration all the resources including human resource, material resource, machinery, budgeted cost must be used efficiently. That is the main responsibility of project management team. In a construction project these resources along with duration plays a vital role.

As the overall growth and success of any project is directly or indirectly dependent on time. The project duration is estimated by addition of individual critical activity duration of entire project i.e. the duration required to execute these given activities. This project duration can also be further decreased by the skills of project manager as well as use of modern techniques. Many Infrastructure projects rely on the schedule techniques which are capable of completing the project on given time frame. Earlier practices involve crashing, substitution which requires additional resources to be deployed and involve many calculations which becomes tedious in nature, but the overlapping does not require any additional resources. The overlapping is also defined as Fast-tracking mechanism of project execution. It is an important aspect of concurrent engineering which allows a methodology to reduce the project delivery time. This fast-tracking mechanism allows for delivering the project prior to its duration which increases the chances of new opportunities for project team.

II. OVERLAPPING

Overlapping is a phenomenon in which two activities are executed simultaneously, for example construction can start before design is finalized by taking some assumption by technical skills. Thus, design and construction can start altogether, if there is a chance of error in doing so, then that error is defined as Rework. Rework is particularly an adopted value in construction project which generally varies from 15-20% that the project practitioner should handle efficiently.

III. OBJECTIVE

A. This develops an Overlapping Decision algorithm solves the question of when to overlap, how much to overlap, and what strategy to use to achieve the overlapping when the objective is to reduce the project schedule while minimizing cost increases.
B. Activity Network diagrams and Gantt chart is prepared with the help of MS Project.

IV. LITERATURE REVIEW

A. Many Practitioner and Researcher have been Analysed on Overlapping Criterion.

1) Krishnan et al. (1995) defined the application of Overlapping in product development and reduction of product delivery time.
2) Peña-Mora and Li (2001) provided an approach of dynamic planning in concurrent engineering by using GERT to develop a fast track mechanism.
3) Bogus et al. (2005) considered overlapping simulation technique is provided by which classified the activity in two stages i.e. upstream and downstream and characterized the activity into four types as Slow Evolution (SE), Fast Evolution (FE), Slow Sensitive (SS), Fast Sensitive (FS). He provided a simulation model and found reliable approach in modelling concurrent engineering activities which is a useful methodology to estimate risk generation and strategies for overlapping. Construction project is executed by breaking into a small packet of work defined as activity, which can further be on the basis of dependency and relation among them.
4) Bogus et al. (2006) provides the methodology of overlapping dependent activities which may sometime lead to errors causing rework which has to be assessed by a proper approach. One such approach is given by Lee et al. (2006).
5) Blacud et al. (2009) analysed sensitivity of construction activities, to interrelate activities by semi structured interview and providing factors and assessing activity's sensitivity to avoid risks during overlapping.

B. In many Infrastructures Project Overlapping can play a vital role as such concept is given by

1) Dehghan et al. (2010), the concept of assessment of overlapping in oil and gas projects.
2) Dehghan and Ruwnapura (2013) established an interrelationship between overlapping and rework and provided formula for rework and amount of overlapping. The overlapping has become a necessary for research team to complete the project before the estimated duration as it is beneficial from many aspects because it increases the prestige of construction company and increase the new opportunities and develop confidence among the project team. This research is used to evaluate the criteria of any construction project during the overlapping. The criteria's adopted in this study remain same for every construction project. These criteria are result of overlapping of activities. Game theory is used to analysed the engineering problems by forming matrix. This game matrix are two-person zero sum games established by (Peldschus, 2005), where player-I strategy is related to variant and player-II strategy is related to criteria. Each criterion is associated with different dimensions, these criteria are transformed into dimension less numbers on interval [0,1] by adopting transformation method given by (Peldschus, 2008; Ginevičius, 2008). The overall strategy will provide a methodology for project team to determine the extent of overlapping of activity and result of overlapping of activity and finding the optimal duration with maximum advantage.
3) Lee et al. (2006) discussed dependability and stability in construction projects and described the benefits of overlapping.
4) Bogus et al. (2011) developed the methodology to classify the up and down stream activity to recognize the potential of rework risk by simulation techniques.
5) Gwak et al. (2016) used exact time cost trade-off to measure the rework cost slope which was incurred due to overlapping activity.
6) Francis (2016) shown the uncertainties of overlapping in construction projects and measure them by Monte-Carlo Simulation. The practice of overlapping was being applied first for manufacturing and commercial application but now overlapping has acquired its own place in various construction and infrastructure project. A known practice for speeding up construction projects is to overlap activities in the design phase. There are various critical activities exists in design phase.

V. OVERLAPPING: A TOOL FOR CONSTRUCTION MANAGEMENT

The construction project operation is completed in three stages i.e., Design-Construction-Delivery. Further to accomplish a task in specific manner the project is breakdown into smaller tasks, these tasks are called activity. The stepwise completion of these activity lead to project finish in the estimated duration, i.e. an approach of traditional method but the fast-tracking or overlapping mechanism is related to execution of two activities simultaneously and the activities which are performed at same time are called parallel activities. The activities are defined in two ways:

1) *Predecessor Activity:* The activity which finish prior to start of any activity is called predecessor activity.
2) *Successor Activity:* The activity which starts after finish of any activity is called successor activity.

To relate these activities with each other a network diagram is drawn, and a critical path is chosen, which has maximum duration and activities of this critical path are called critical activities. These critical activities are mainly responsible for project delay and cost escalation. If the executions of these critical activities are handled with proper supervision and carefully then the project accomplishment would be better. The overlapping is the tool with which these critical activities will be completed in lesser duration which is the main demand of project management team. The degree of overlapping is depended upon activity relationship. There exist 4 types of activity relationship as shown in Fig-1. From the Fig-1 relationship (Independent and Interdependent) type relationship can be overlapped to any extent as there is no dependency, while dependent and semi-dependent type relationship activities overlapping are limited.

VI. ACTIVITY RELATIONSHIPS

There are four types of activities relationships -

1) *Dependent Activities:* In order to start, one activity requires the last data from another activity.
2) *Semi-Independent Activities:* To start, one activity requires only partial information from other activities.
3) *Independent Activities:* No information dependence exists between the two activities.
4) *Interdependent Activities:* The exchange of information in two ways between activities takes place until it is completed.

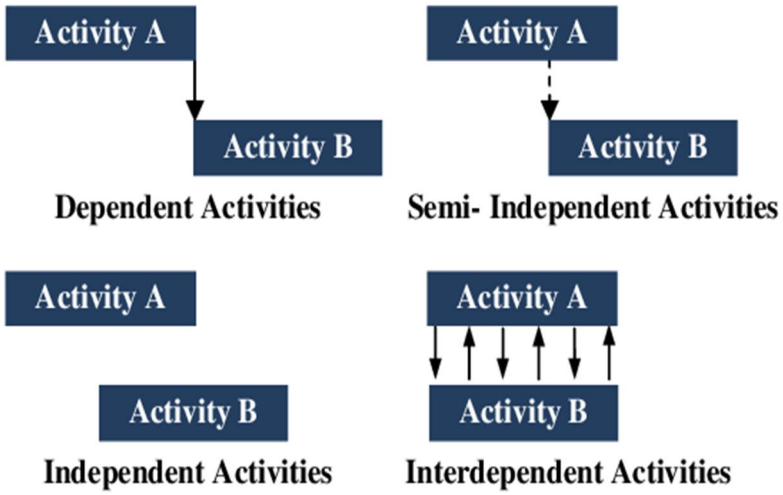

Fig. 1 Activity Relationships

VII. EVOLUTION AND SENSITIVITY

Evolution defines the rate at which plan data is produced from the beginning of an action through the completion of the activity. The range of evolution can be "fast" or "slow".

The Sensitivity is depending on the activity evaluation. if evaluation of activity is fast then sensitivity is low and if evaluation of activity is slow then then sensitivity is High. So, activity evaluation is main cause of sensitivity “low” or “high”.

VIII. DECISION ALGORITHM FOR OVERLAPPING AT MINIMUM COST

A. Determine the critical path activities in the non-overlapped schedule.
B. Determine the evolution and sensitivity characteristics for each activity on the critical path.
C. For each potential overlapping strategy (for each activity pair), calculate the cost per day (or other appropriate time measure) of overlapping.
D. For each activity pair, select a strategy with a range of values that lead to minimal cost growth.
E. Select the activity pair that has the lowest cost for overlapping and overlap that pair with the strategy identified in step 4.
F. Re-run the schedule, if further time savings is desired, repeat the process starting at the first step.

Input information processing and decision making

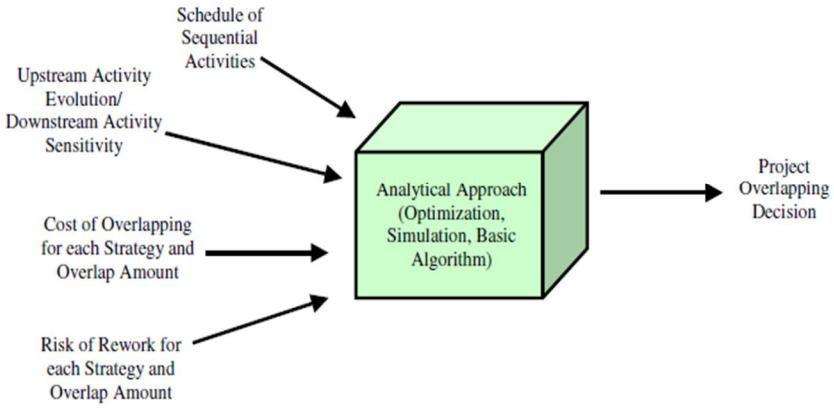

Fig. 2

1) *Overlap Duration* – Overlap duration is calculated by multiplying the Degree of overlapping (Oij) and the successor activity's duration (Dj)

$L_{ij} = O_{ij} \times D_j$

2) *Degree of Overlapping* – The duration by which activity is overlapped is defined as degree of overlapping. Overlap rate is calculated by Dividing the overlap duration (Lij) by successor activity's duration (Dj)

$O_{ij} = L_{ij} / D_j$

3) *Rework Duration – It is calculated by*

$R_{ij} = f(L_{ij})$

$R_{ij} = 0.2\ (L_{ij})$

4) *Probability of Rework* –

$$\begin{cases} (0/3)^{1/2} & \text{if } (A_E = S \ \&\ A_S = L) \\ -1.6(O)^3+2.4(0)^2+0.01O & \text{if } (A_E = F \ \&\ A_S = H) \\ (O/3)^{1/2} & \text{if } (A_E = S \ \&\ A_S = H) \\ (O)^3+1.5(O)^2+0.001O & \text{if } (A_E = F \ \&\ A_S = L) \end{cases}$$

5) *Time Impact* – The actual time saving is the difference of overlapping period and rework period.

Time saving = Overlapped duration − Rework duration

Time saving = $L_{ij} - R_{ij}$

6) *Rework Cost* – Rework amount is calculated by,

Rework cost = Rework amount × Overall activity cost

$R_c = R_{ij} \times C_{oc}$

IX. TEST INVESTIGATION

We consider a construction project consist with 18 activities and their predecessor along with their Direct cost, Duration, minimum overlap and maximum overlap and their indirect cost to be considered 700/day and rework cost 500/day. The network diagram is drawn of this construction project and critical or subcritical path found.

The critical path formed are 1-6-10-12-15-17-18 = 169

And sub-critical path formed are 1-6-9-12-15-17-18 = 161

The overall maximum overlapping duration is 8 days because if project is further overlapped then path 1-6-9-12-15-17-18 = 161 will be critical.

Now generate the critical activities evaluation and sensitivity Matrix.

M_C = F H
S L
S L
F H
S L
S H

After that execute Overlapping decision algorithm for find out the optimal overlapping strategy.

Information of Project Activities

Activity	Predecessors	*Duration*(days)	Direct cost	A_E (evolution)	AS (sensitivity)	O_N	O_M
1	—	24	2,400	Fast	High	—	—
2	—	25	2,800	Slow	High	—	—
3	—	33	3,200	Slow	Low	—	—
4	—	20	30,000	Fast	Low	—	—
5	1	30	15,000	Fast	High	0.0	0.65
6	1	24	40,000	Slow	High	0.0	0.3
7	5	18	22,000	Fast	High	0.0	0.5
8	6	24	1120	Slow	Low	0.0	0.5
9	6	25	1300	Slow	Low	0.0	0.6
10	2, 6	33	1450	Slow	Low	0.0	0.8
11	7, 8	20	1350	Slow	High	0.0	0.6
12	5, 9, 10	30	2,000	Fast	Low	0.0	1
13	3	24	1,800	Slow	High	0.0	0.5
14	4, 10	18	2,200	Slow	Low	0.0	0.75
15	12	16	4,500	Slow	High	0.0	0.8
16	13, 14	30	1,000	Fast	High	0.0	0.65
17	11, 14, 15	24	4,000	Slow	Low	0.0	0.7
18	16, 17	18	3,000	Fast	High	0.0	1

Project Network Diagram

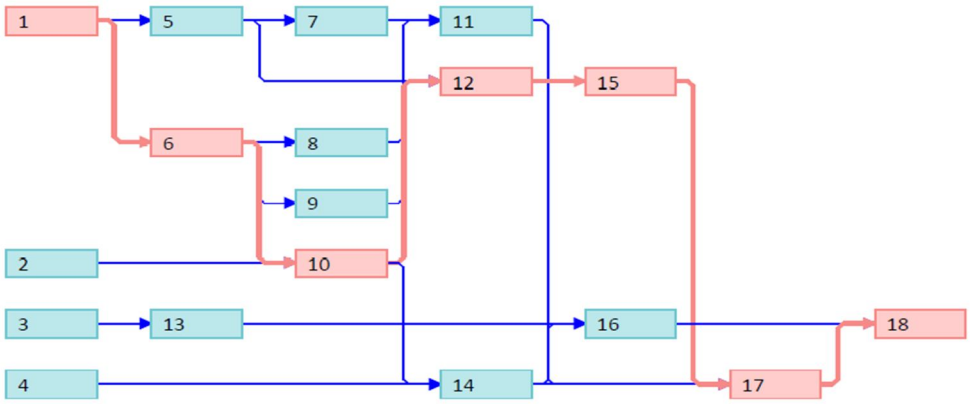

Fig. 3

Gantt Chart of the Project

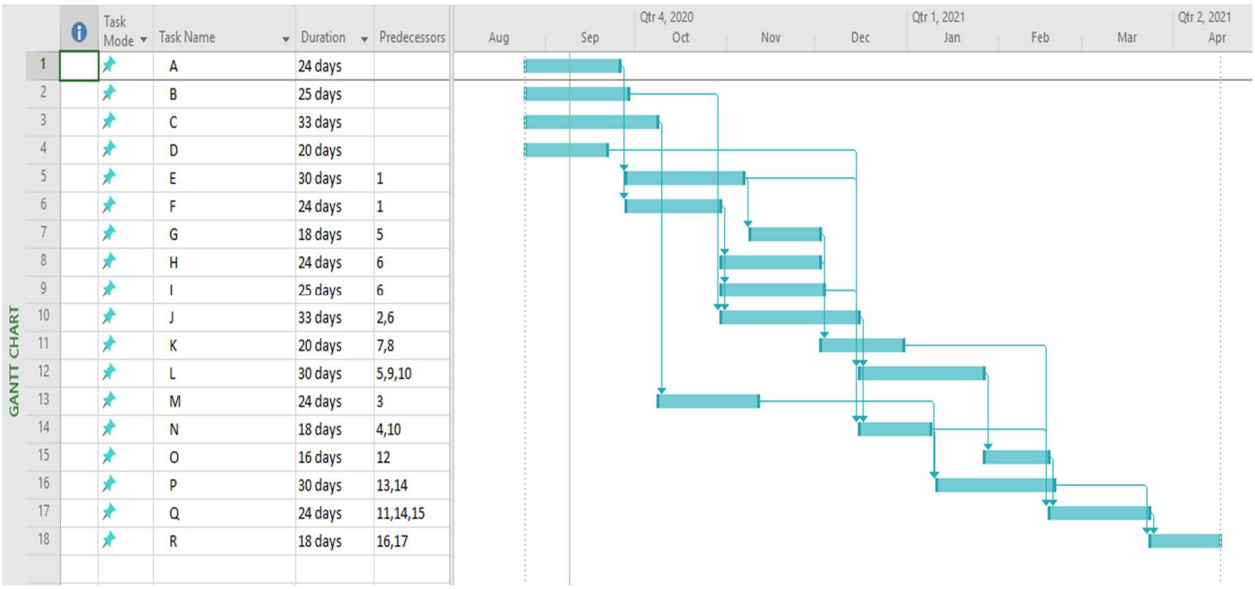

Fig. 4

X. TEST RESULT

Optimum overlapping strategy of Project activities

Overlap activity	Degree of Overlapping	Overlap duration (days)	Rework duration (days)	Rework probability	Time Saving	Rework cost
1–5	0.218026	6.54	1.31	0.10	5.23	655
1–6	0.299989	7.20	1.44	0.17	5.76	720
5–7	0.21767	3.92	0.78	0.10	3.14	390
6–8	0.499969	12.00	2.40	0.41	9.6	1200
6–9	0.599973	15.00	3.00	0.45	12	1500
2–10	0.799835	26.39	5.28	0.52	21.11	2640
6–10	0.799959	26.40	5.28	0.52	21.12	2640
7–11	0.599985	12.00	2.40	0.58	9.6	1200
8–11	0.599974	12.00	2.40	0.58	9.6	1200
5–12	0.285024	8.55	1.71	0.10	6.84	855
9–12	0.286209	8.59	1.72	0.10	6.87	860
10–12	0.285853	8.58	1.72	0.10	6.86	860
3–13	0.499996	12.00	2.40	0.55	9.6	1200
4–14	0.749908	13.50	2.70	0.50	10.8	1350
9–14	0.749951	13.50	2.70	0.50	10.8	1350
12–15	0.8	12.8	2.56	0.64	10.24	1280
13–16	0.217192	6.52	1.30	0.10	5.22	650
14–16	0.218397	6.55	1.31	0.10	5.24	655
11–17	0.699977	16.80	3.36	0.48	13.44	1680
14–17	0.699992	16.80	3.36	0.48	13.44	1680
15–17	0.699999	16.80	3.36	0.48	13.44	1680
16–18	0.216634	3.90	0.80	0.10	3.1	400
17–18	0.218784	3.94	0.79	0.10	3.15	395

XI. CONCLUSION

In this research, we highlight the overlapping mechanism of project activities by taking pair wise critical activity and overlapping them by incremental duration up to the extent such that any other path does not become critical path. This has to be remembered because formation of more critical path can make the problem tedious. This overlapping concept is related to the activity relationship which has to be taken into effect. The time and cost impact by overlapping is also reviewed on the project schedule and cost reduction and optimum overlapping benefits by these activities pair are found. The obtained result will be used full for project practitioners to efficiently overlap the project activity and adopt the fast -tracking mechanism of the project in order to reduce cost and schedule.

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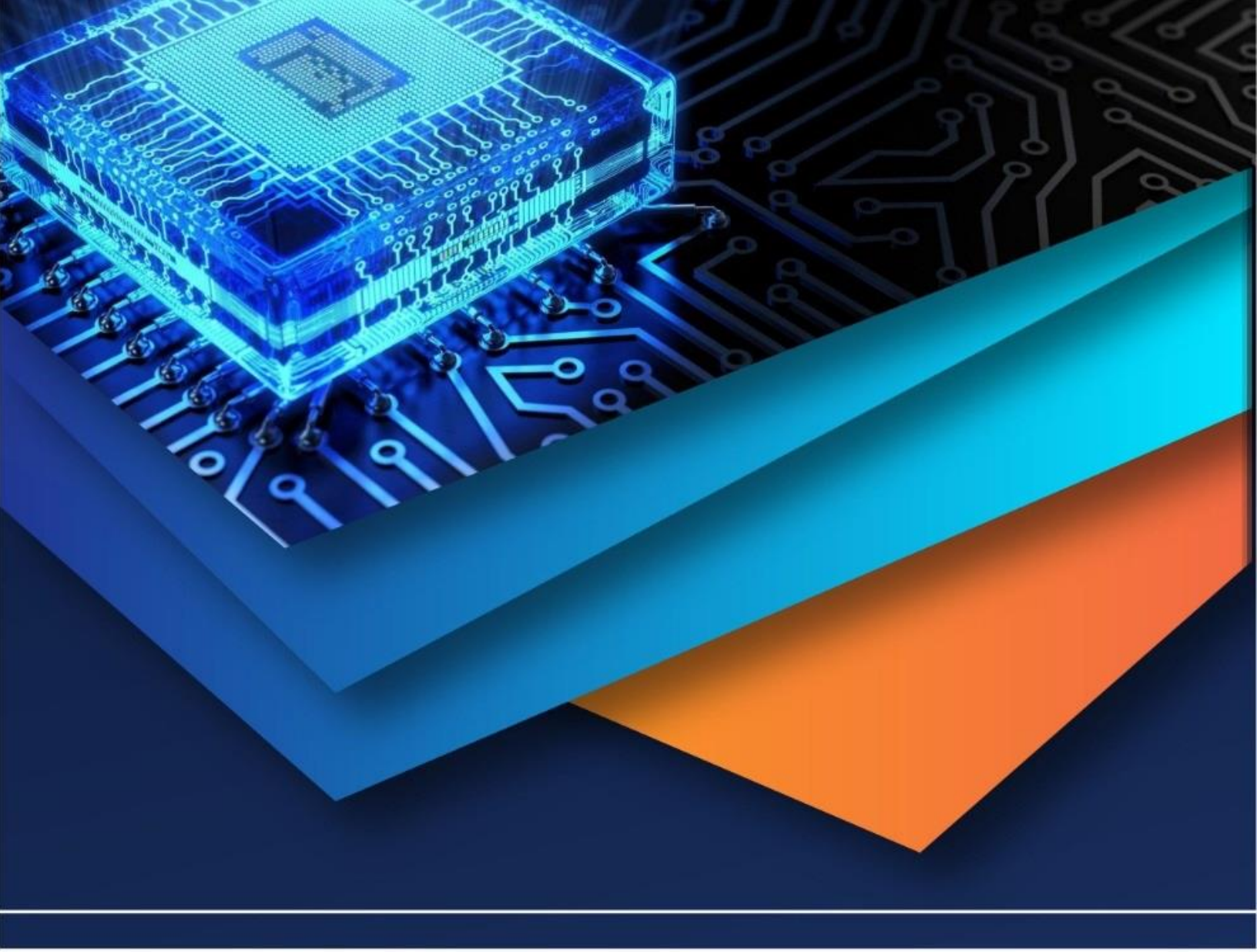

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